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HyGEM - a new Strategic Research Council project for linking geophysical models to hydrological models

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HyGEM

- Integrating geophysics, geology and Hydrology for improved Groundwater and Environmental Management

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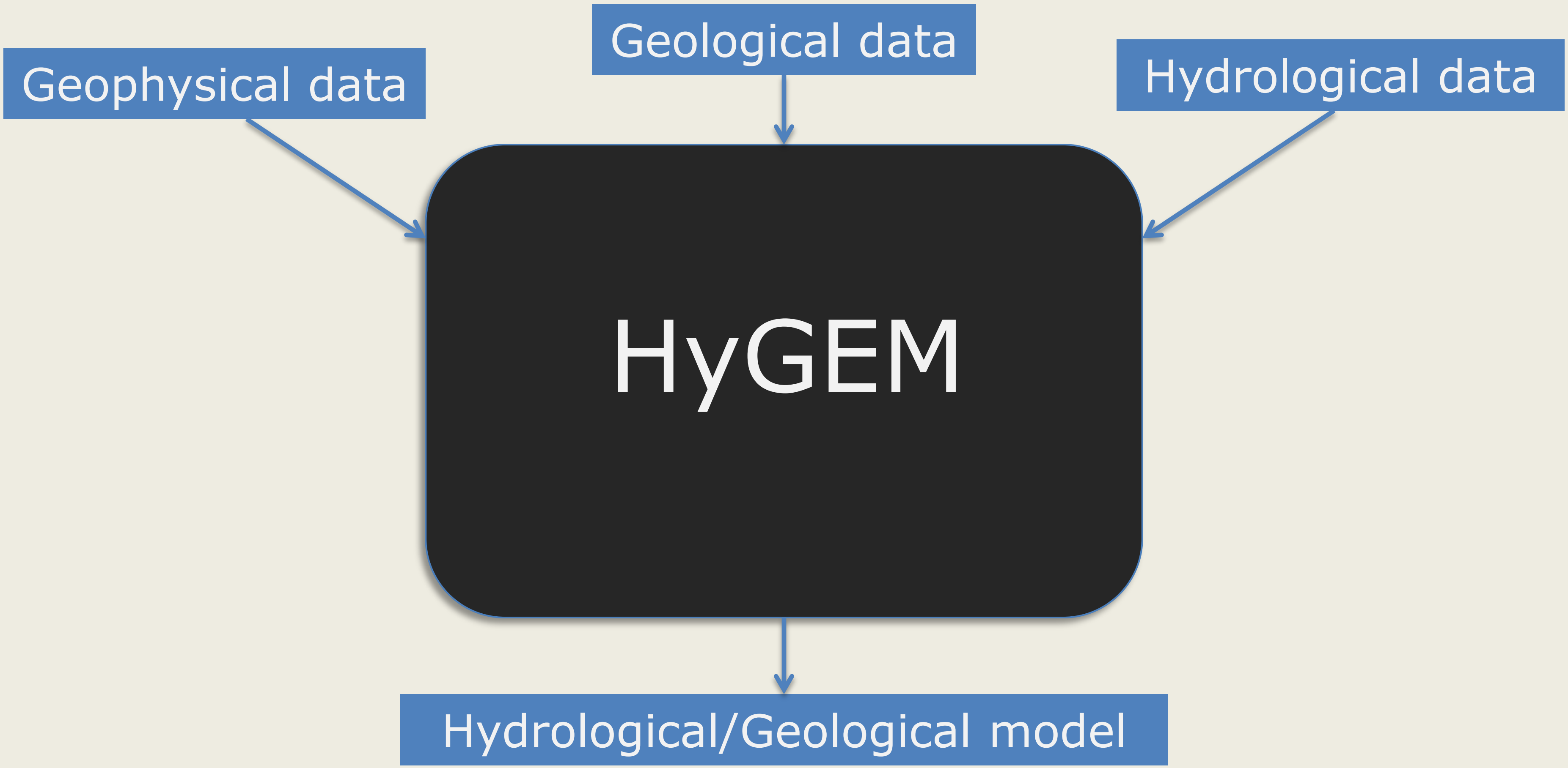
Motivation

- Today the integration of geophysical and geological/hydrological data is
  - Subjective
  - Largely un-documented
  - Manual
- Large information loss when combining different data sets through a chain of processes and persons
- Information loss by changes of model space layout

Objectives


Geological data
Geophysical data
Hydrological data
HyGEM
Hydrological/Geological model

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Objectives

- Create tools for direct and (semi-) automatic integration of geophysical and geological data into geological and hydrological models
- $\Rightarrow$ Better water resources and environmental management
- Results are
  - Reproducible
  - Documented
  - Objective
  - Uncertainties described

Partners, national

- Department of Geoscience, Aarhus University
- The Geological Survey of Denmark and Greenland
- Department of Environmental Engineering, Technical University of Denmark

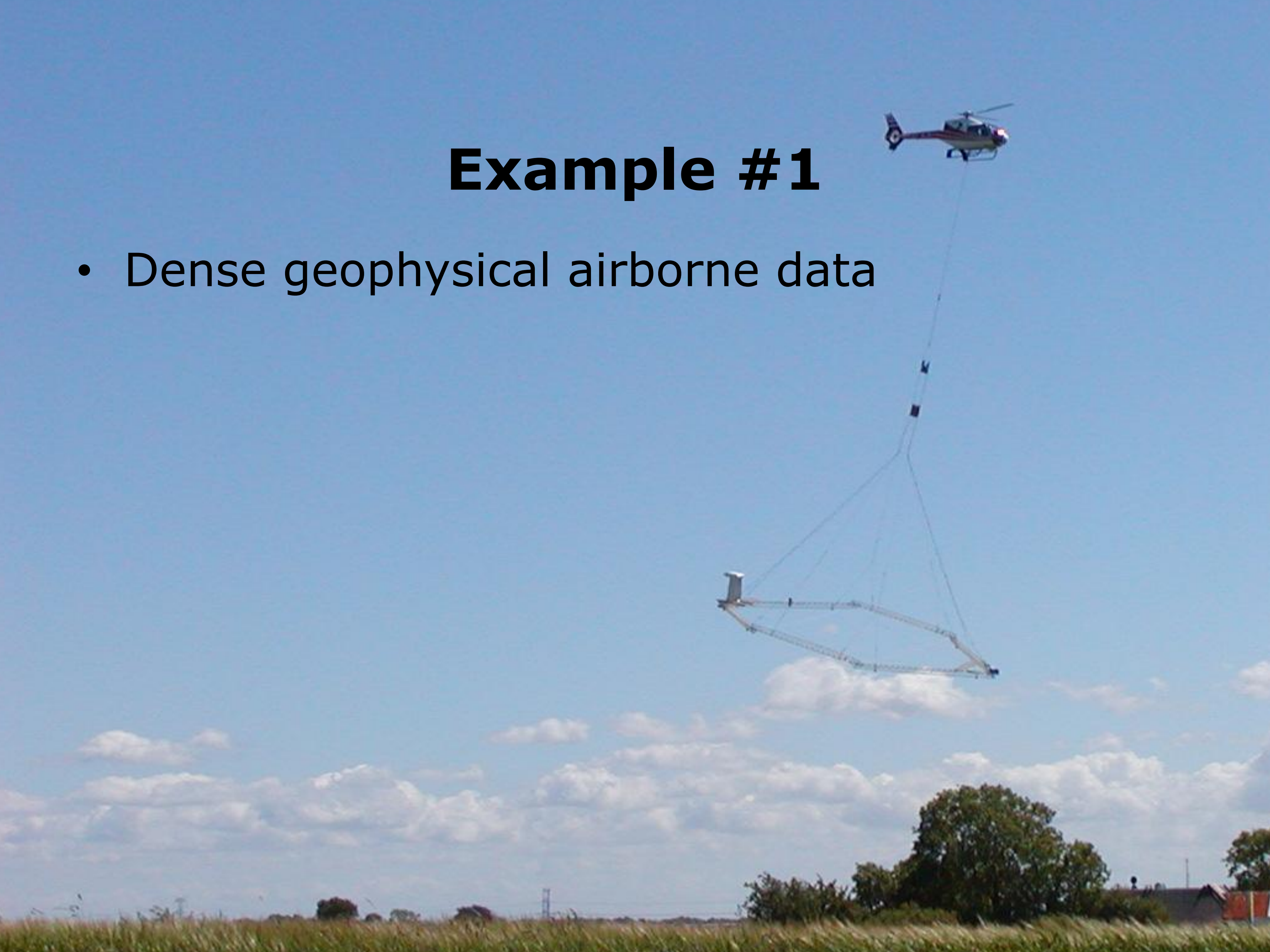
- Aarhus Vand A/S
- Alectia A/S
- SkyTEM Surveys ApS
- Aarhus Geophysics ApS

Partners, international

- The U.S. Geological Survey (USGS)
- Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia.
- Geological Survey of Holland (TNO)

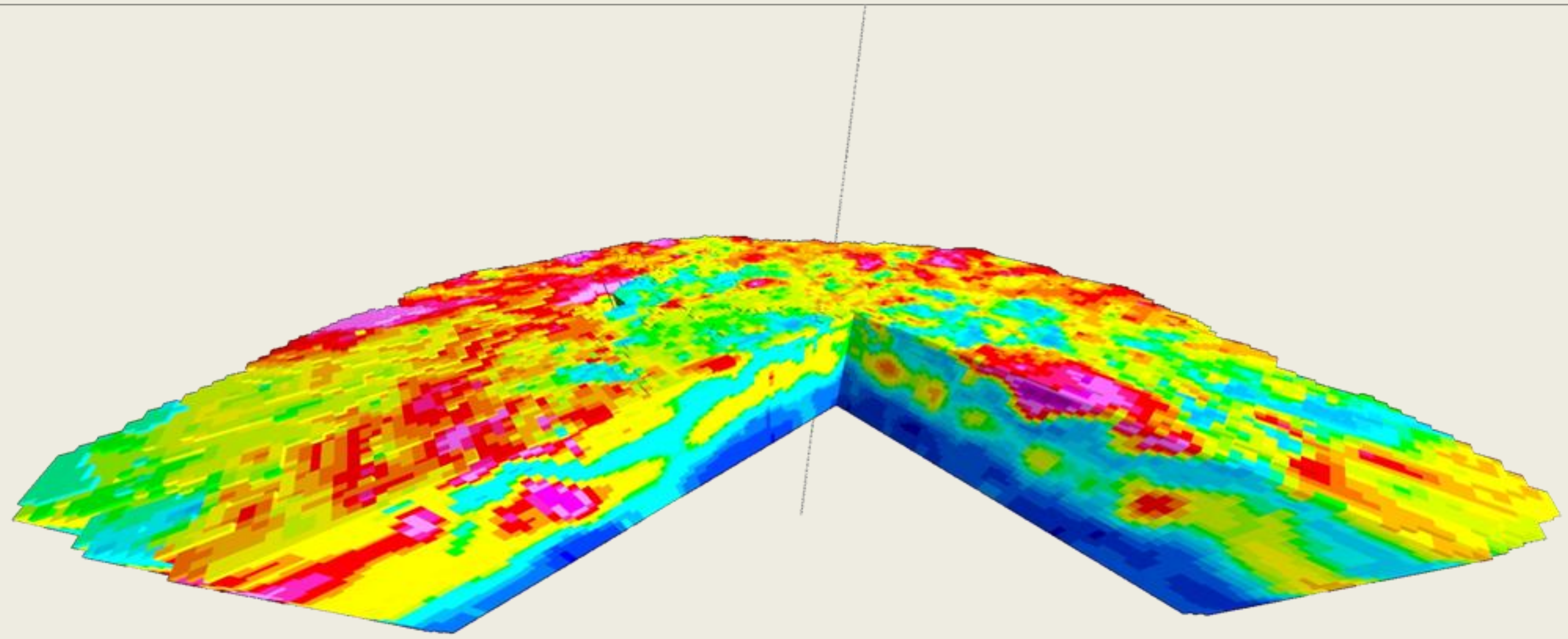
Example #1

- Dense geophysical airborne data



Example #1

- Dense geophysical airborne data
  - Processed by a geophysicist to a resistivity model



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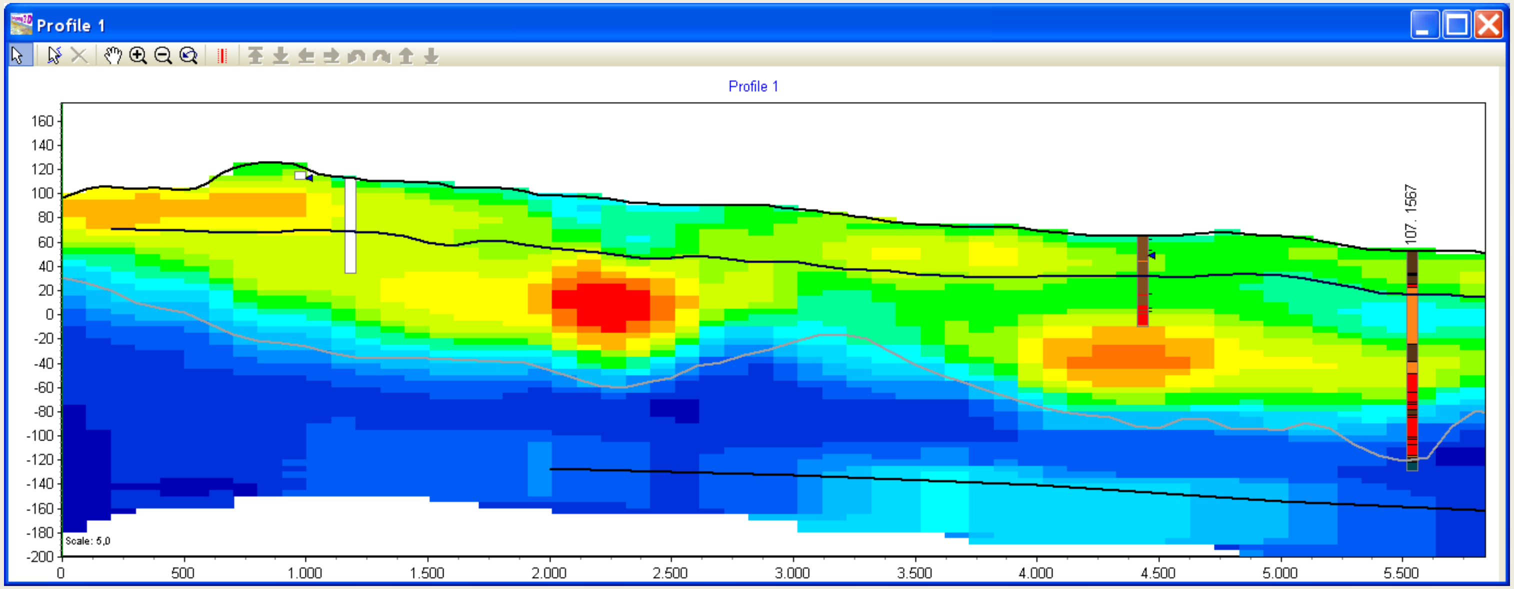
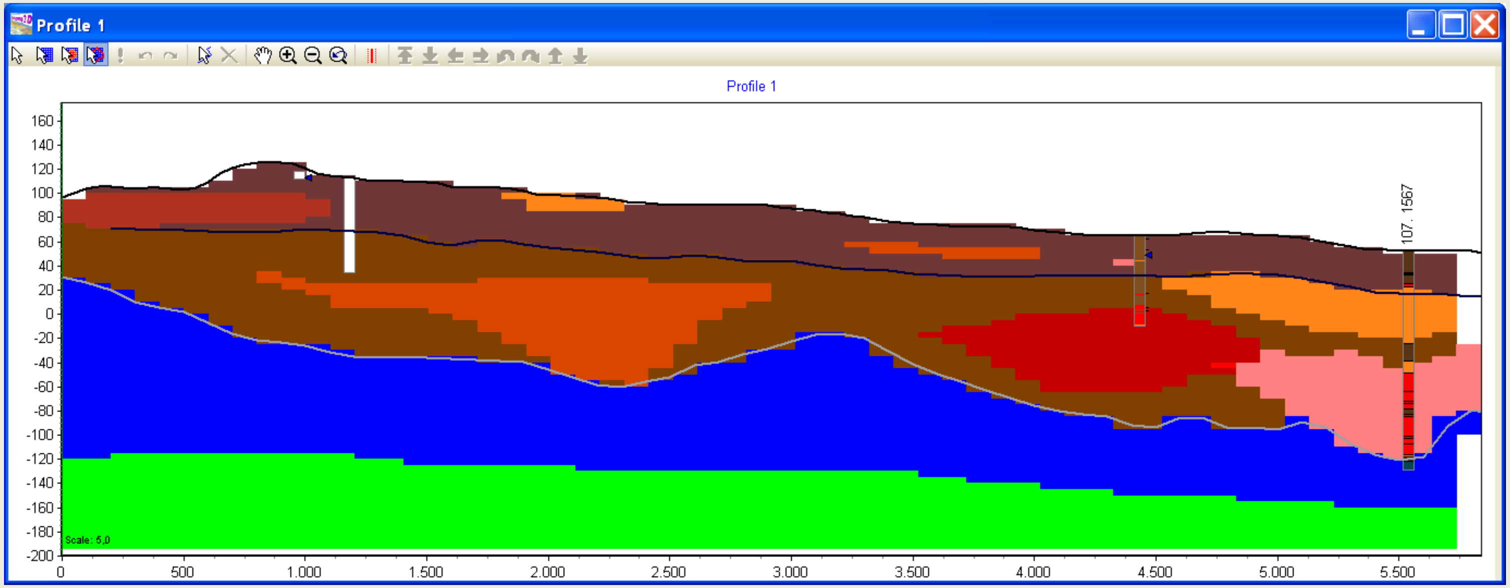


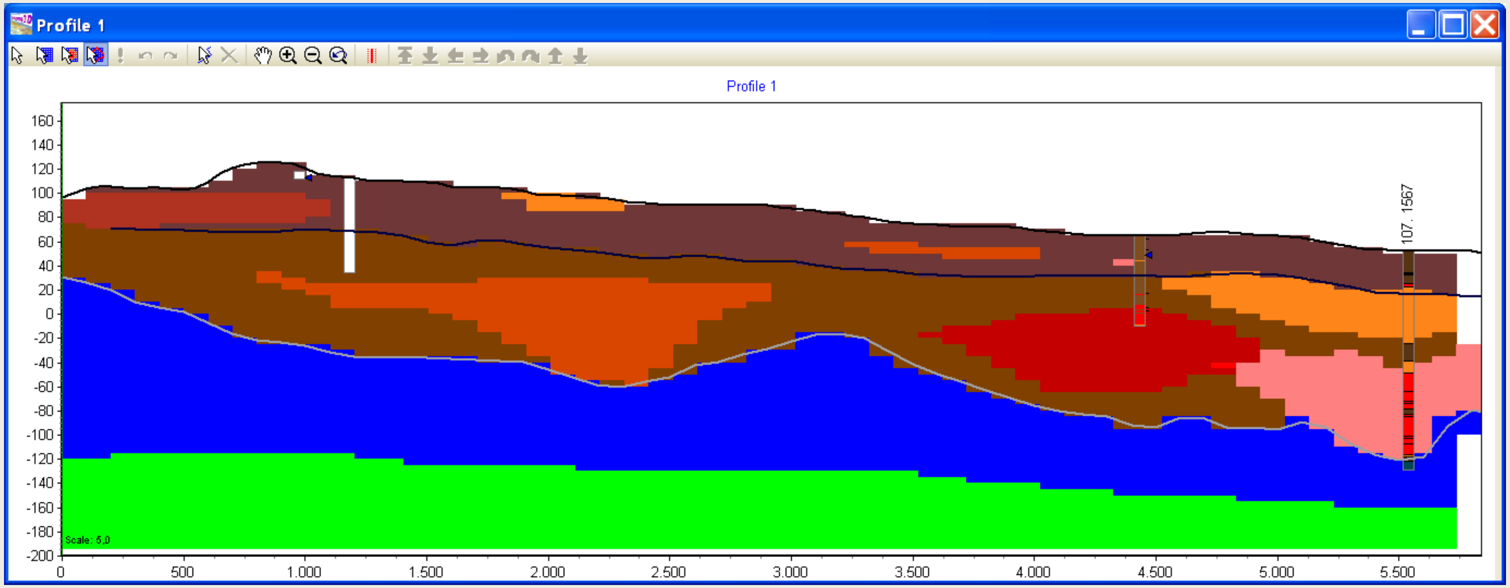
Example #1

- Dense geophysical airborne data
  - Processed by a geophysicist to a resistivity model
  - Interpreted by a geologist to a geological model



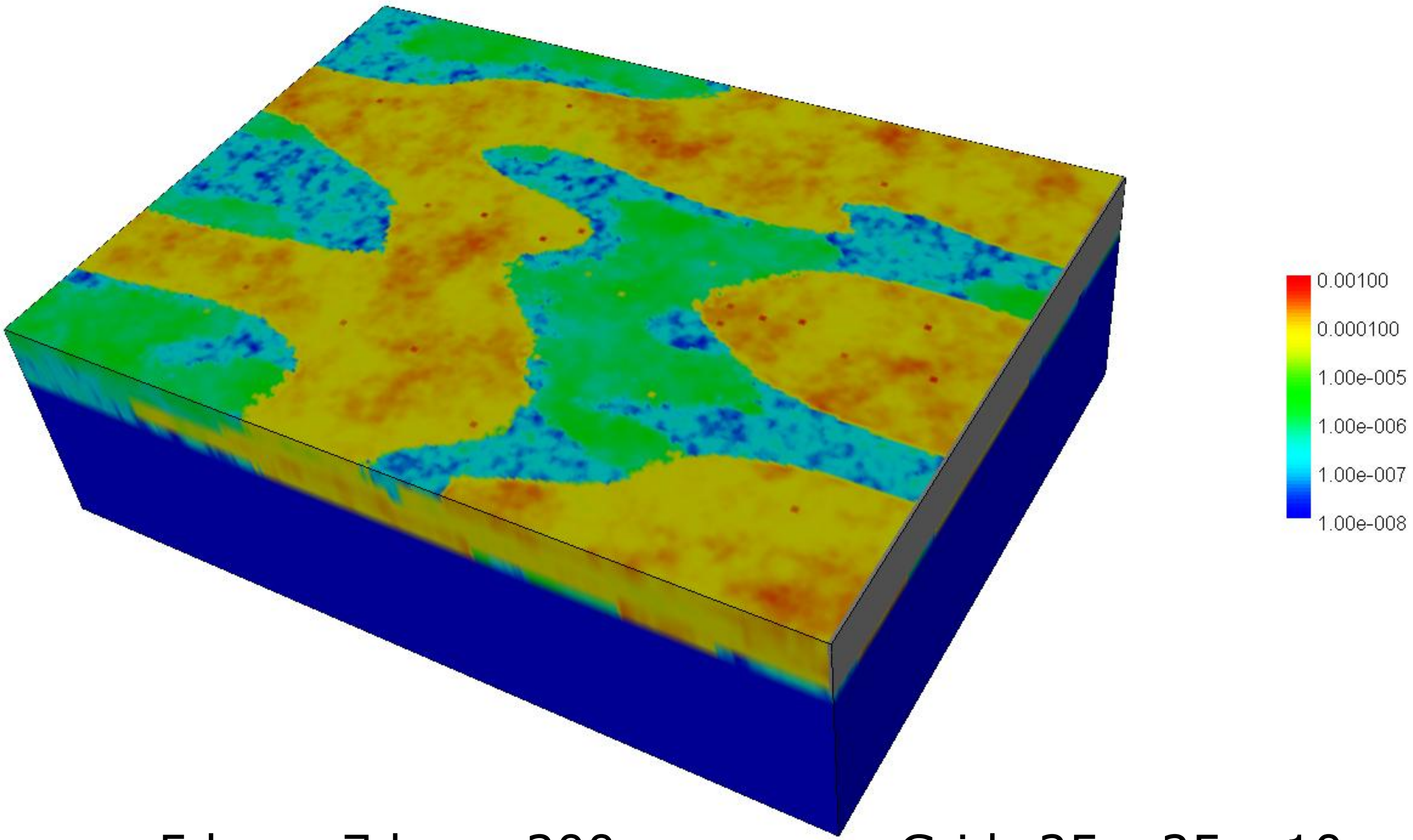
Example #1

- Dense geophysical airborne data
  - Processed by a geophysicist to a resistivity model
  - Interpreted by a geologist to a geological model
  - Translated into a hydrological model by a hydrogeologist (model reduction)



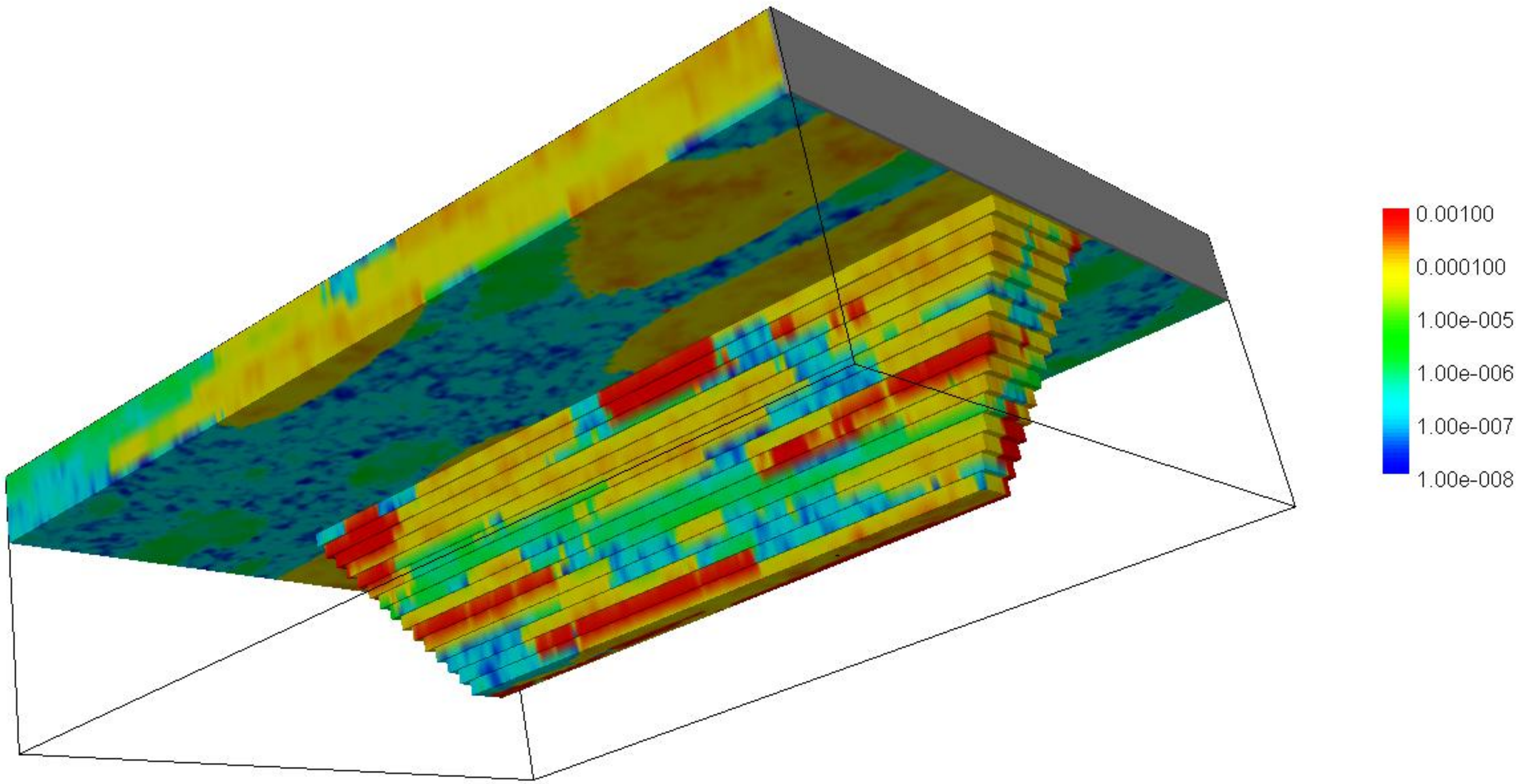
Example #2

- Example from Steen Christensen
- Synthetic
- Heterogeneous geology with buried valley
- Impermeable basis



Studied volume: 5 km × 7 km × 200 m

Grid: 25 × 25 × 10 m

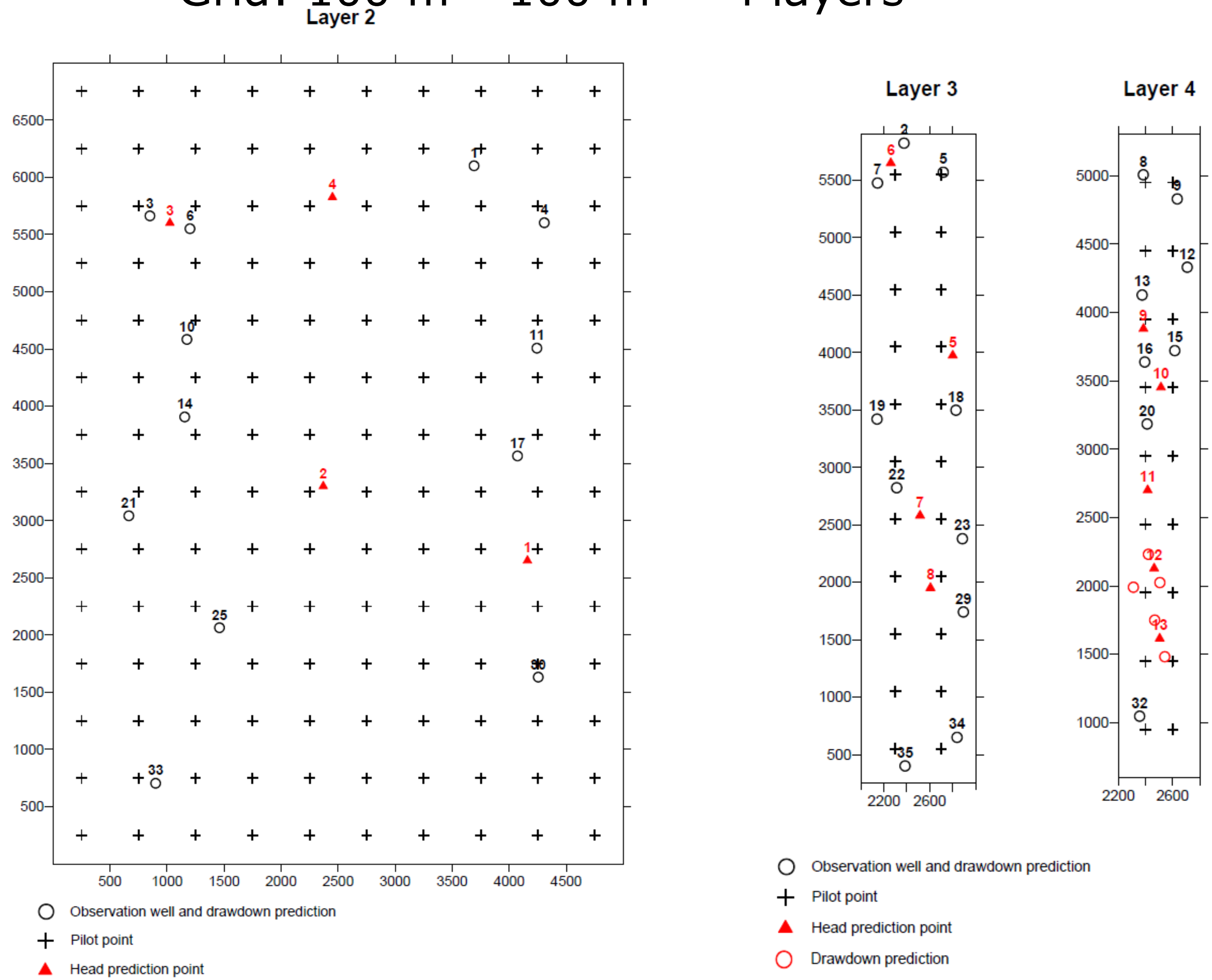

0.00100
0.000100
1.00e-005
1.00e-006
1.00e-007
1.00e-008

In practice:

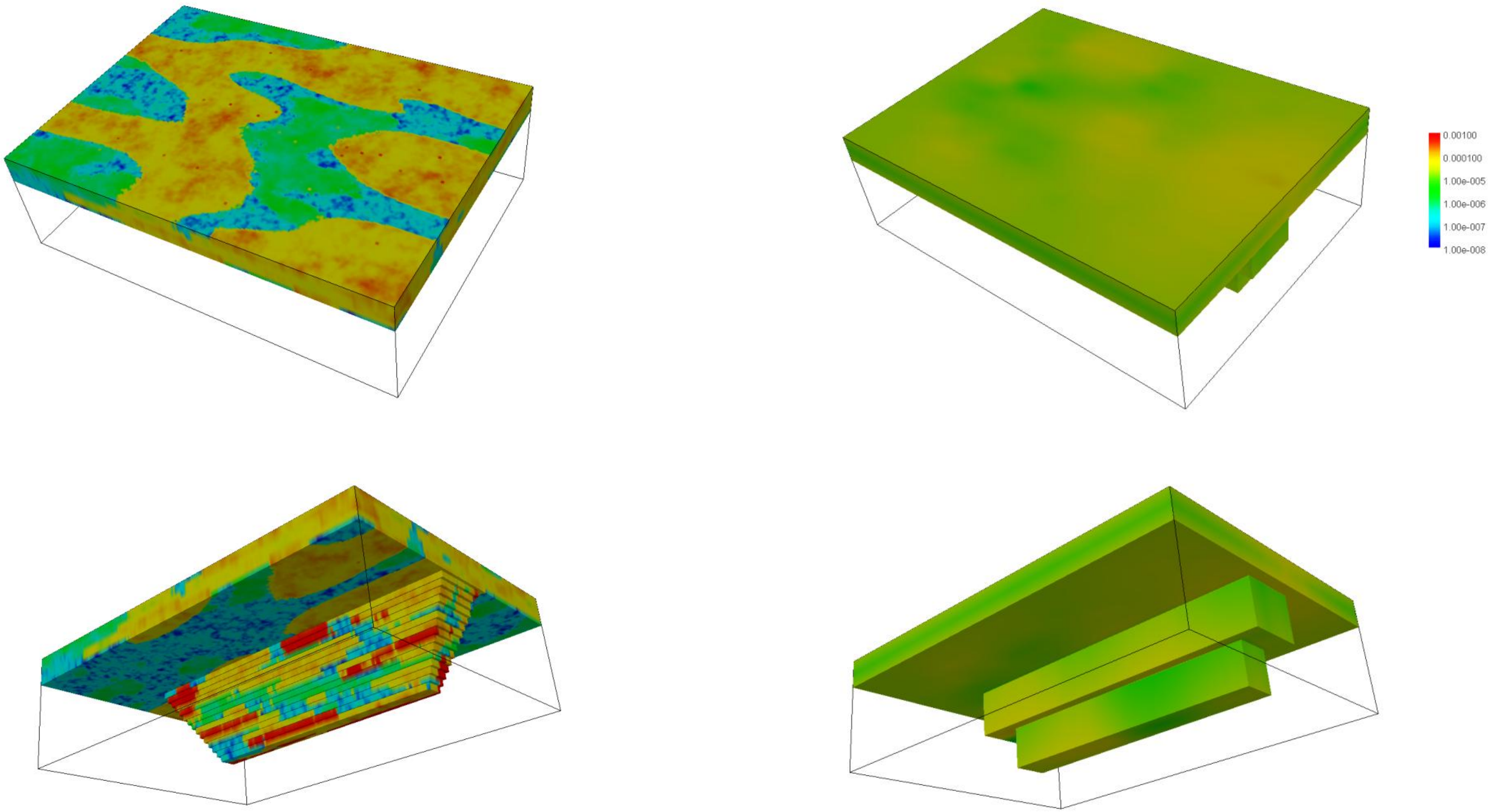
- Build simplified model from available date – e.g. borehole information
- Calibrate the model to fit hydrological data – e.g. hydraulic head in wells
- Make prediction with the calibrated simplified model

Simple model parameters, calibration data, head and drawdown predictions

Grid: 100 m × 100 m × ”4 layers”

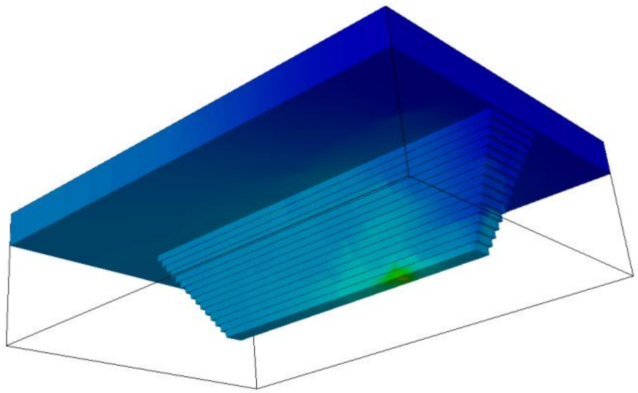


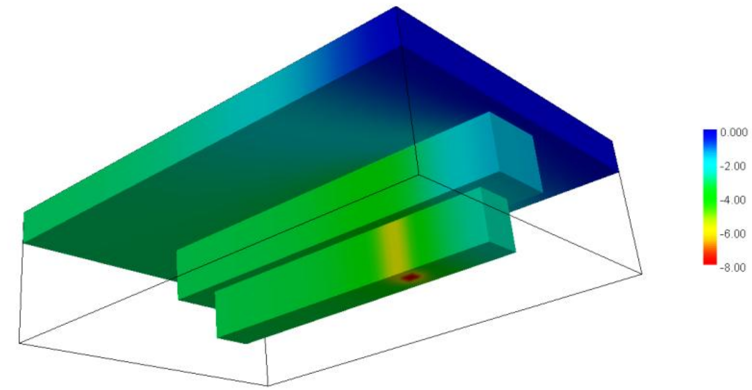
"Real K field" versus simple model "perfectly calibrated K field" (realisation 1)



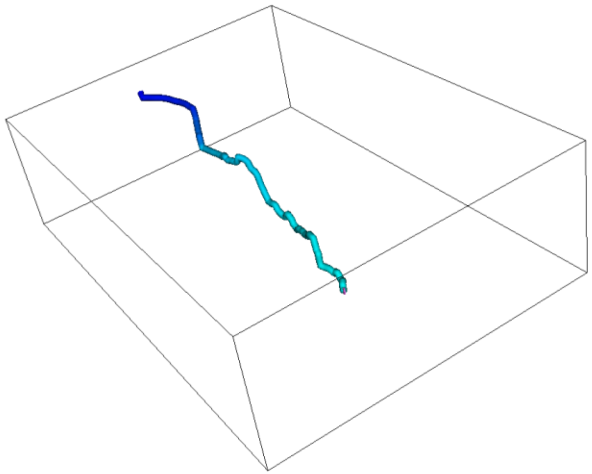
(Confining bed leakances not visualised)

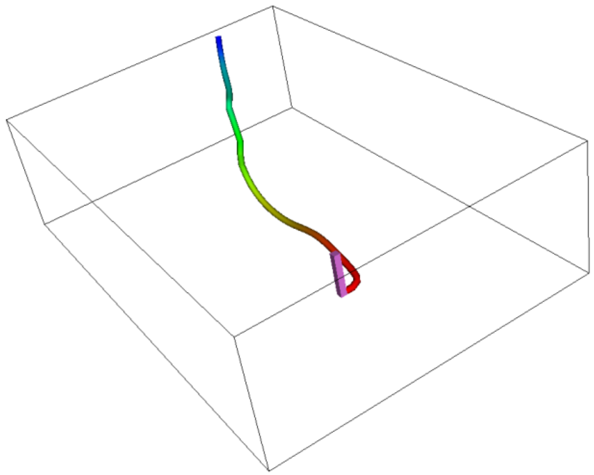
”Real drawdown” versus simple model ”predicted drawdown” (realisation 1)





"Real pathline" versus simple model "predicted pathline" (realisation 1)





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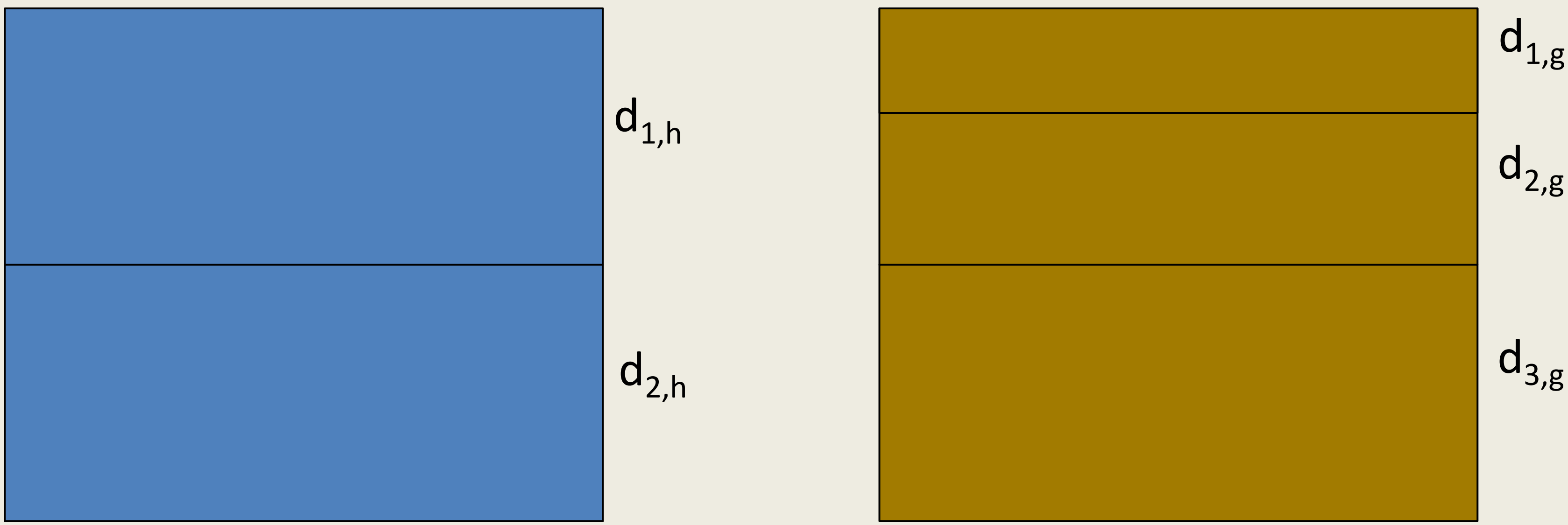
HyGEM developments

- Coupled inversion
  - Geometry: Layer interfaces and thicknesses in groundwater model and geophysical model must be identical
  - Petrophysical: Correlation of electrical and hydraulic conductivity
- Sequential inversion
  - Invert geophysical data *then* invert for hydrological/geological parameters
- Geostatistical approach
  - Statistical links between e.g. lithology and resistivity used to build probable models

Coupled inversion: Geometric

Groundwater model

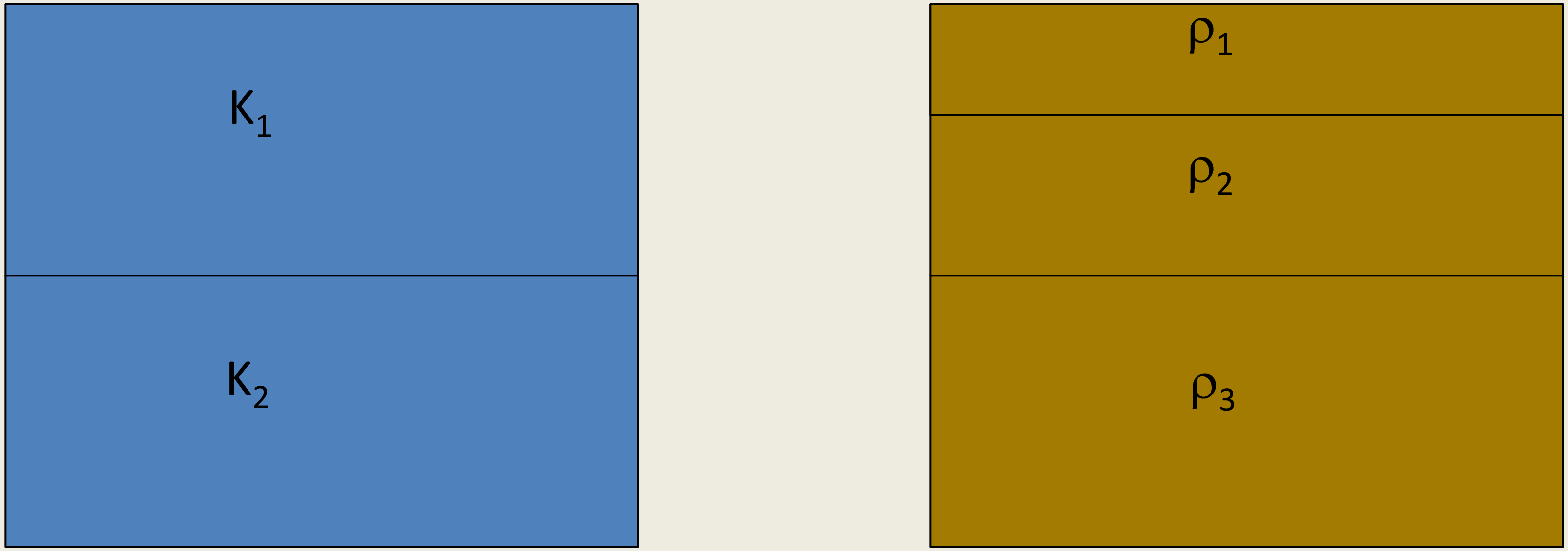
TEM model



$$PCC = \frac{1}{s_c^2}\left(d_h - d_{1,g} - d_{2,g}\right)^2$$

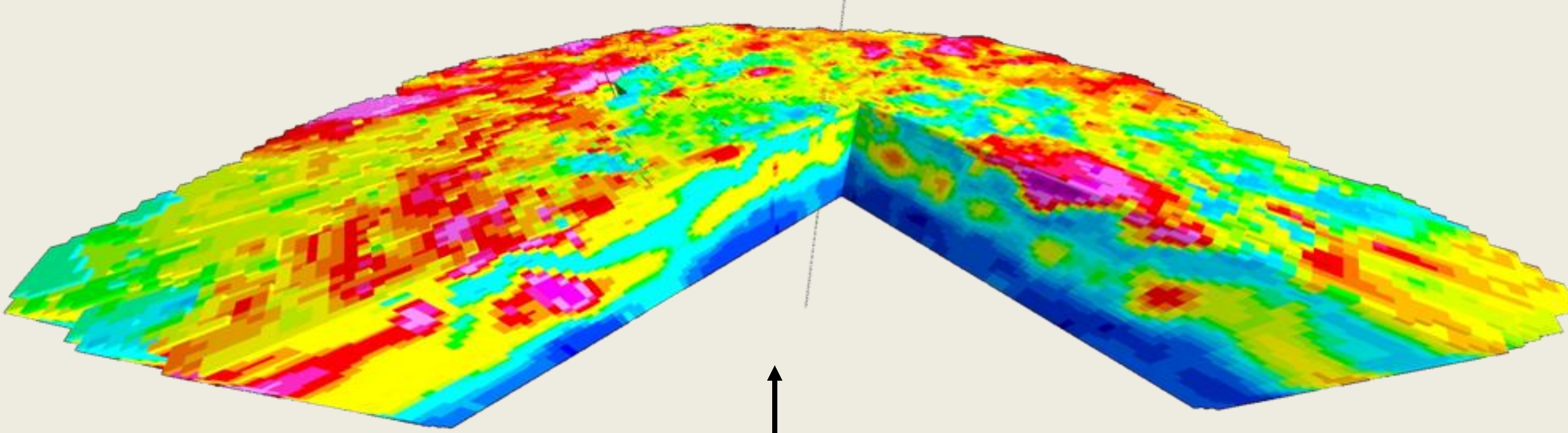
Coupled inversion: Petrophysical

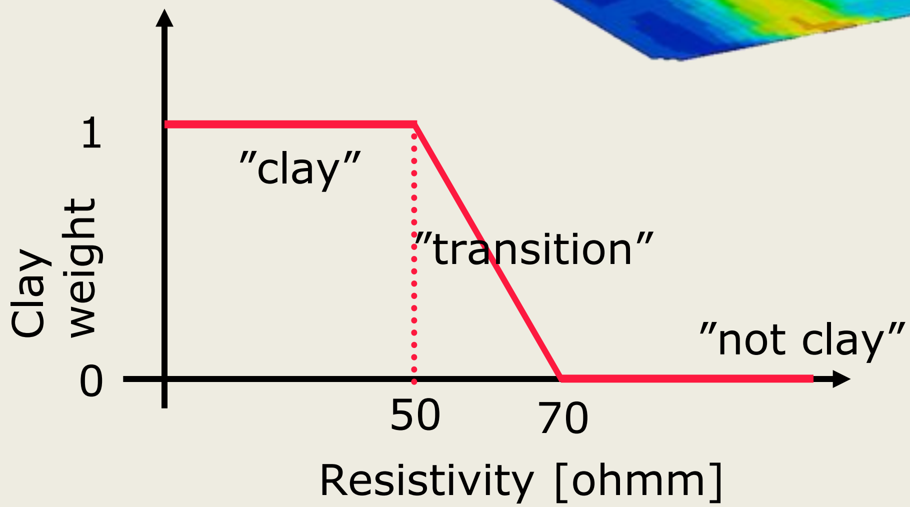
Groundwater model TEM model



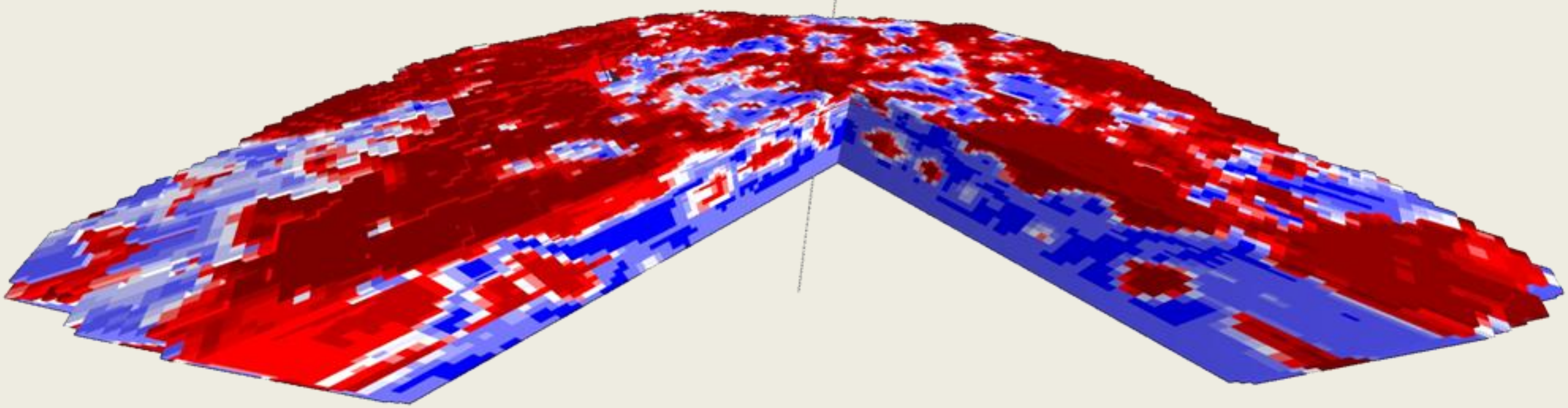
$$PC=1/S(C+\ln(K_2)-\ln(\rho_3))^2$$

Sequential inversion: SSV





Sequential inversion: SSV



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Geostatistical approach

- Describe relationship between lithology and resistivity
- GERDA and Jupiter !

Formation	Lithology	Restivity intervals (ohmm) 0-1	1-2	2-3	3-5	5-10	10-20	20-30	30-40	40-50	50-60	60-80	80-100	100-120	120-160	160-200	Thick-ness (m)
Morild	Sand/silt							■	■	■	■	■	■	■	■	■	Up to 212
Troldbjerg	Sand											■	■	■	■	■	Up to 95
Ribjerg	Clay/sand							■	■	■	■	■	■	■	■	■	Up to 55
Lønstrup Klint	Clay/sand						■	■	■	■	■	■	■	■	■	■	Up to 35
Upper Skærumhede Clay	Clay				■	■	■	■	■				■				5 - 20
Åsted	Till				■	■				■	■	■	■				3 - 12
Middle Skærumhede Clay	Clay			■	■	■											5 - 20
Brønderslev Clay Member	Clay/sand				■	■	■	■	■	■	■	■					10 - 55
Brønderslev Till Member	Till, sandy					■	■						■				5 - 30
Lower Skærumhede Clay	Clay, silty			■													Up to 85
Skærumhede Till	Clay till					■				■	■						5 - 15
Upper Cretaceous	Chalk					■				■			■				-

Sandersen *et al.* 2009

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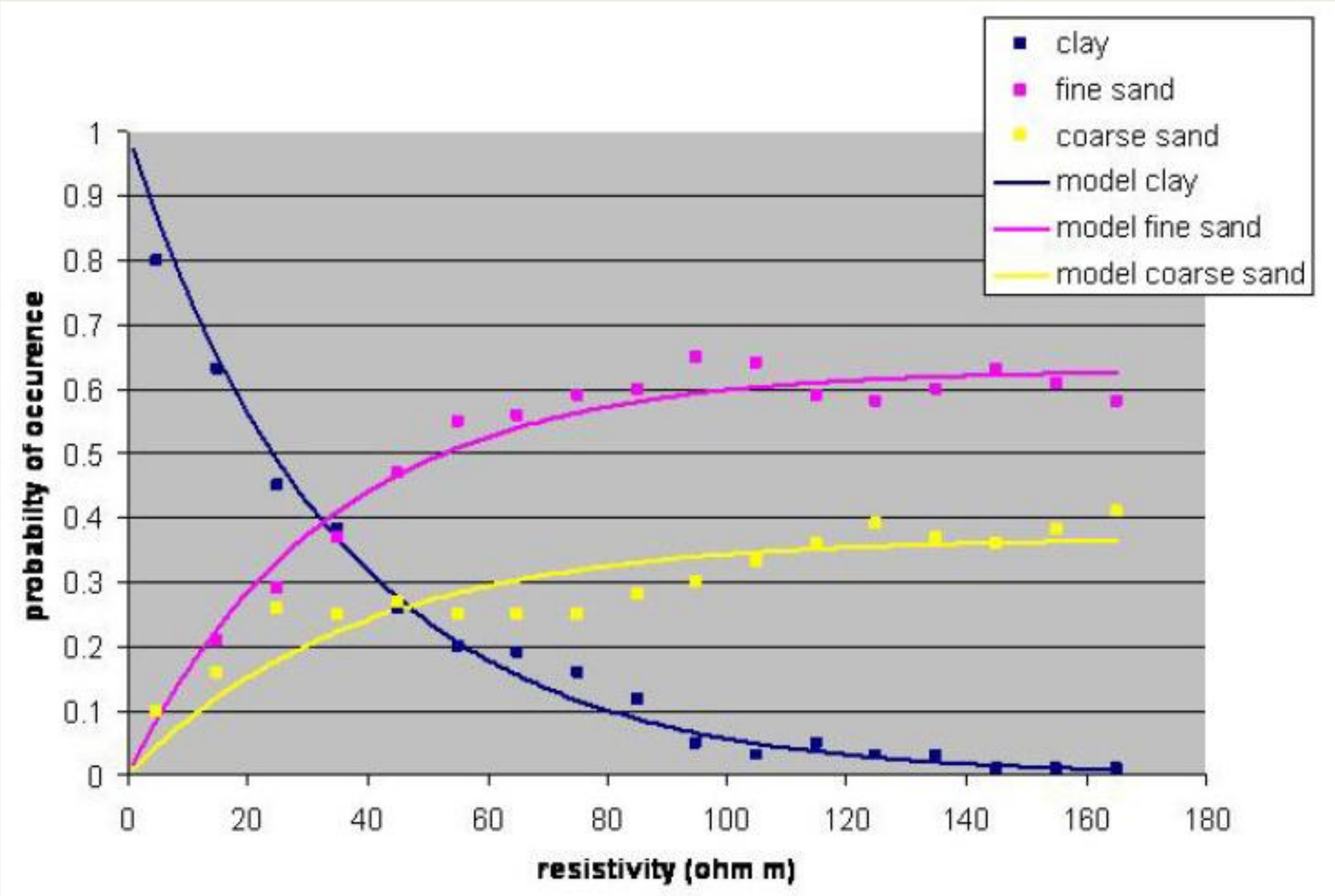
Geostatistical links



Gunnik, 2007

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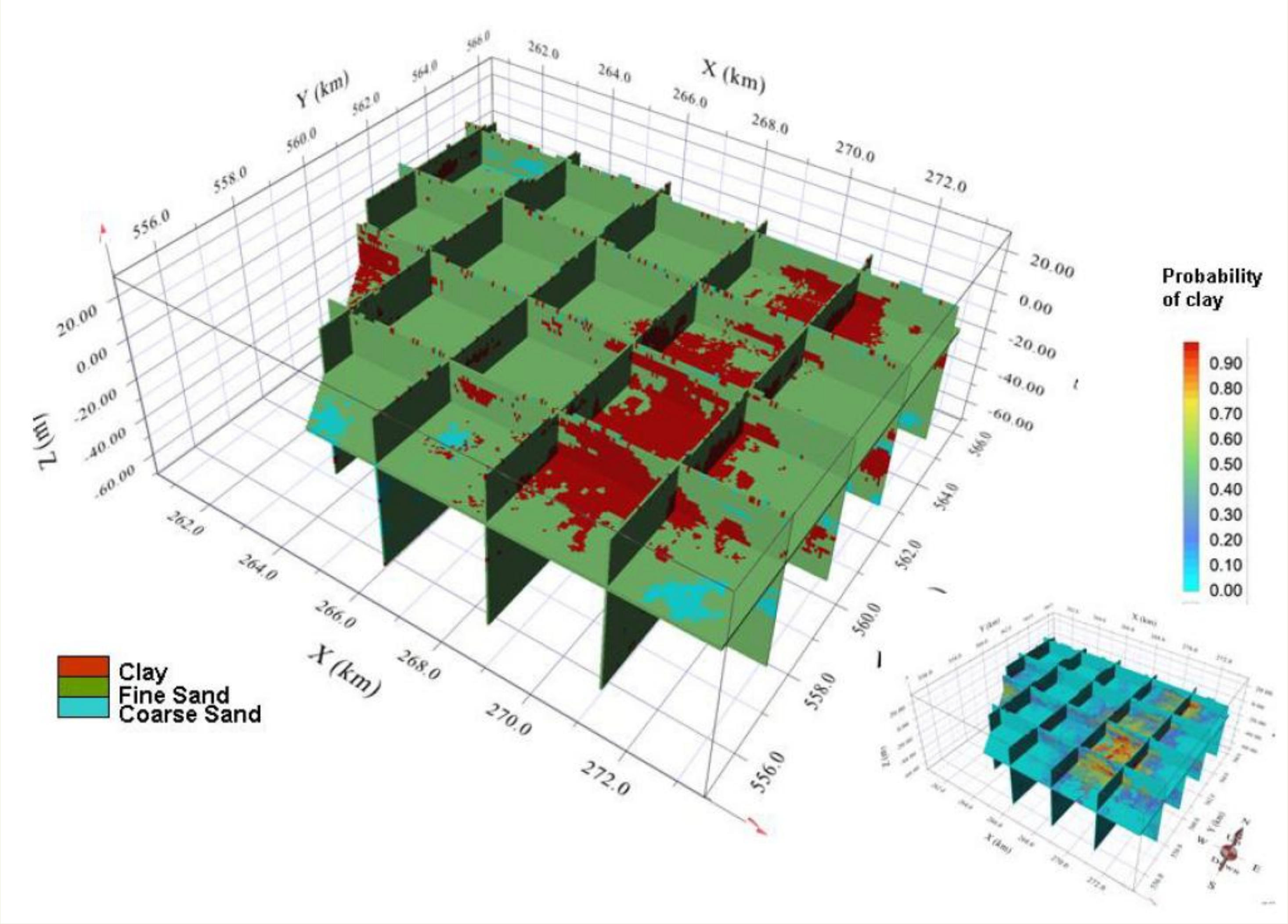
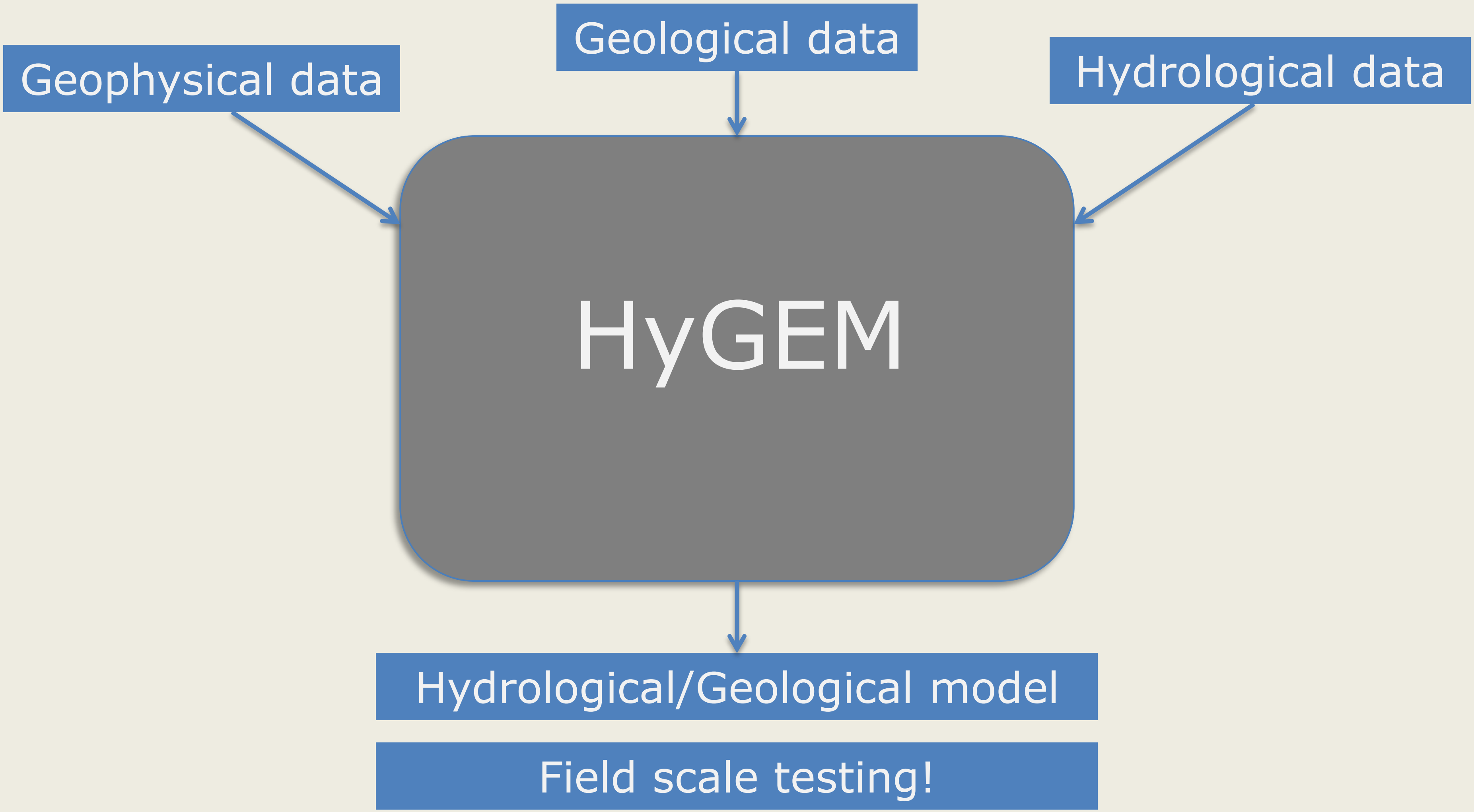
Geostatistical links



Objectives


Geological data
Geophysical data
Hydrological data
HyGEM
Hydrological/Geological model
Field scale testing!

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