GEUS

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A new concept for identifying a scale of potential predictive capability of spatially distributed models

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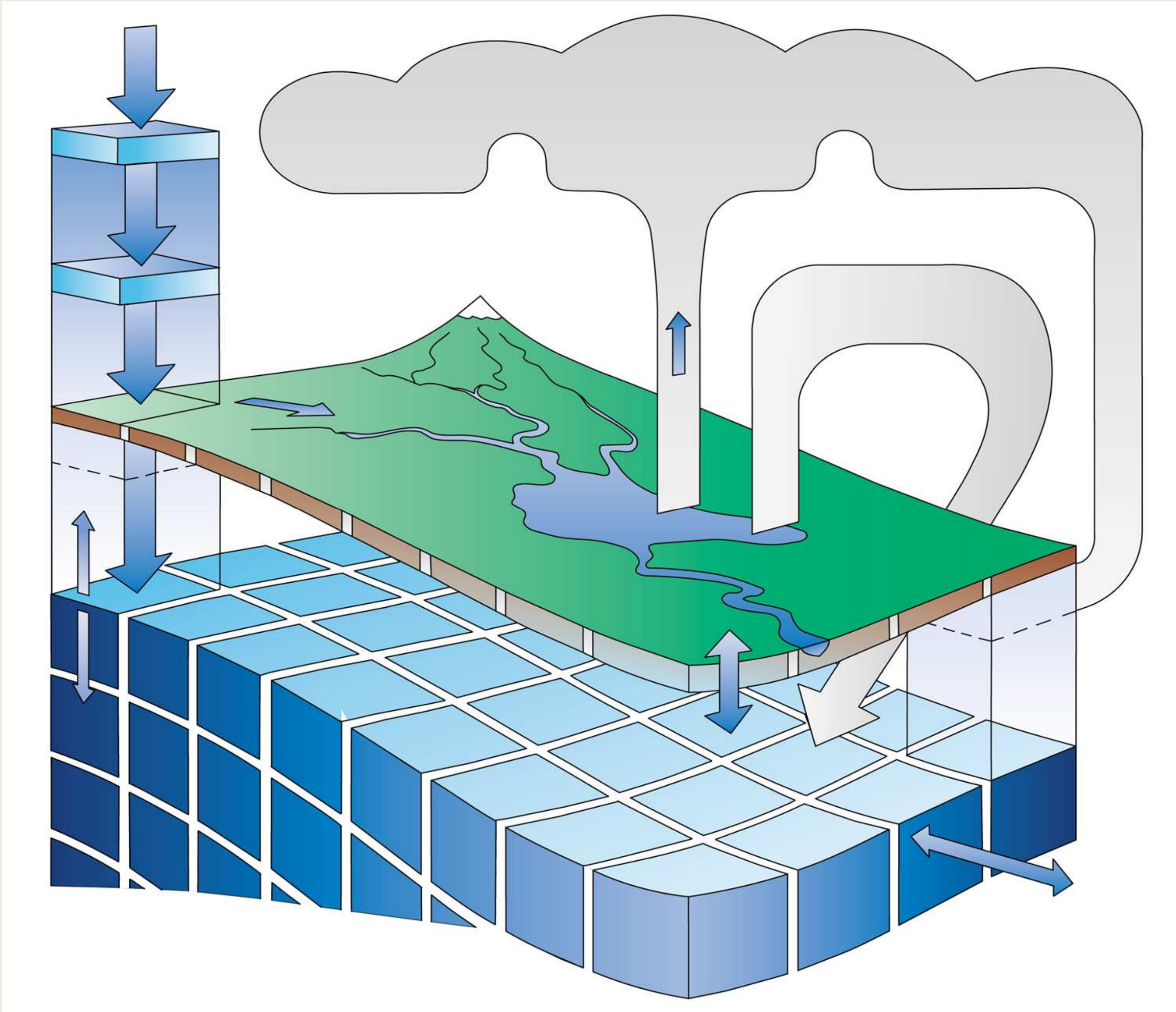
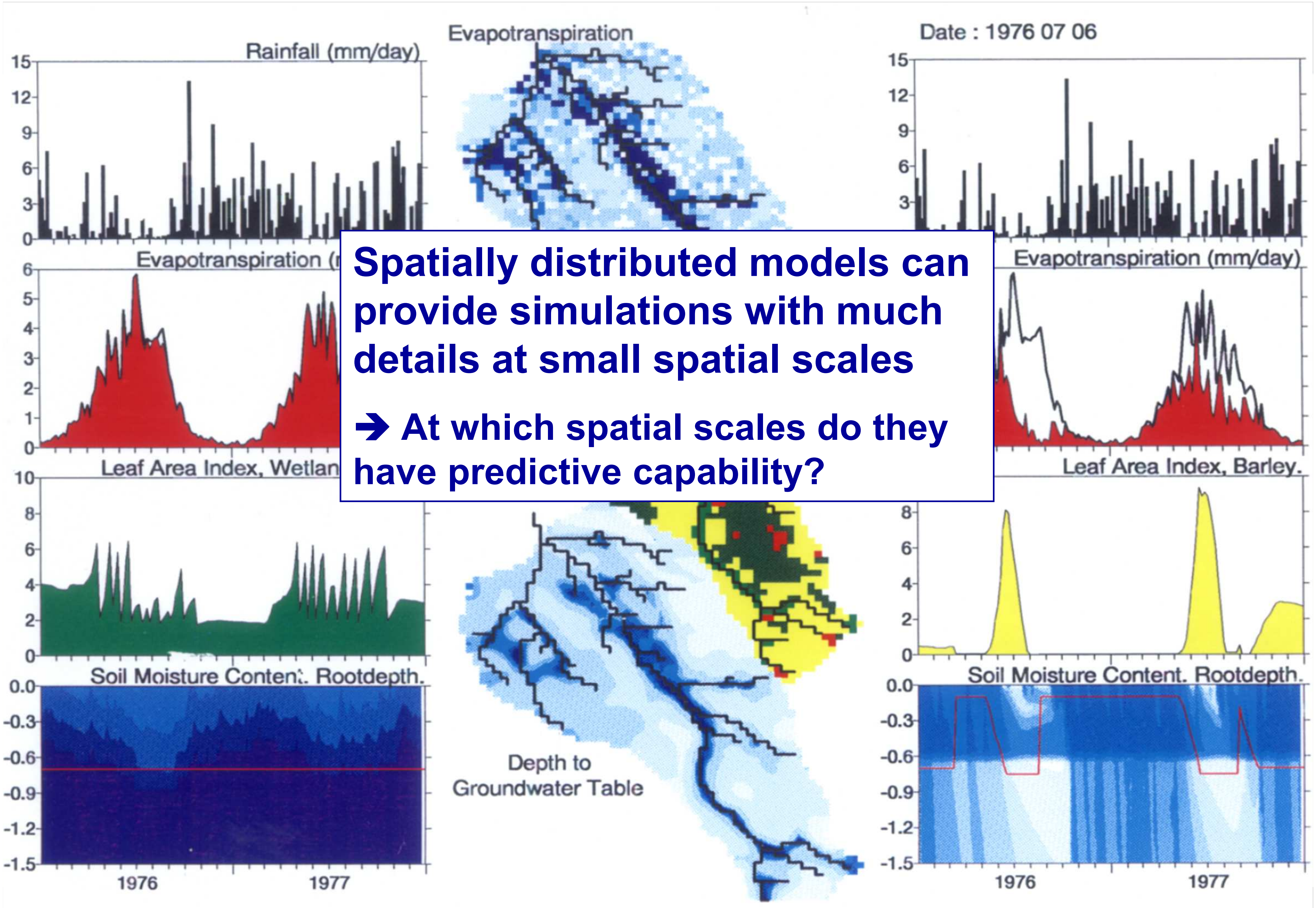
Outline

- Problem – How good are distributed models – and at which spatial scale?
- Representative elementary scale (RES) concept
- Example 1: Precipitation uncertainty
- Example 2: Geological uncertainty – nitrate modelling
- Conclusions

Sophisticated model codes

- How good are our models?





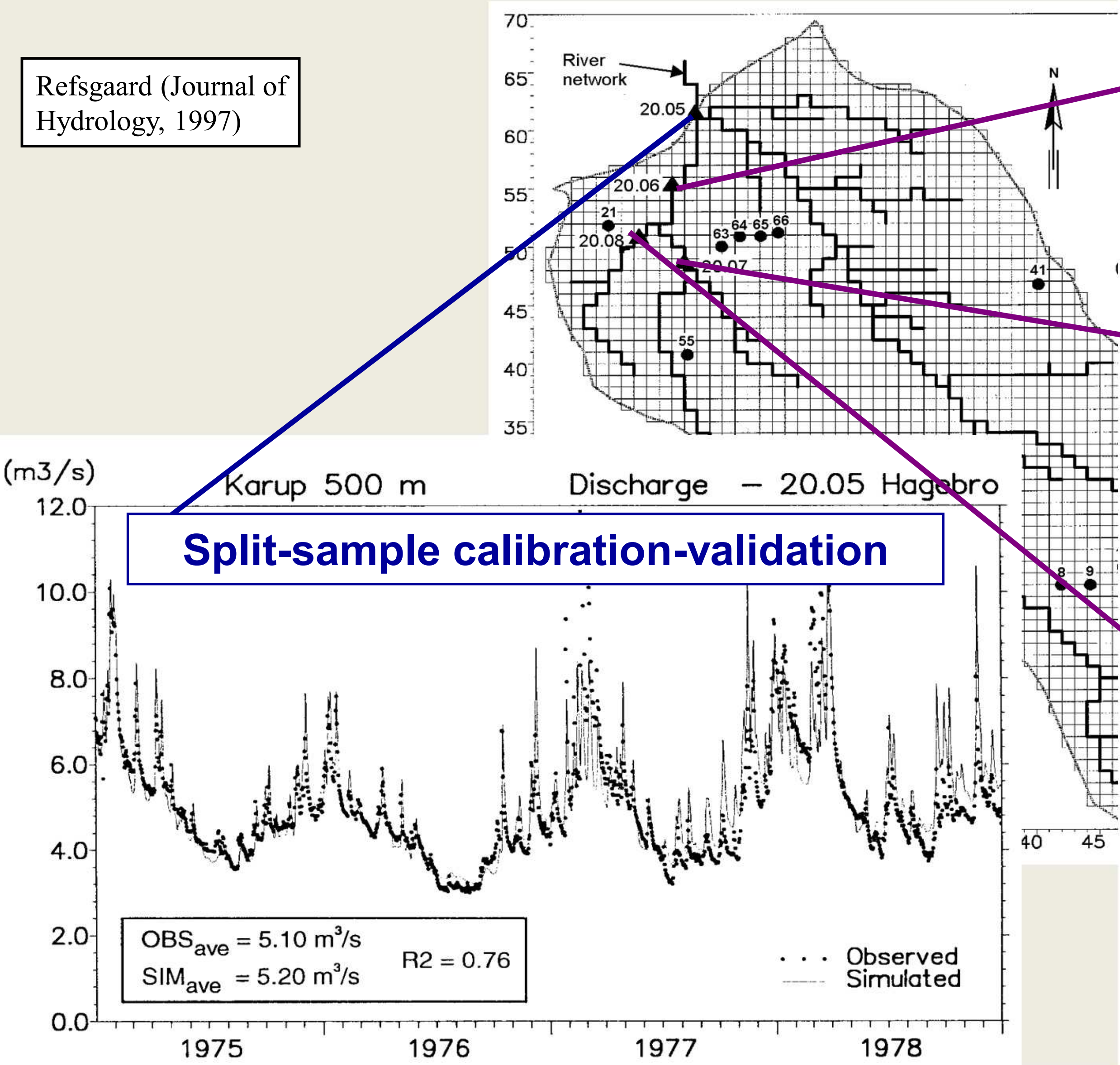
Spatially distributed models can provide simulations with much details at small spatial scales

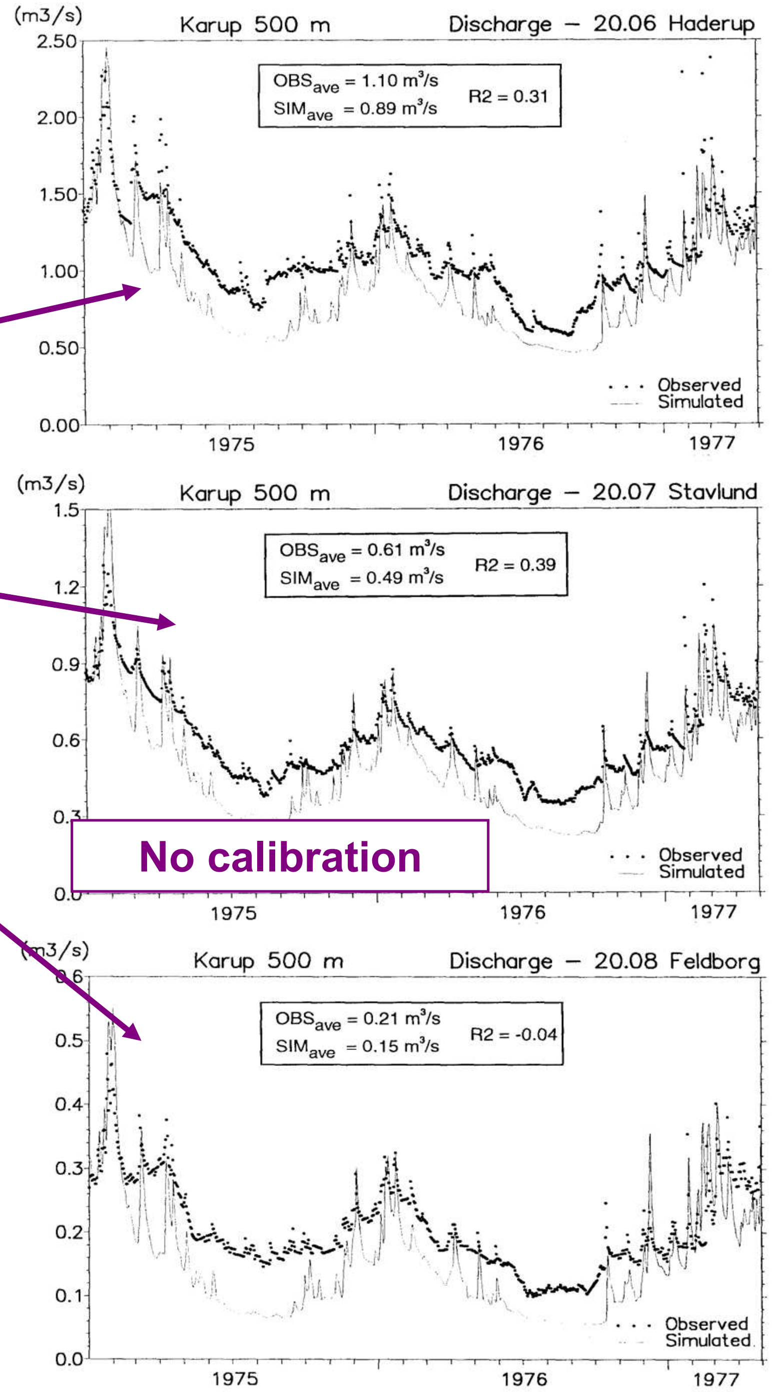
➔ At which spatial scales do they have predictive capability?

Model performance at scales smaller than calibration scale

- validation against internal variables

Refsgaard (Journal of Hydrology, 1997)





What is constraining model performance at small scales?

- Process description/model structure not adequate at small scales
  ➔ *Model codes exist (but can be improved)*
- Bias in model structure or model parameters
  ➔ *Major problem*
  ➔ *Can be compensated through calibration*
    → *problems for predictions beyound calibration conditions*
    → *problems for scales smaller than calibration scale*
- Lack of data to resolve small scale heterogeneity
  - Climate data, particularly precipitation
  - Soil and vegetation data
  - Geology
  - Etc.

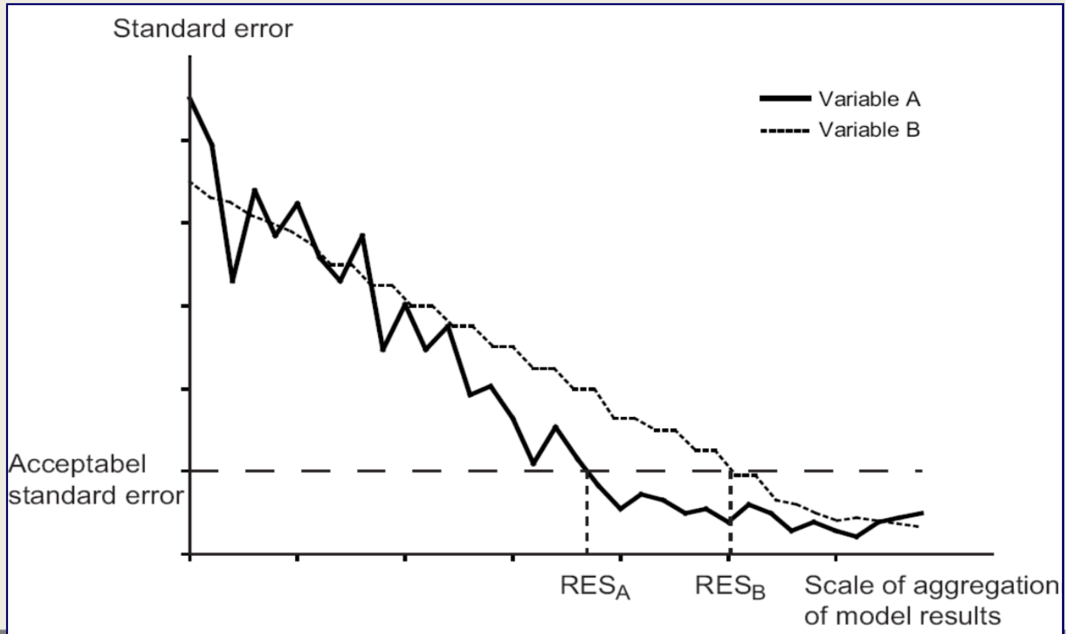
This presentation

Scale analysis

- Representative Elementary Scale (RES)

RES = The smallest spatial scale at which a model potentially has predictive capability

- Describe local scale heterogeneity geostatistically e.g. by use of probability density functions and semi-variograms
- Stochastic analyses of local scale characteristics
  - Generate n realisations → n model runs
  - Calculate the effects of the differences between the n models e.g characterised by the coefficient of variation among the results from the n model runs
  - Analyse results for aggregation of results to different spatial scales



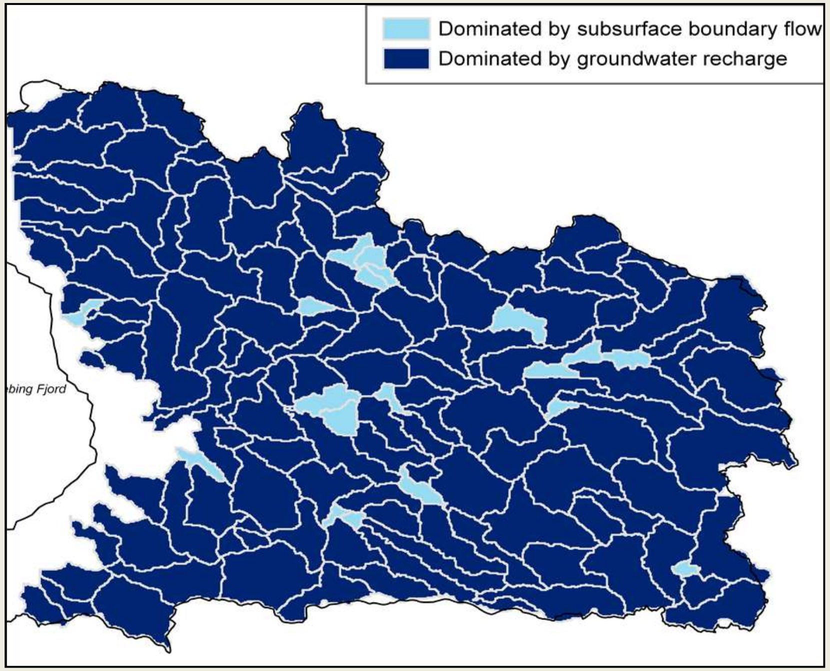
Example 1: Precipitation uncertainty

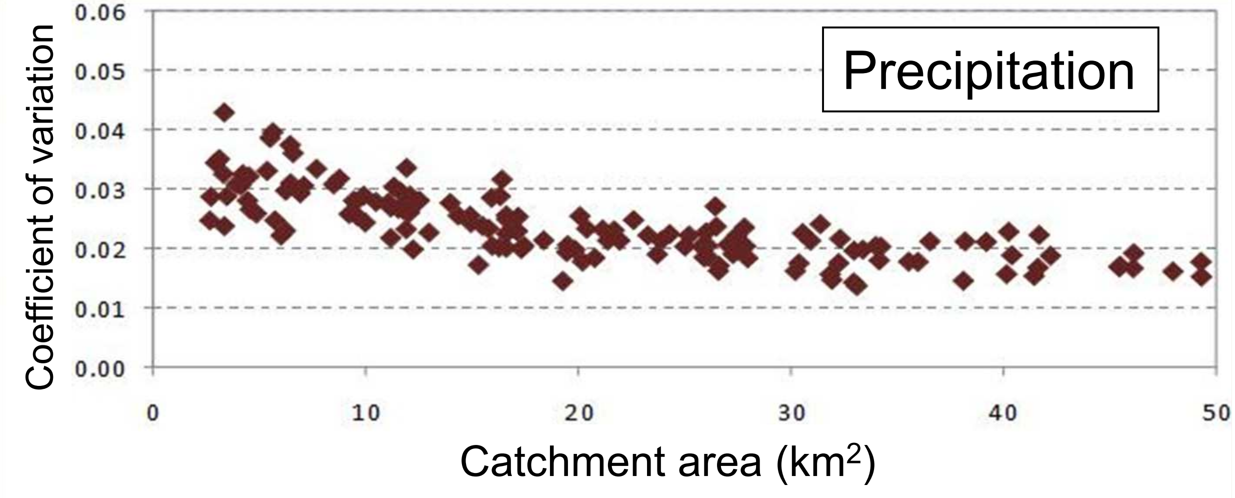
He et al. (WRR, W09526, 2011)

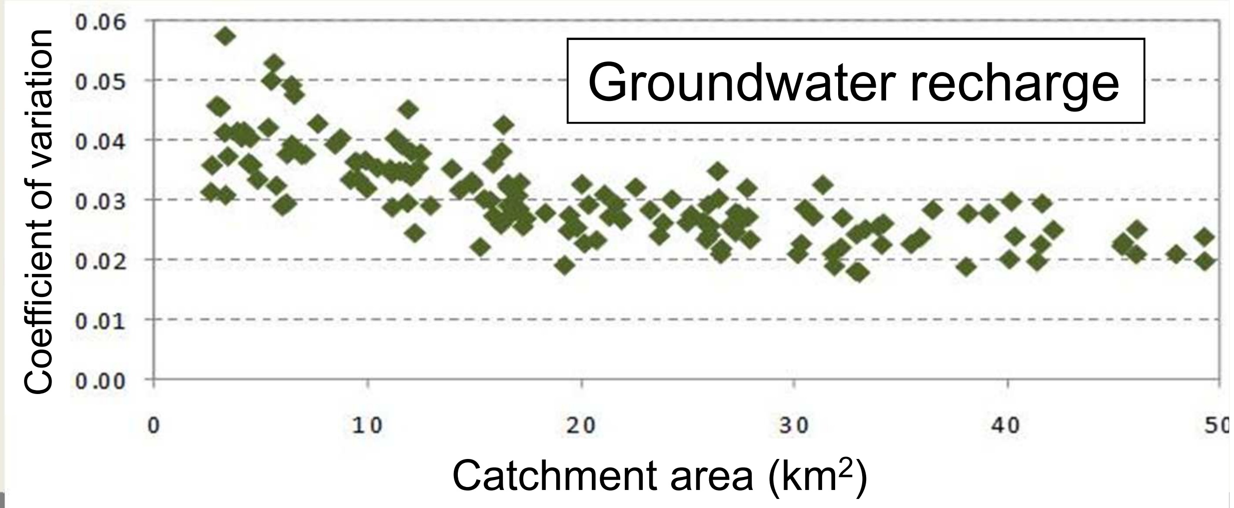
- Statistical model for precipitation uncertainty
  - Weather radar + 31 raingage stations
  - Uncertainty at 2 km grid, daily values
  - Generate 200 realisations of precipitation fields
- Propagate precipitation uncertainty through a hydrological model
  - Coupled groundwater-surface water (MIKE SHE)
  - 3,500 km^2 Skjern catchment Denmark (HOBE hydrological observatory)
- Analyse relation between spatial scale and uncertainty as differences (coefficients of variation) between 200 model runs

Scale analysis

Uncertainty at 148 subcatchments with areas ranging between 3 and 49 km²



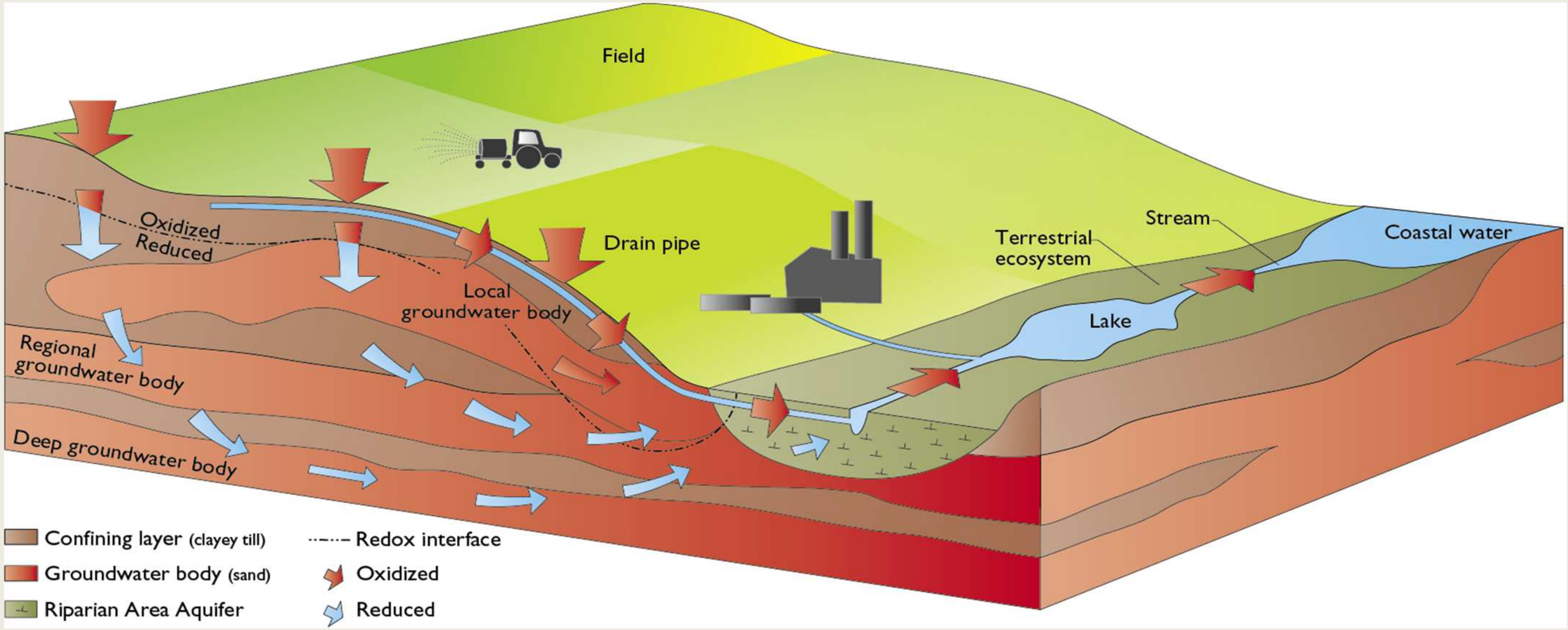




Example 2: Nitrate reduction in saturated zone

NiCA project – www.nitrat.dk

2/3 of the nitrate leaching from the root zone is reduced/disappears in the subsurface when flow lines cross below the redox interface



Summary of problem

- Nitrate load to surface water must be reduced by ~50%
- 2/3 of the nitrate leaching from the root zone is reduced (disappears) in the subsurface when flow lines cross below the redox interface
- Uniform regulations (identical for all agricultural fields) to reduce nitrate leaching ➔ efficiency of only 1/3
- If we knew the areas where subsurface reduction takes place we could design cost effective measures to reduce nitrate load
- **Due to unknown geological heterogeneity**
  - **we do not know where subsurface reduction occurs**
  - **we do not know at which spatial scale our models have the potential to provide reliable predictions (without calibration)**

Mapping of subsurface properties

MiniSkyTEM – a new geophysical instrument

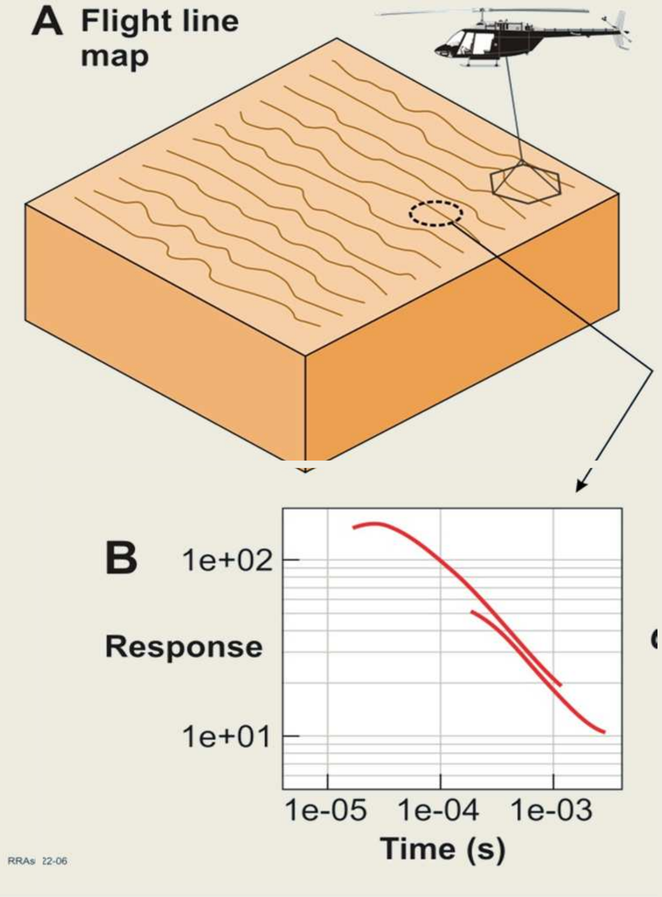
SkyTEM

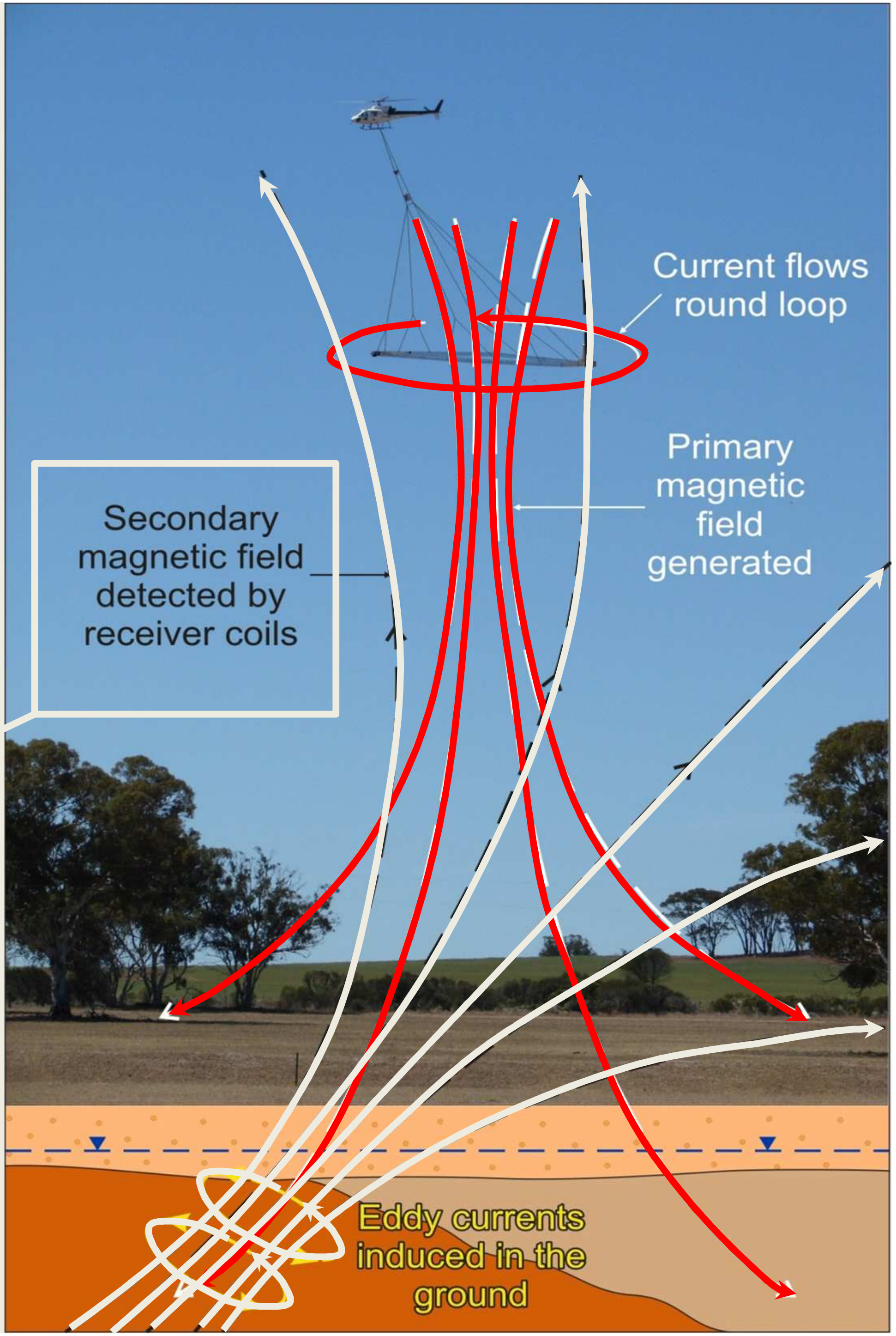
- Transient Electromagnetic System (TEM)
- Airborne

MiniSkyTEM (further developed in NICA)

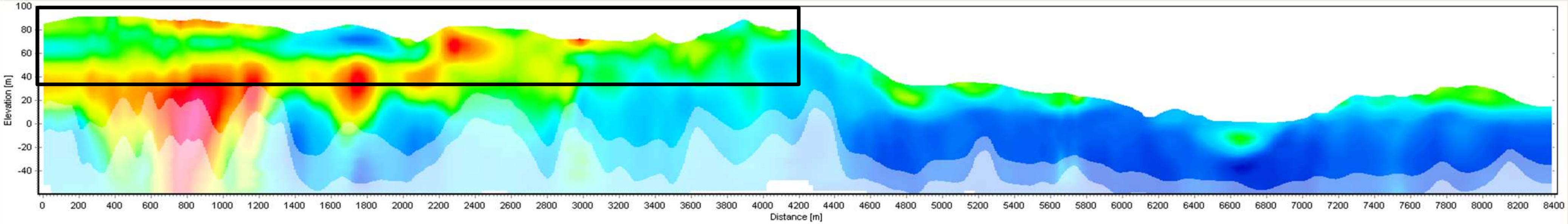
- 2000 line-km survey in a week
- Provide information on resistivity of the upper about 100 m of the subsurface
- Spatial resolution in top layers:
  - Vertically: 1-2 m
  - Horisontally: 30-50 m

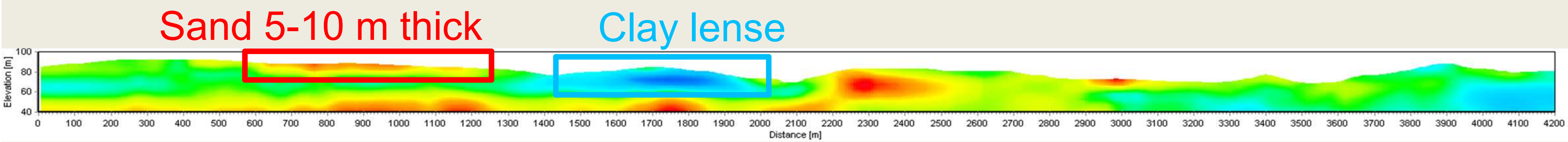
SkyTEM measurement principles



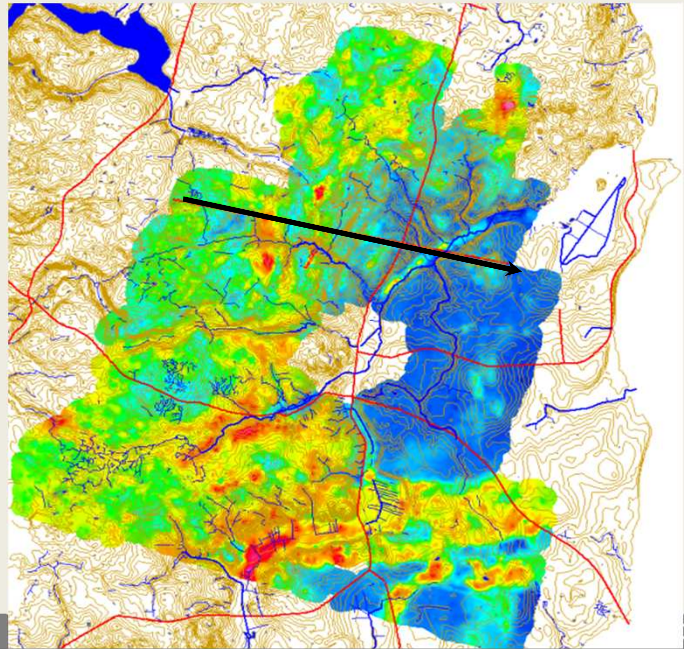


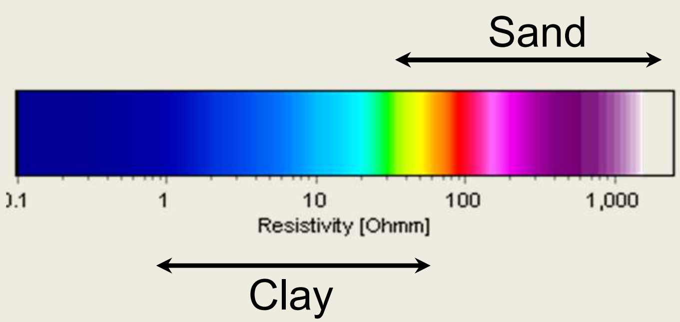
Geophysical mapping - SkyTEM





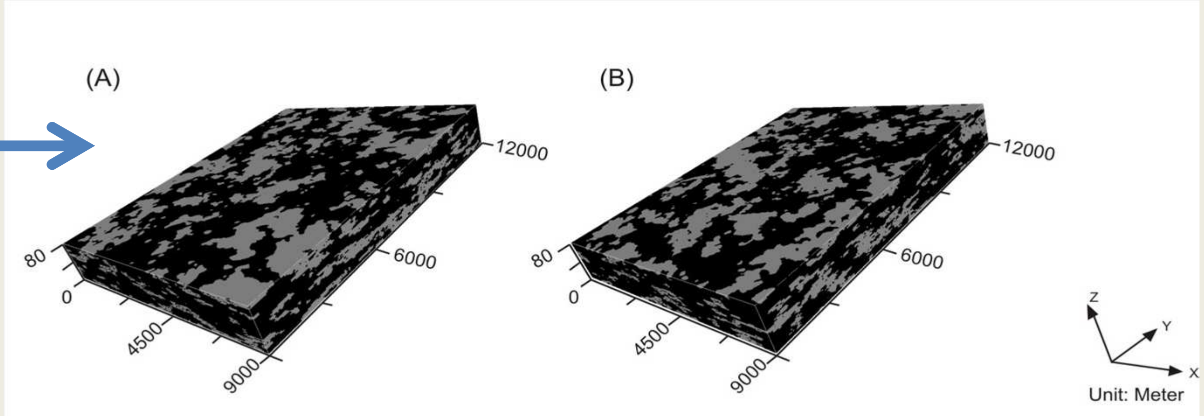
Average resistivity 15-20 m depth

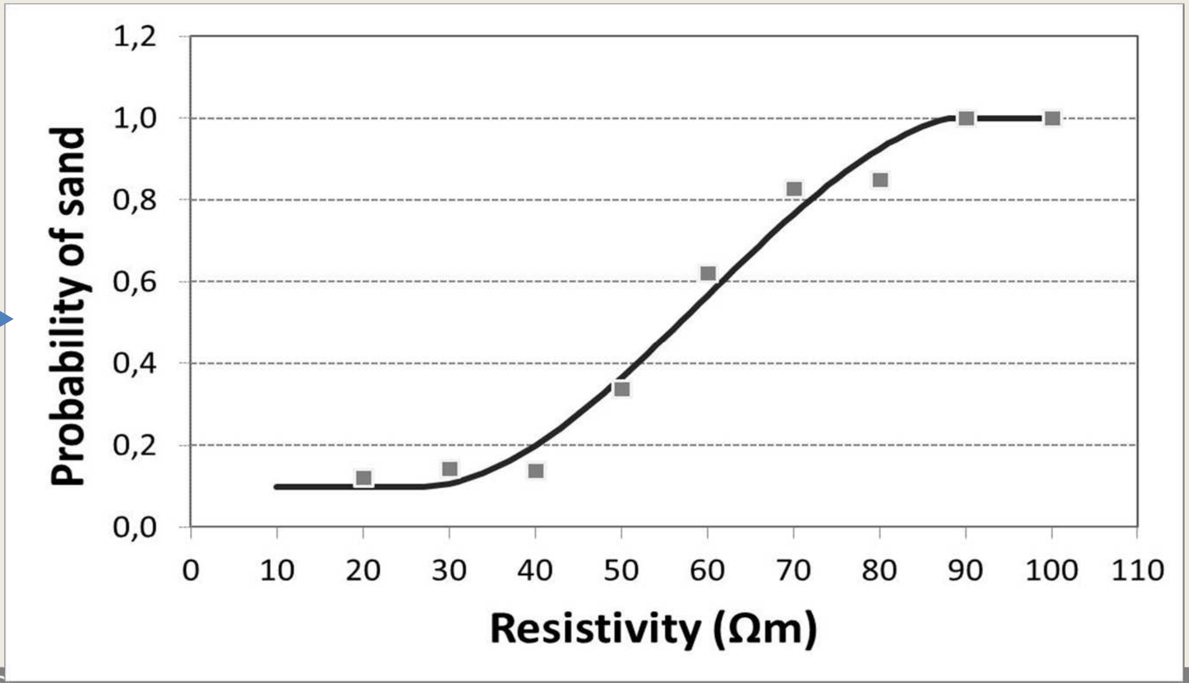




Stochastic geological realisations

- TProGS (Carle et al., 1998)
- Conditioned by borehole data
- Soft conditioned by geophysical data

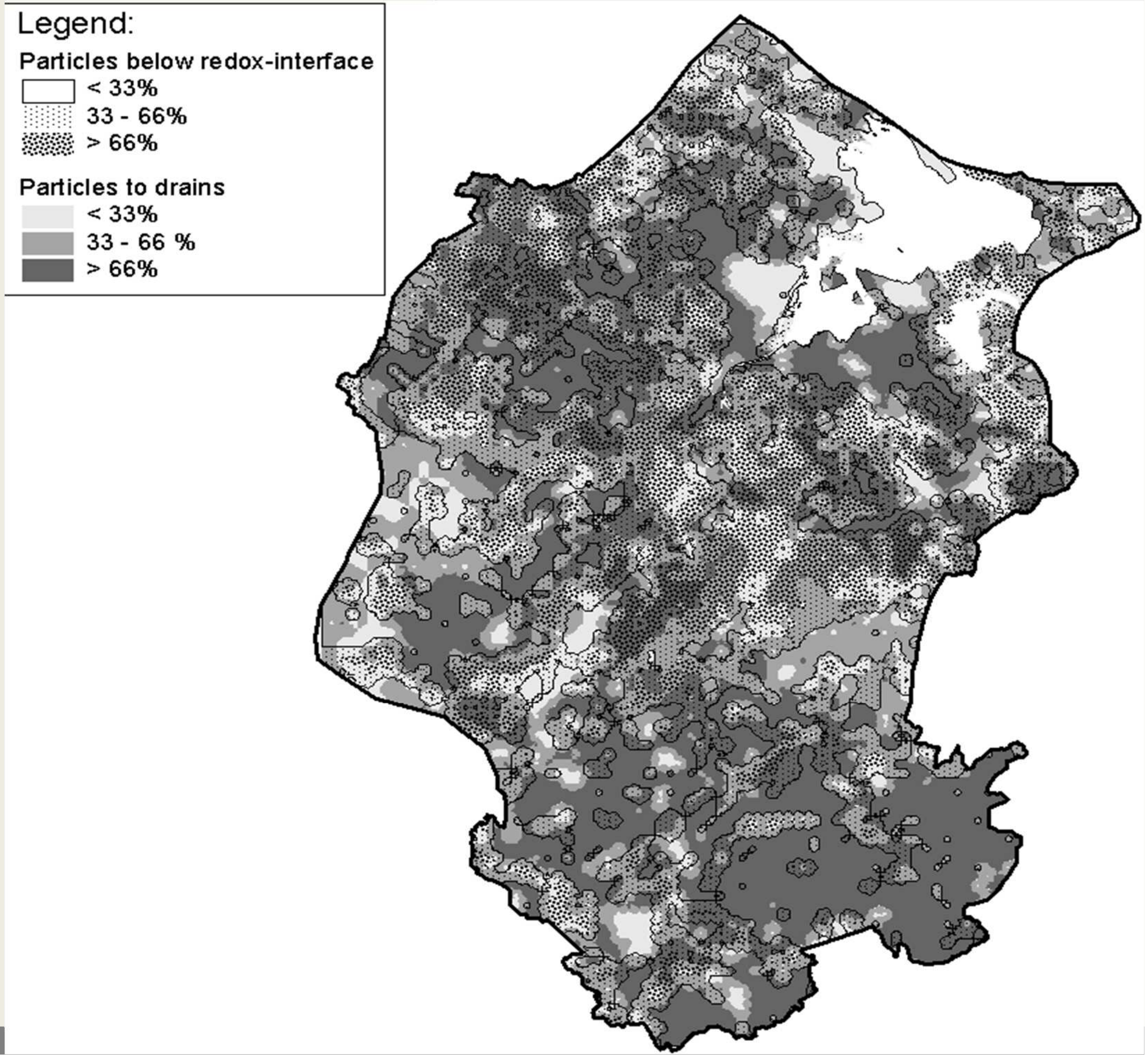




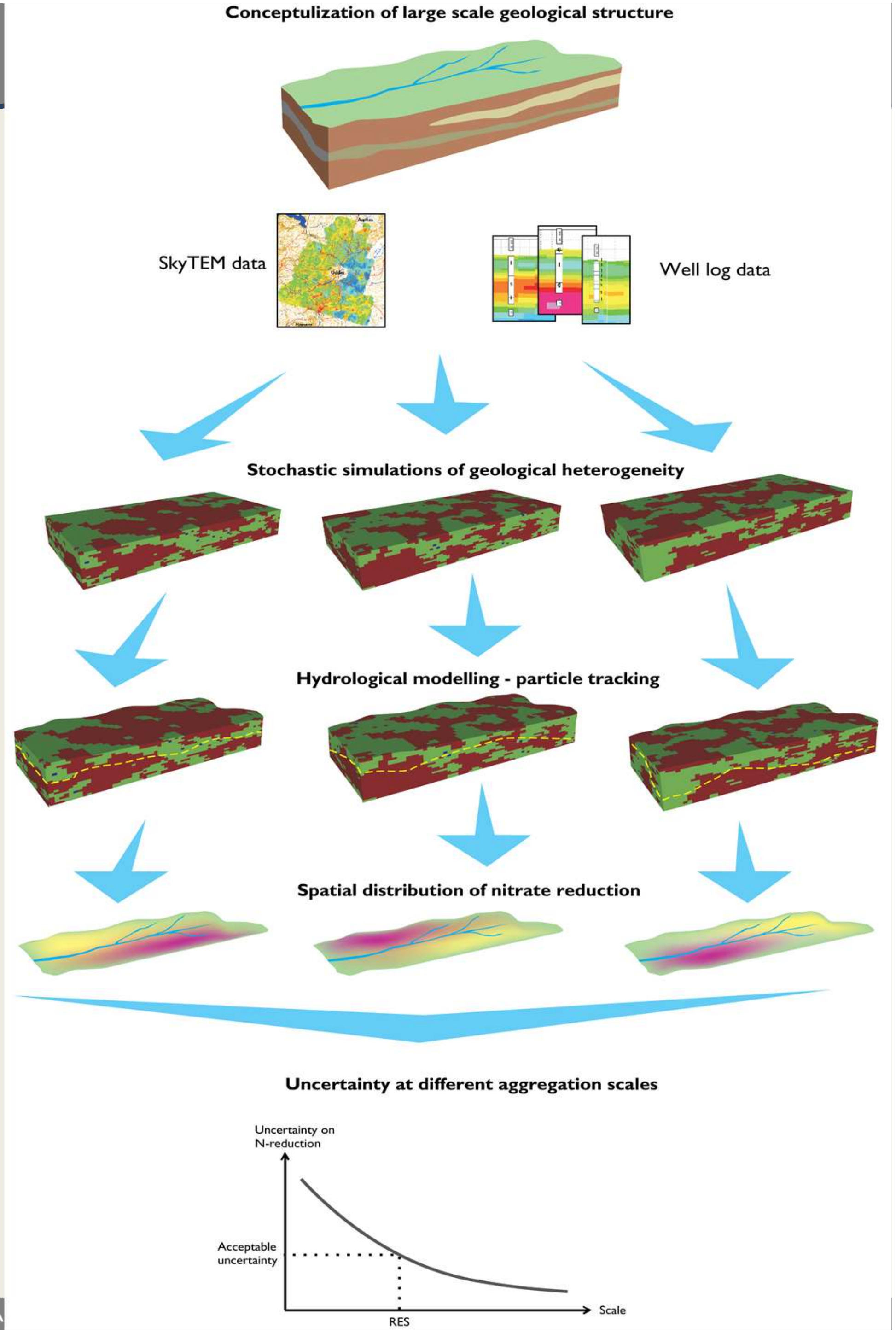
Simulation of nitrate reduction in subsurface

- particle tracking model

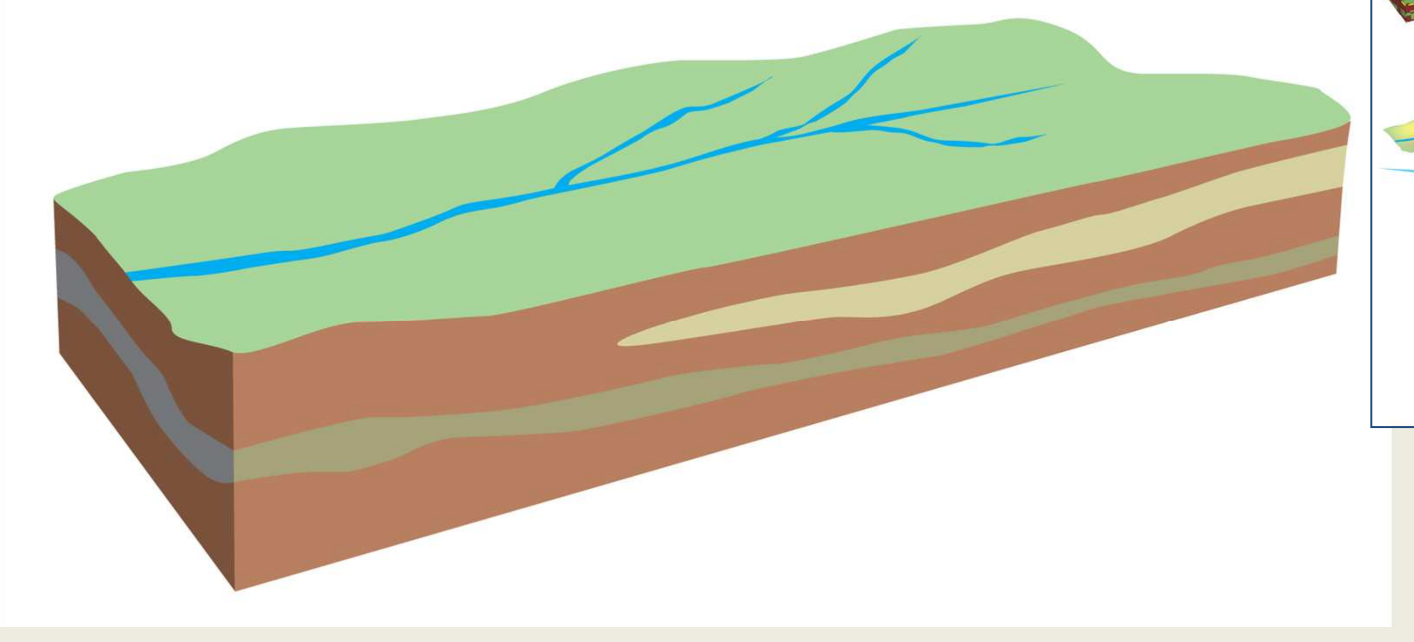
- particles crossing below the redox-interface into reduced zone ➔ nitrate reduction

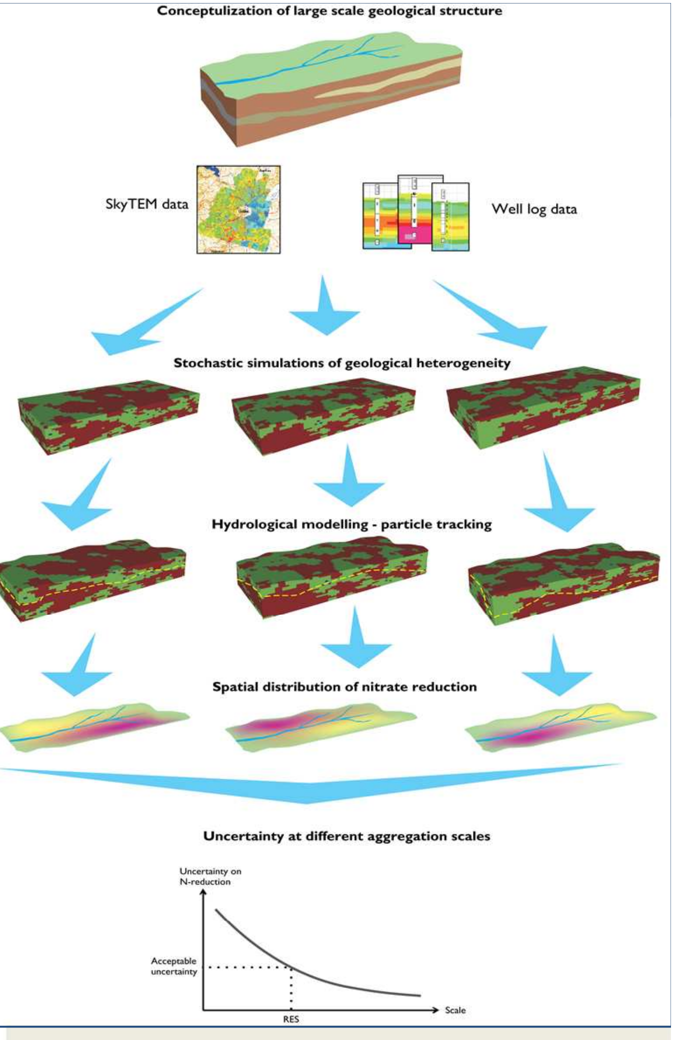


Overall methodology

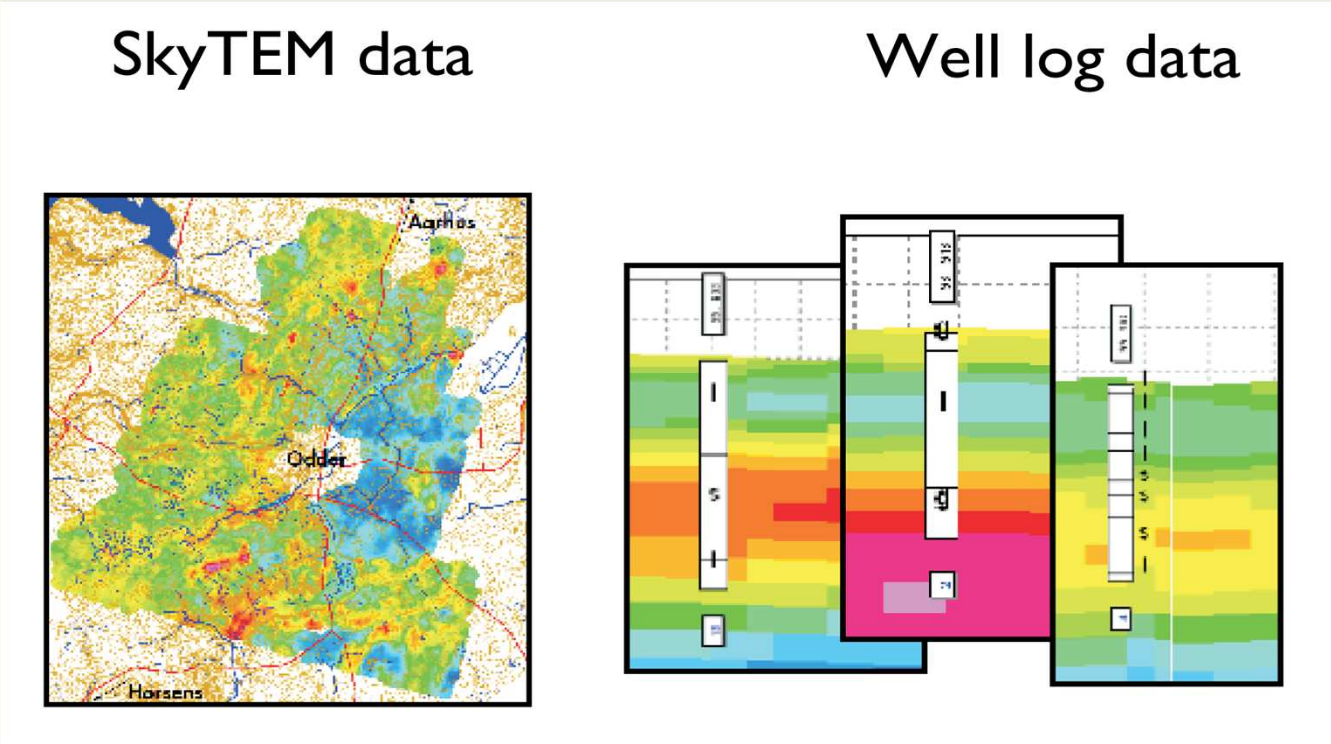


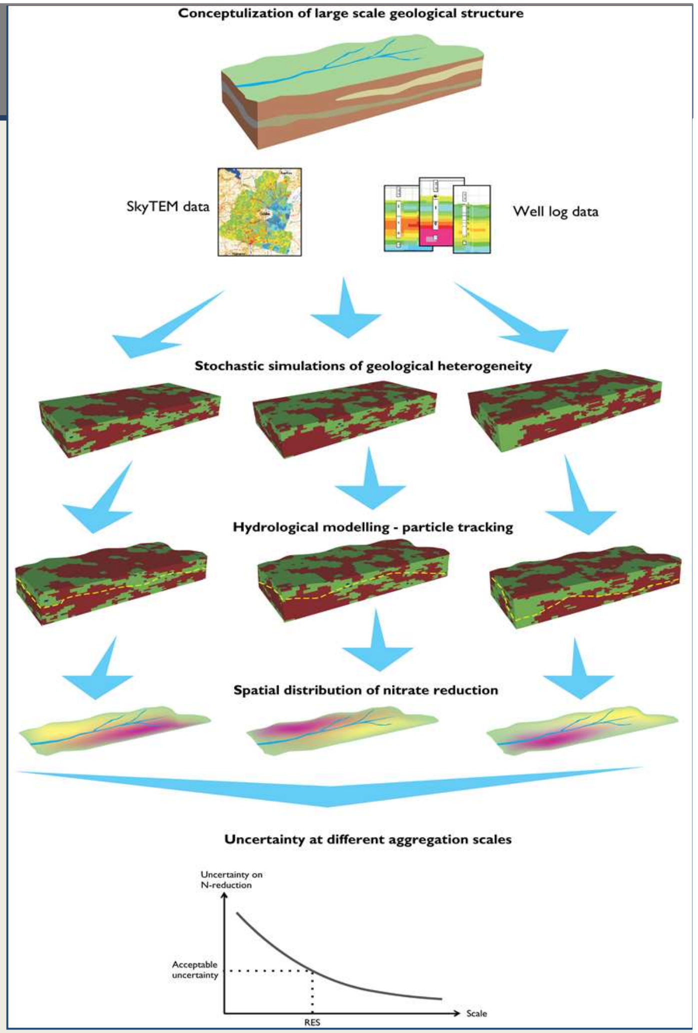
Step 1: Conceptualise large scale geological structures



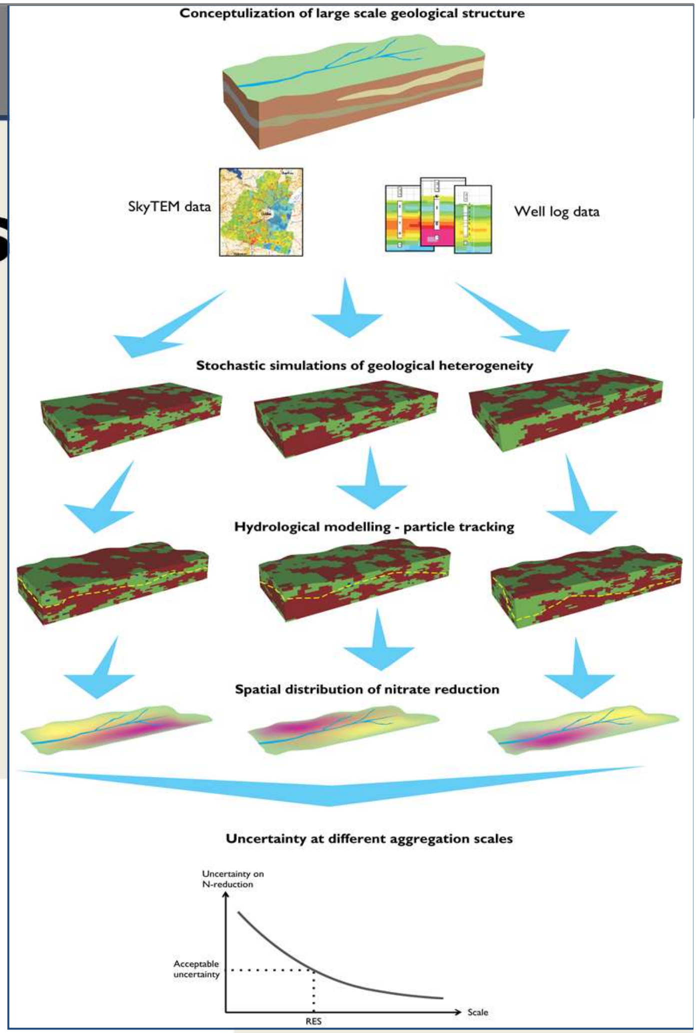


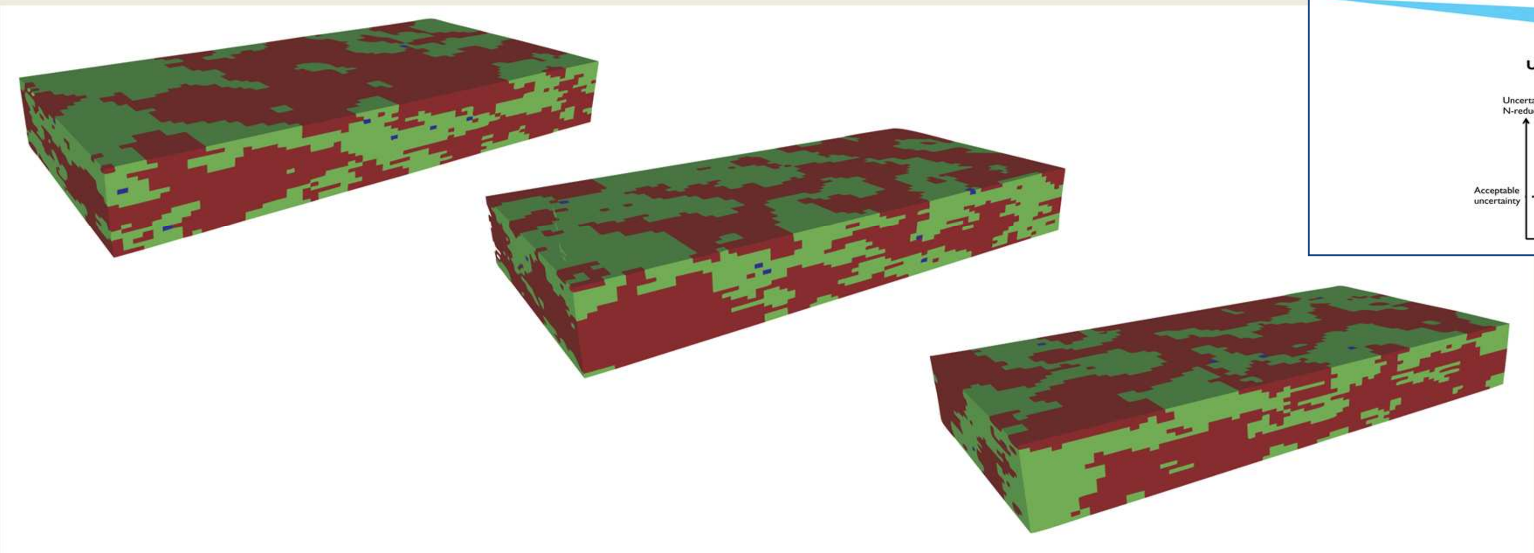
Step 2: Utilise local geophysical and well log data to construct stochastic geological model and condition realisations



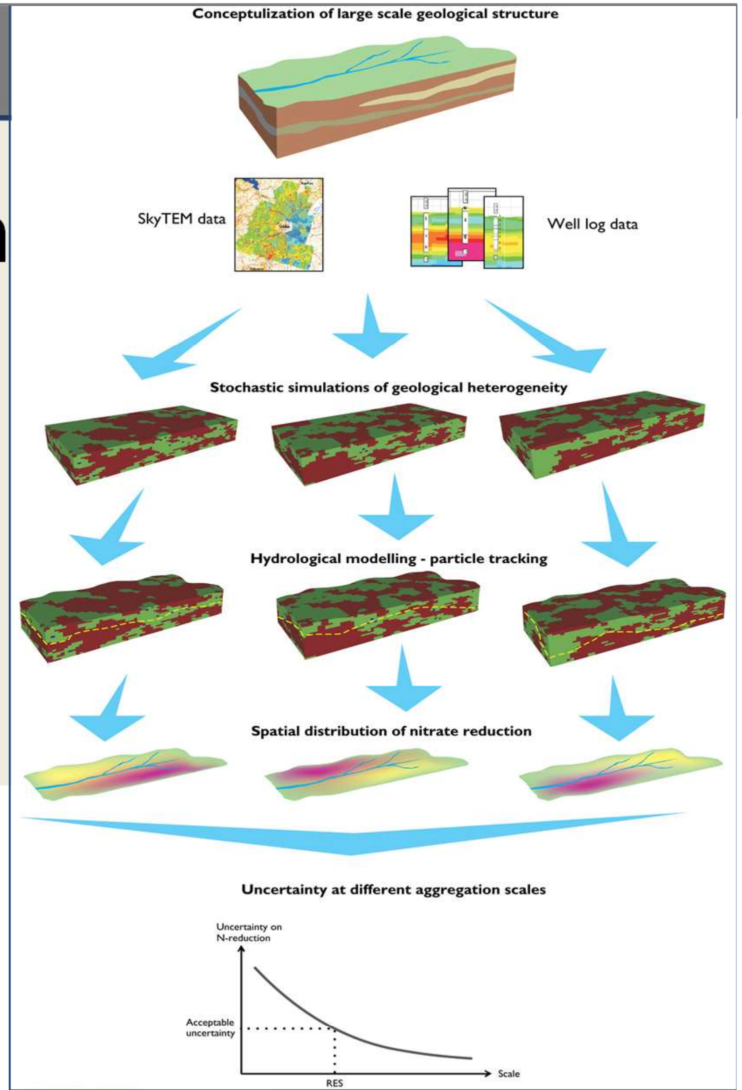


Step 3: Stochastic simulations of geological heterogeneity



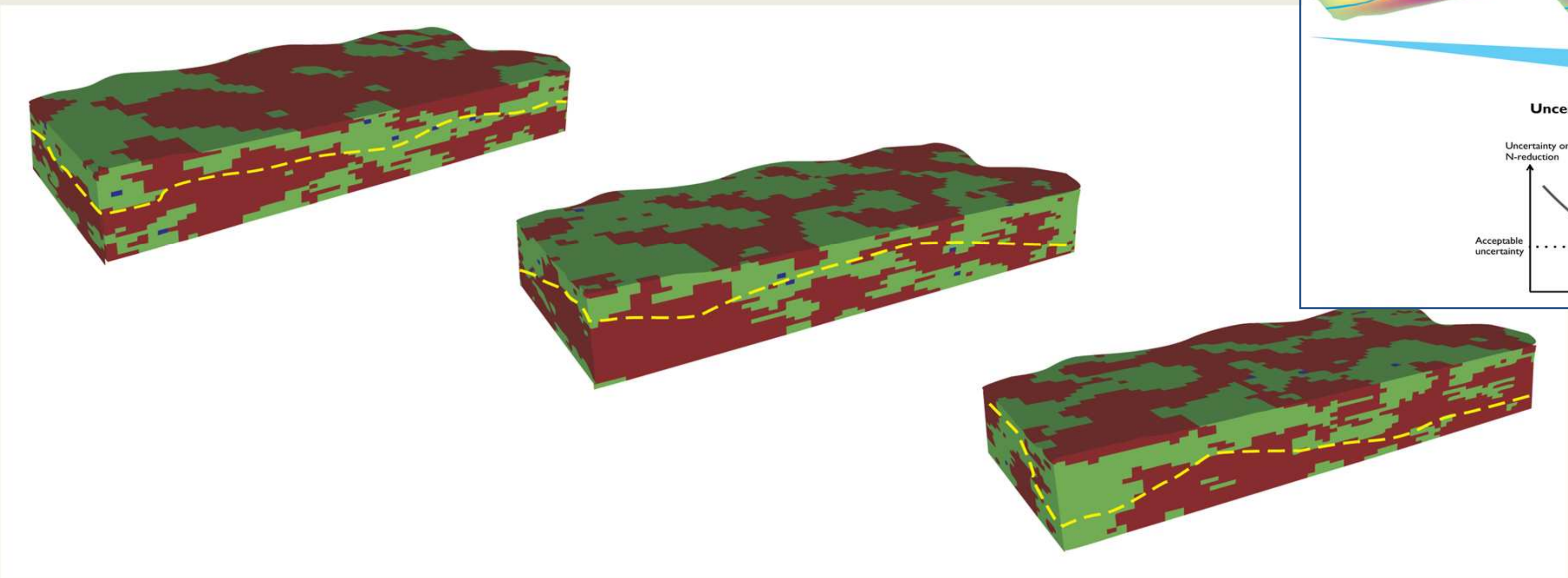


Step 4: Hydrological modellin – particle tracking

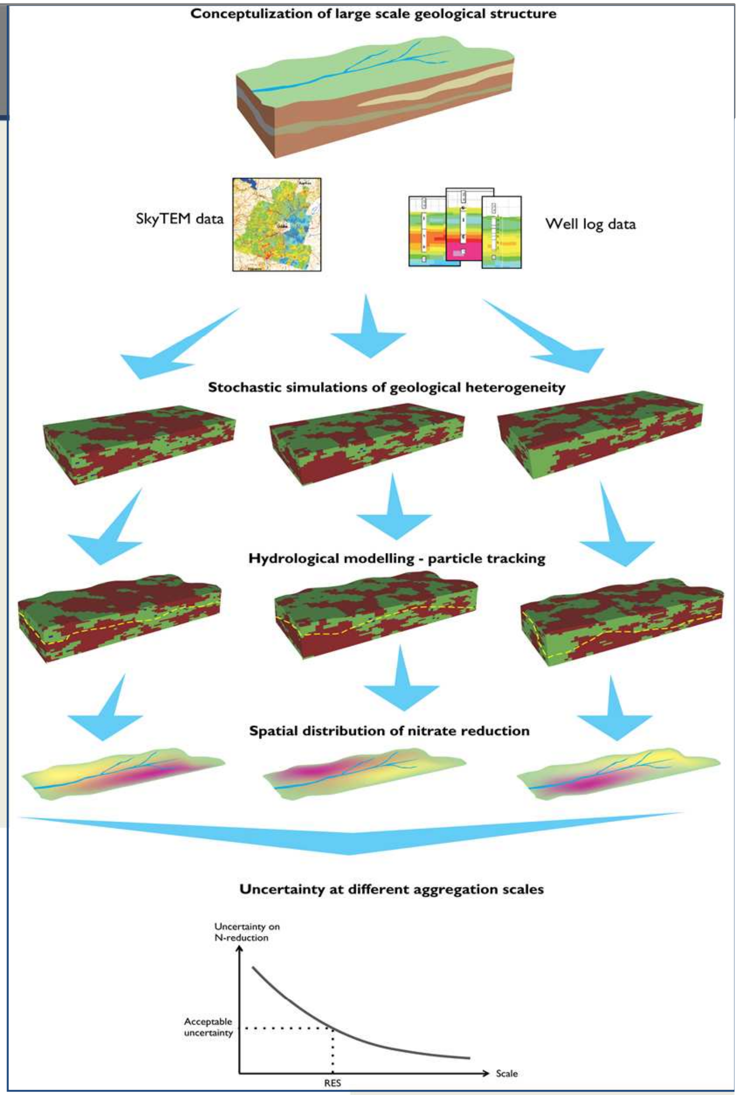


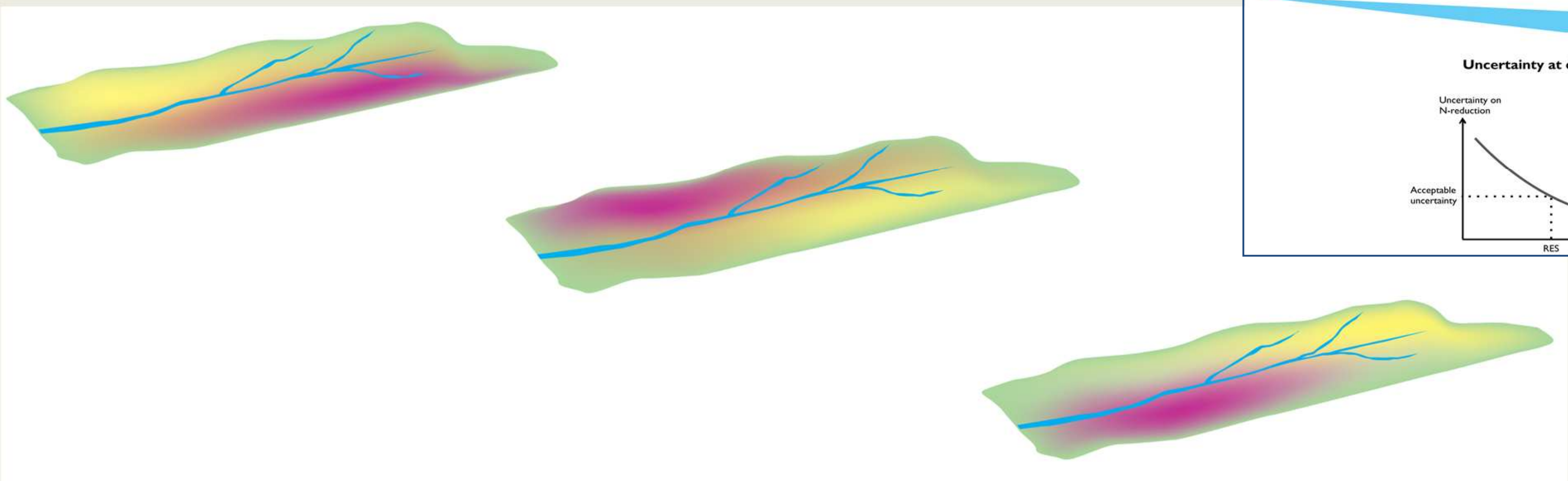
For each geological realisation

- Calibrate flow model
- Particle tracking ➔ nitrate reduction when passing redox-interface

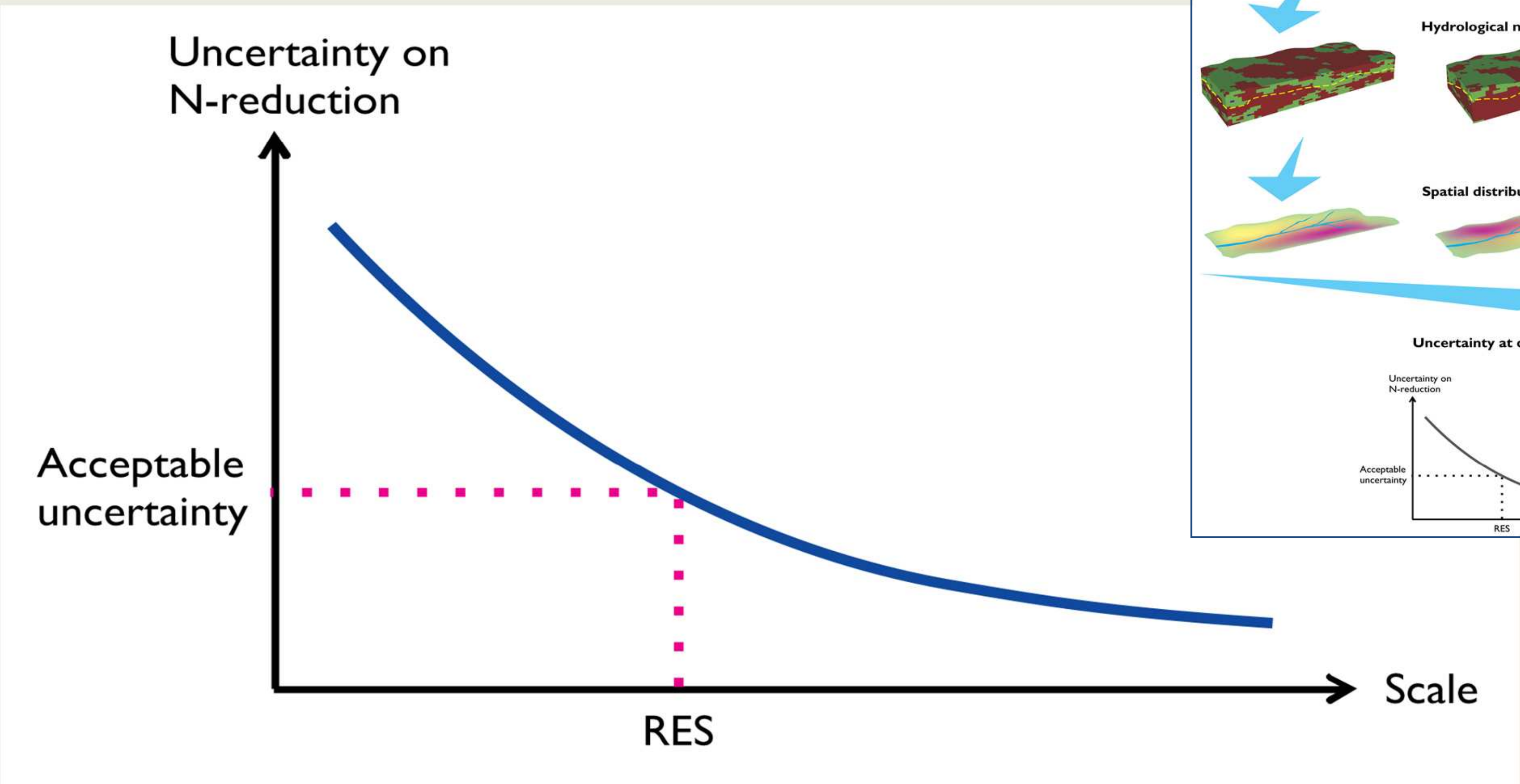


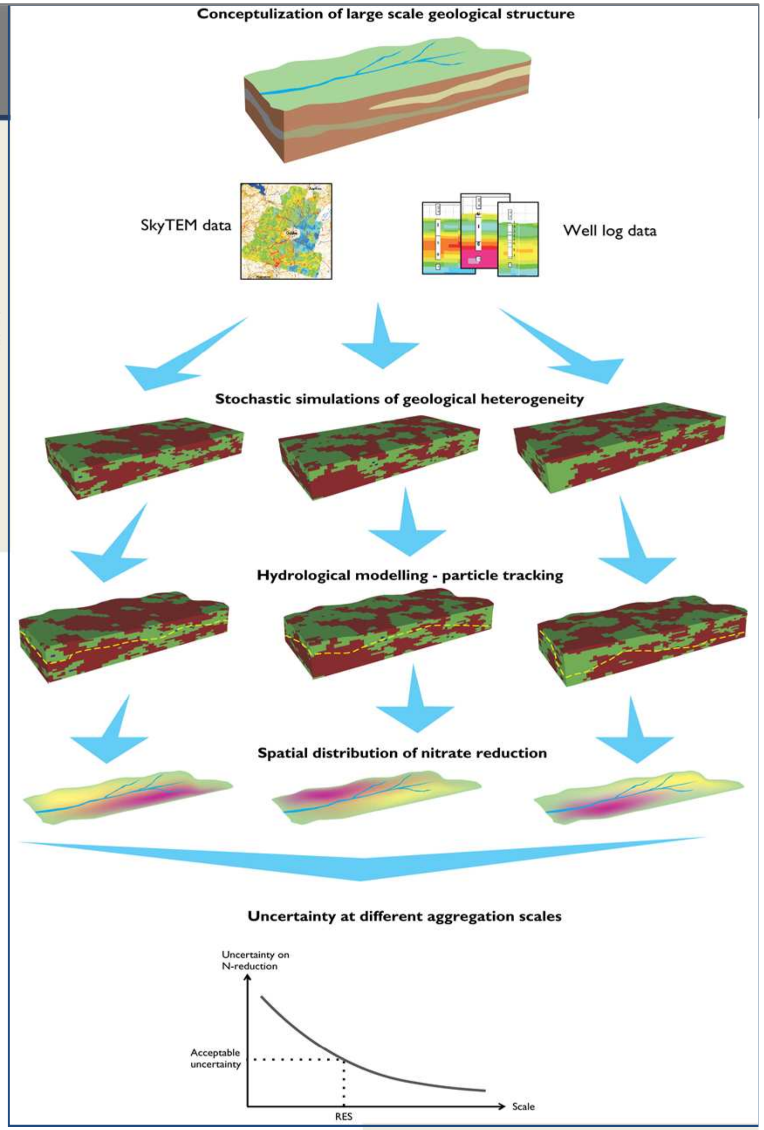
Step 5: Spatial distribution of nitrate reduction





Step 6: Uncertainty at different aggregation scales





Conclusions

- Need to assess at which scales we should consider trusting our spatially distributed models
- Predictive capability of distributed model constrained by the spatial resolution of key data
- Representative Elementary Scale (RES)
  - Modification of Representative Elementary Area concept (Wood et al., 1988; Beven, 1995)
  - A measure of the largest scale at which a model potentially has predictive capability
  - No unique RES value, but site and application specific

Further information

Example 1: He X, Refsgaard JC, Sonnenborg TO, Vejen F, Jensen KH (2011) Statistical analysis of the impact of radar rainfall uncertainties on water resources modelling. Water Resources Research, 47, WR09526 http://www.agu.org/pubs/crossref/2011/2011WR010670.shtml

Example 2: NICA - Nitrate reduction in geologically heterogeneous catchments http://nitrat.dk

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