Integrating Geophysics, Geology, and Hydrology to Enhanced Hydrogeological Modelling

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HyGEM

Integrating geophysics, geology and **Hy**drology for improved **G**roundwater and **E**nvironmental **M**anagement

HyGEM is supported by the Danish Council for Strategic Research

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Motivation

- **Today the integration of geophysical and geological/hydrological data is**
  - Subjective
  - Largely un-documented
  - Manual

- **Possible information loss when combining different data sets through a chain of processes and people**

- **Information loss by changes in model discretization**

- **Need workable tools on large scale watershed investigations**

Objectives
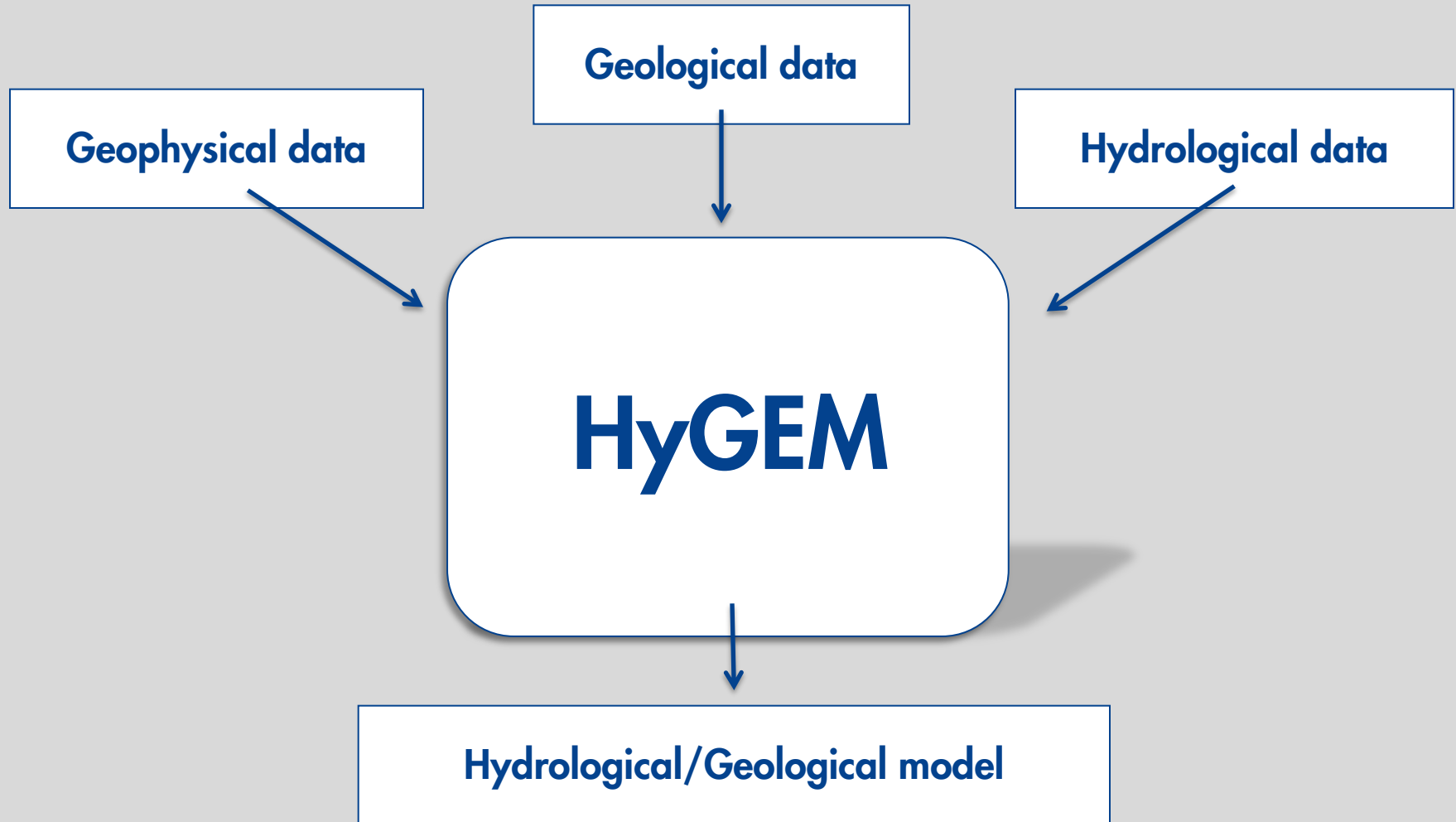
Objectives

- **Create tools for direct and (semi-) automatic integration of geophysical and geological data into hydrological models**

- **⇒ Better water resources and environmental management**

- **Results must be**
  - Reproducible
  - Documented
  - Objective
  - Uncertainties described

Tools

- **Airborne Electromagnetic**
- **Magnetic Resonance Sounding**
- **Geophysical borehole logging**
- **Pump tests**

- **Borehole (lithology) and geophysics database "mining"**

- **Geophysical data inversion**
- **Groundwater modeling**

- **Joint/coupled geophysical and groundwater inversion**

Danish Partners

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

- **Industry partners**
  - Aarhus Vand A/S
  - Alectia A/S
  - SkyTEM Surveys ApS
  - Aarhus Geophysics ApS

International Partners

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

- **International advisory board**
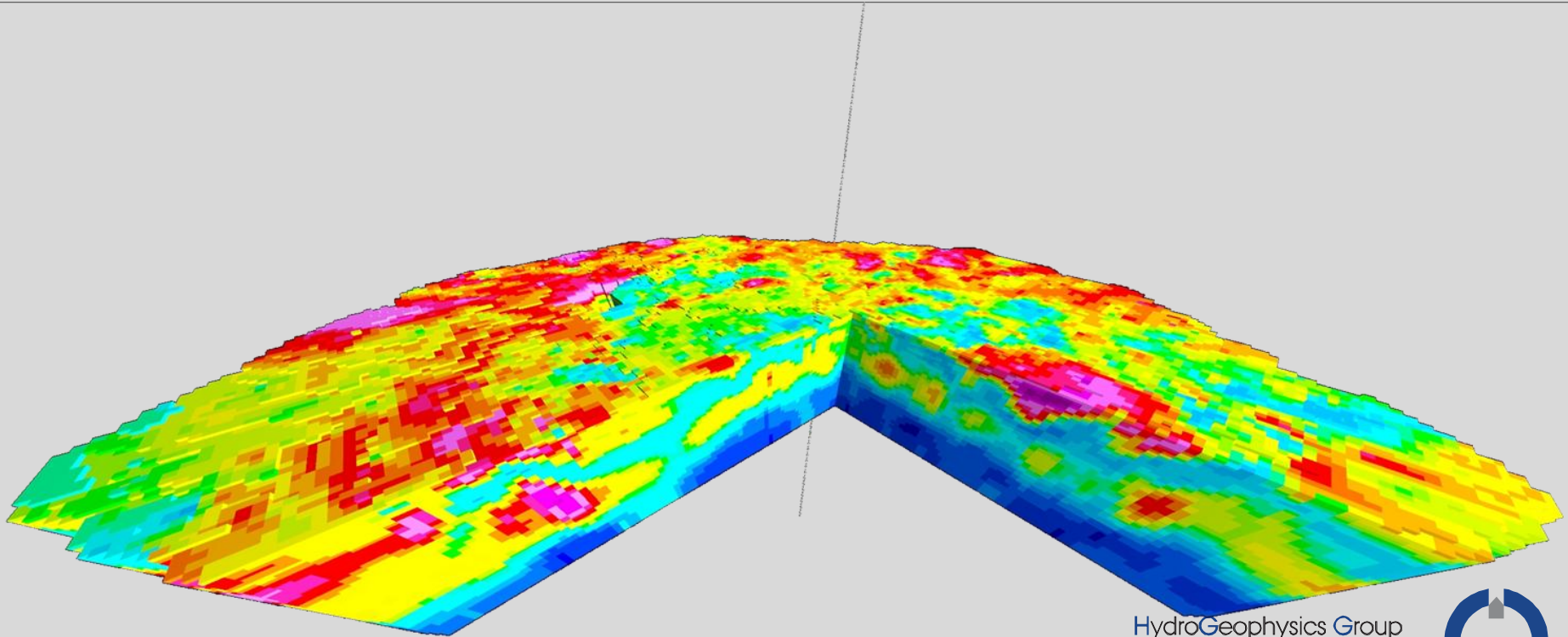 - Professor Rosemary Knight
  - Professor Ty Ferré

Example

- Dense geophysical airborne data

Example

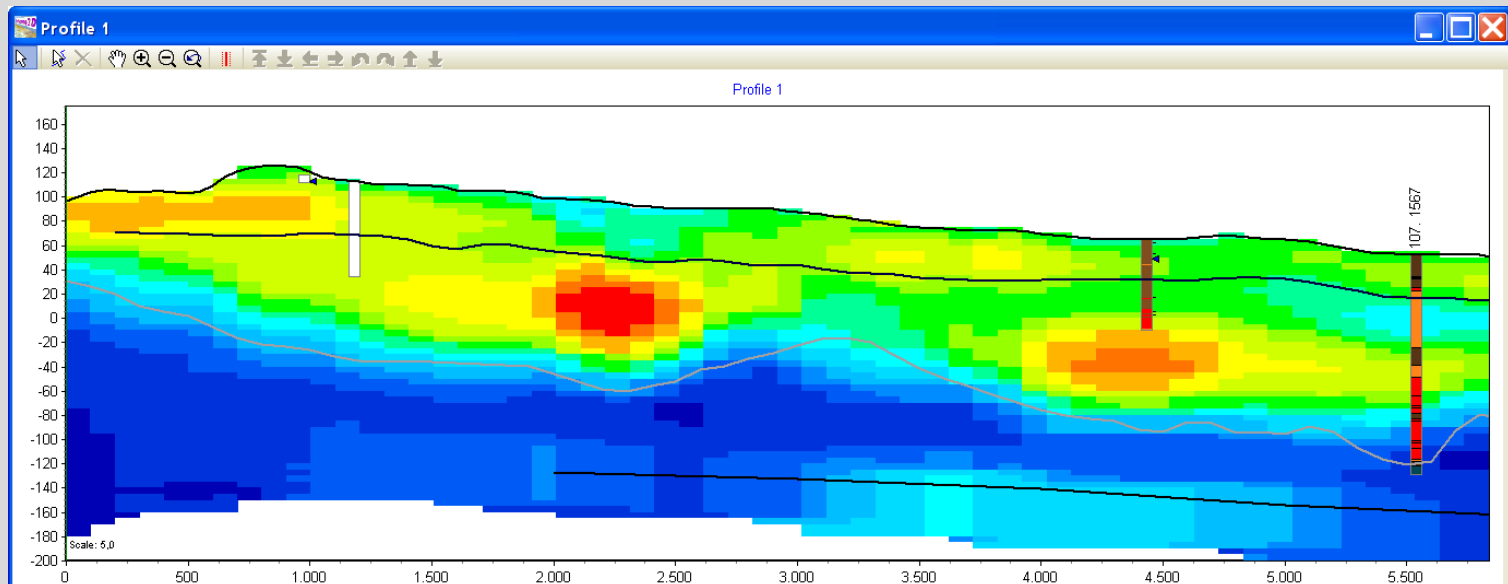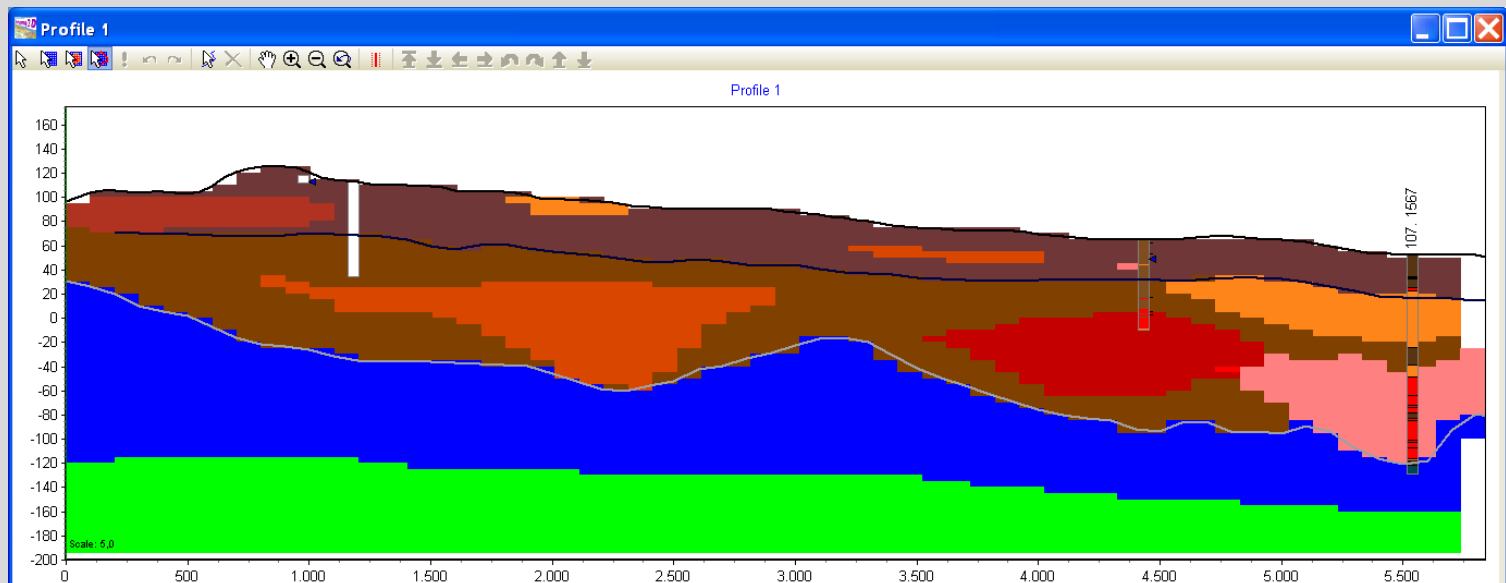- **Dense geophysical airborne data**
  - Processed by a geophysicist to a resistivity model

Example

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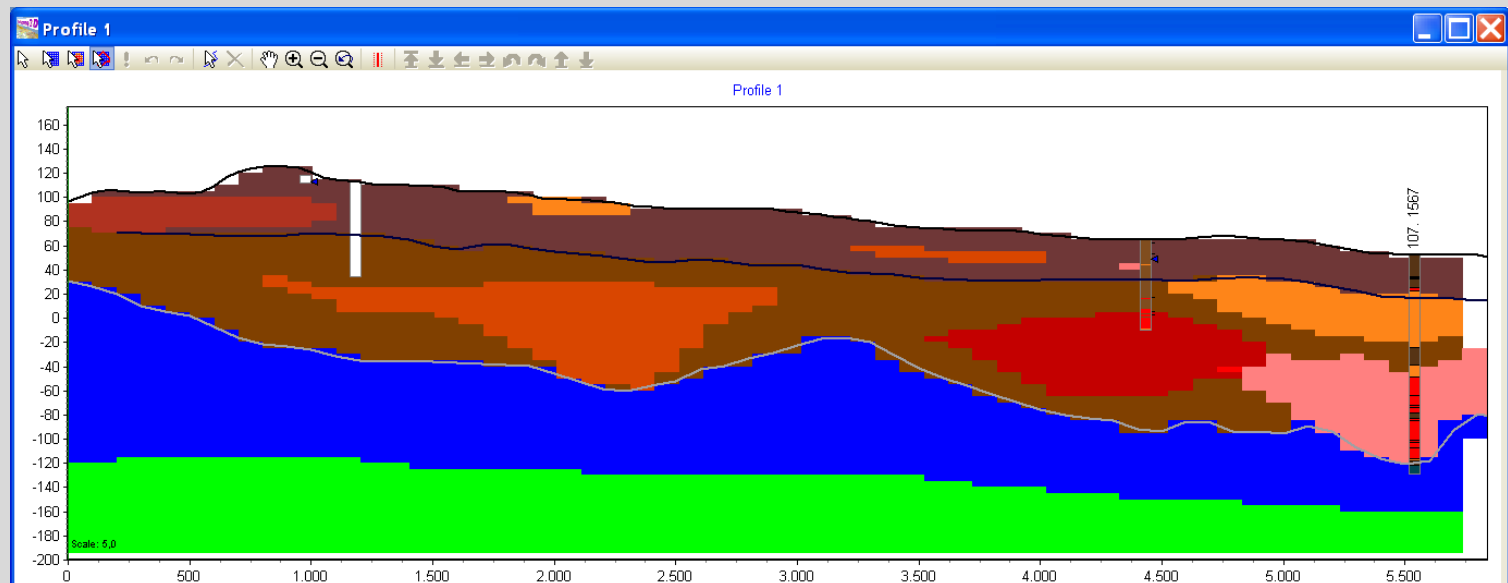 - Processed by a geophysicist to a resistivity model

Example

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

Example

- **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

- **One option: automatic translation to clay/sand model**

Resistivities

Clay/sand

Clay weight

1

0

"clay"

"transition"

"not clay"

5
0

7
0

Resistivity [ohmm]
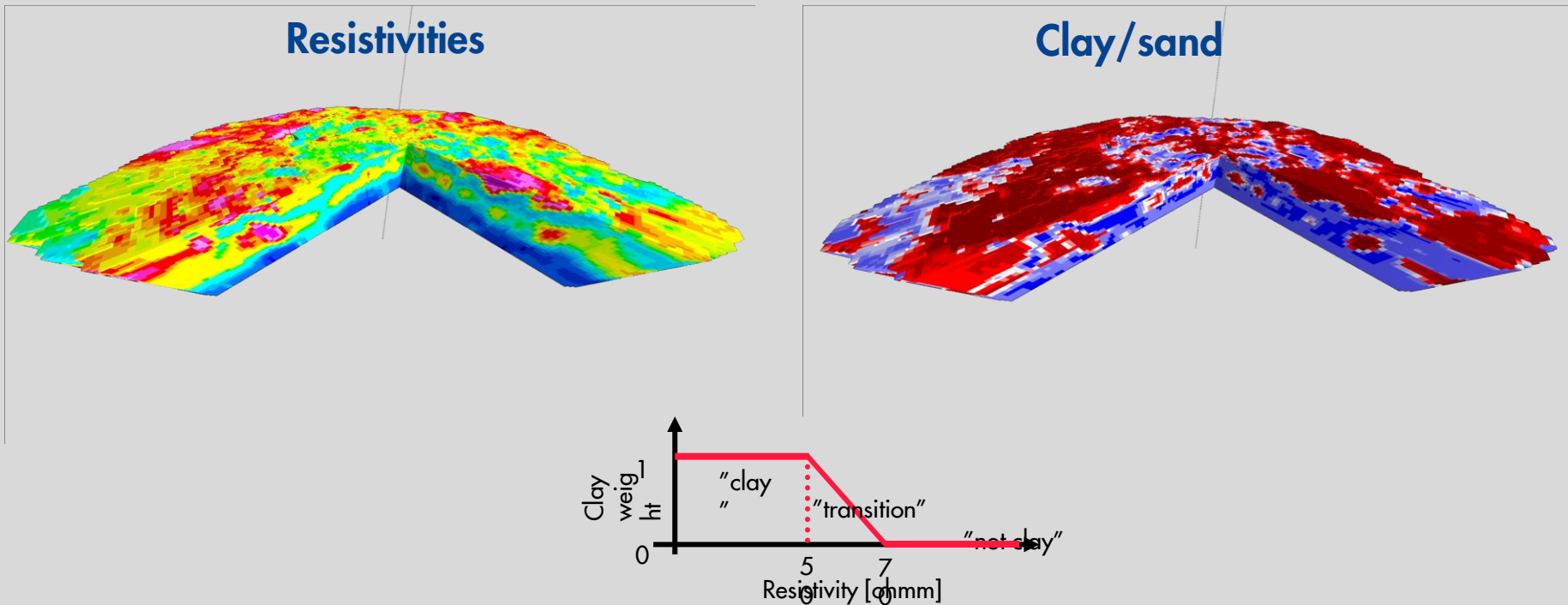
Tasks – the Hard Core Geophysics

- **Development of instrumentation**
  - Airborne electromagnetic – SkyTEM: Further enhance horizontal and vertical resolution by automated correction for early time data distortions
  - Magnetic Resonance Sounding: new wireless remote noise measuring system

- **Development of algorithms**
  - Octree grid based inversion of AEM and groundbased data.
  - Grid fits well with future joint inversion of groundwater models and geophysical data

- **Surveys in Denmark, Holland, USA and Australia**

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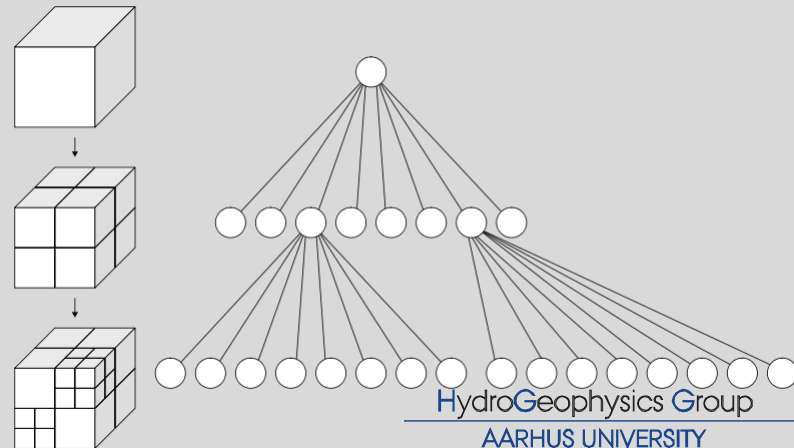
Tasks – Spatial Correlation…

- **Investigate spatial correlation between geophysical properties and lithology formations**

- **Borehole database with more than 200 000 boreholes and terabytes of geophysical data (mostly TEM and resistivity)**

- **Multivariate geostatistics**

Formation	Lithology	Restivity intervals (ohmm)															Thick-ness (m)
		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	
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
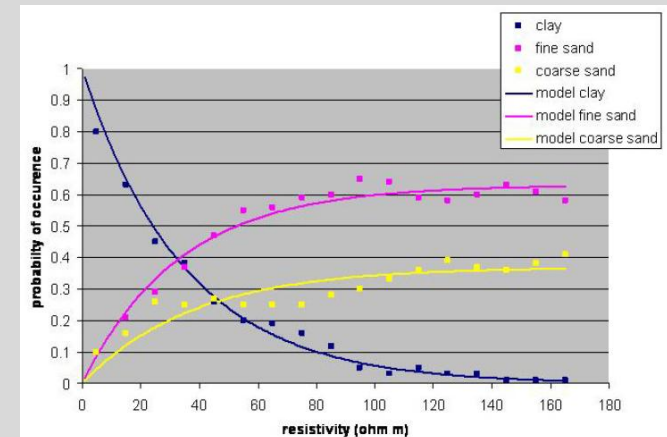
Tasks – Inversion – hydro and geophysics

- **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

Tasks – Testing the Hypotheses

- **Test-bench environment for accessing new ideas in a controlled environment for geophysical and hydrological modeling**

Join Us

- **We can contribute with**
  - SkyTEM, MRS, boreholelogs, lithology logs
  - Modflow and MikeShe hydrological models
  - Engaged PhD's and post docs
  - Advanced software packages for modeling of geophysical and hydrological data

- **The data can be made available for collaboration research projects**

Conclusion

- **HyGEM will develop more automatic approaches for coupling geological, hydrological and geophysical data on large scale water shed scale**

- **Development of instrumentation, algorithms and concepts**

- **We are for sure not able to go all the way, but this is a start !**

www.hygem.org