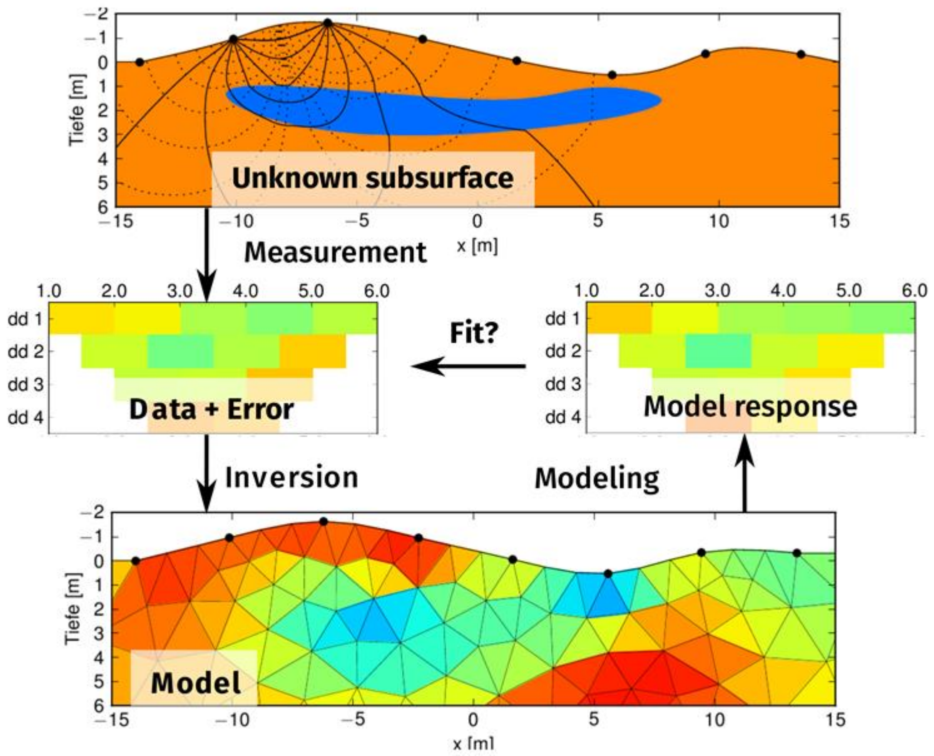
Near Surface Geophysical methods for site characterization 4. Geophysical Inversion (of ERT data)



Repetition ERT: Surface Arrays & Sensitivity

Crosshole ERT Arrays & Sensitivitities

Fundamentals of Geophysical Inversion

Objective and Ambiguity

Comparison of different ERT arrays

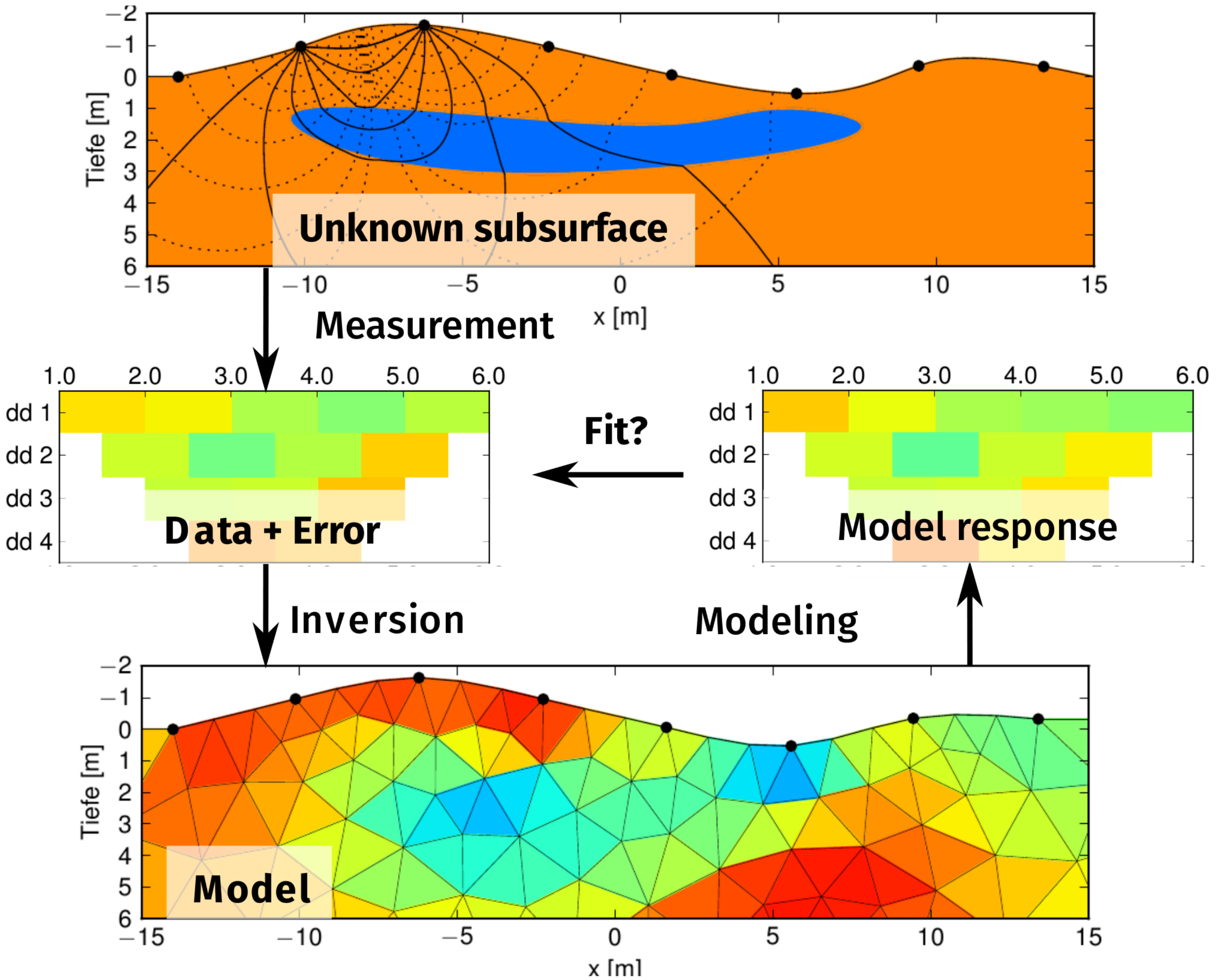
A recent case study from Borkum

Electrical Resistivity tomography

- Four electrodes: 2 for current (A-B), 2 for voltage (M-N)
- Different arrangement of these: geoelectrical arrays
- Mapping: moving a constant array along a profile
  typical array: Wenner array A—M—N—B ➔ Notebook
- Sounding: Increasing the (current) electrode spacing
  Typical array: Schlumber array (Vertical Electrical Sounding VES)
- Combination of sounding & mapping = 2D ERT
- Sensitivity shows area of influence

Geophysical Inversion

1. Data acquisition
2. Preprocessing (quality check and filtering)
3. Parameterization (i.e., mesh generation)
4. Inversion
5. Evaluate fit between measured & simulated data
6. Postprocessing & visualization of final model(s)
7. Interpretation



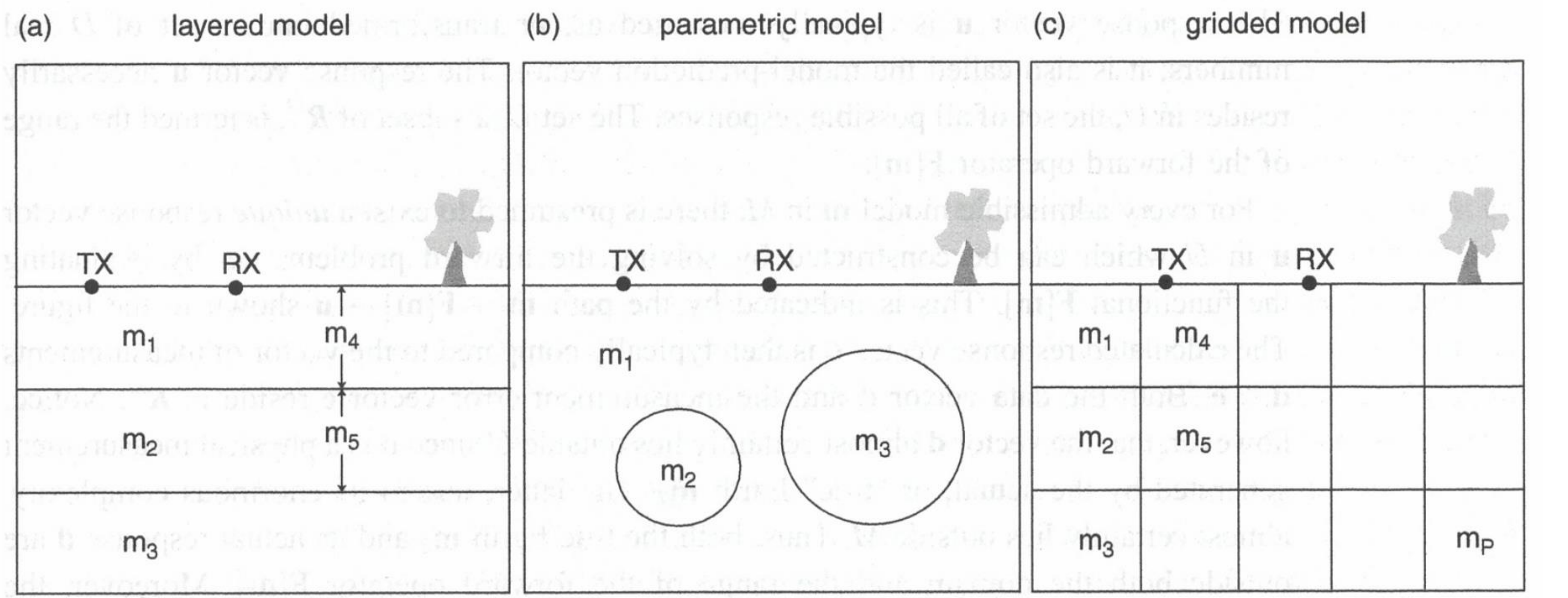
Everett, 2015

Model types and dimensions

1D: soundings, refraction

0D: gravity, magnetics

2D,3D: ERT, seismics, EM, grav/mag



A fundamental principle: Occams razor

William of Occam, monk in scotland, 14th century

Pluralitas non est ponenda sine neccesitate!

Don‘t make it more complicated than necessary.

Of all models explaining your data, choose the simplest!

How can we define „simple“?

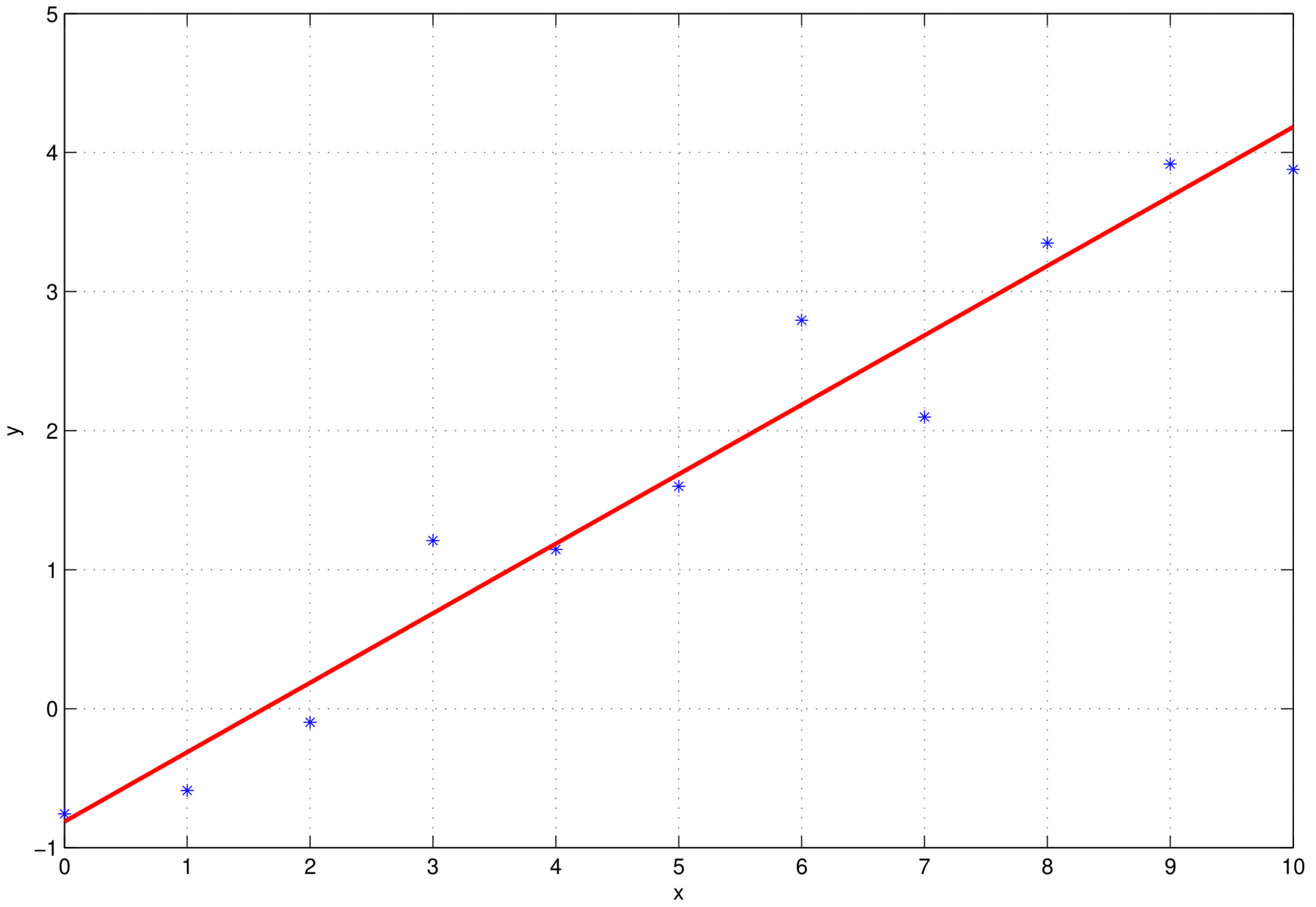
- Least number of model parameters (e.g. layers)
- Least number or strength of contrasts: smoothness
- Estimate probabilities, information content or model entropy
- Fitting the data no more than the should be fitted

Geophysical Inversion

- Objective: find a model m that explains the data reasonably
- Forward response f(m) should be close to data d (within error ε)
- Minimization of an objective function in a least-squares (regression) sense
- Chi-square (mean misfit) $\chi^2 = \phi_d$ / N

$$\Phi_d = \sum_{i=1}^{N} \left(\frac{d_i - f_i(\mathbf{m})}{\epsilon_i} \right)^2$$

Simplest inverse problem: Linear regression



Data y given on measuring locations x

y = a + b*x = G * x

G = [1 x]

M(a,b) = $(G^T*G)^{-1}$ G^T x

Ready formula

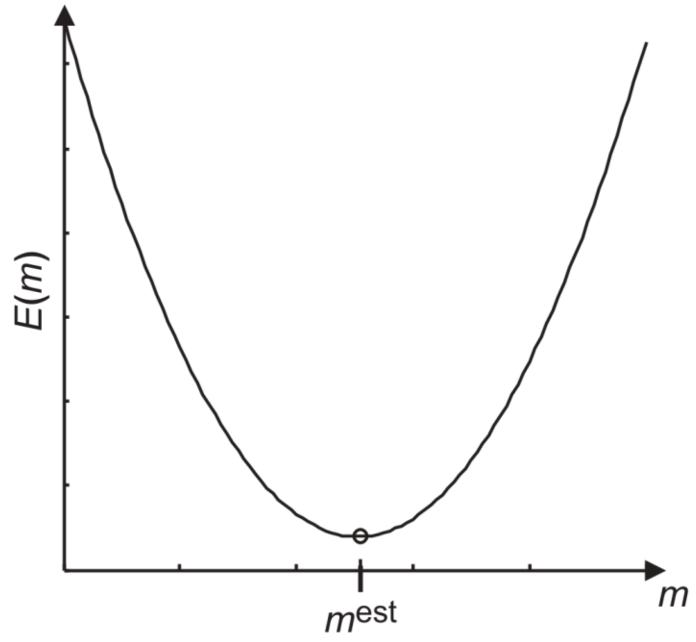
Minimization methods

- Trial and error (hand or interactive modelling)
- Grid Search (test all possible combinations in a grid)
- Machine Learning, Neural Networks (training necessary)
- Global search: Genetic Algorithms, Monte Carlo methods
- Gradient methods: Steepest descent, conjugate gradients
- Newton methods: Use second derivative of objective function

Objective function types

Linear

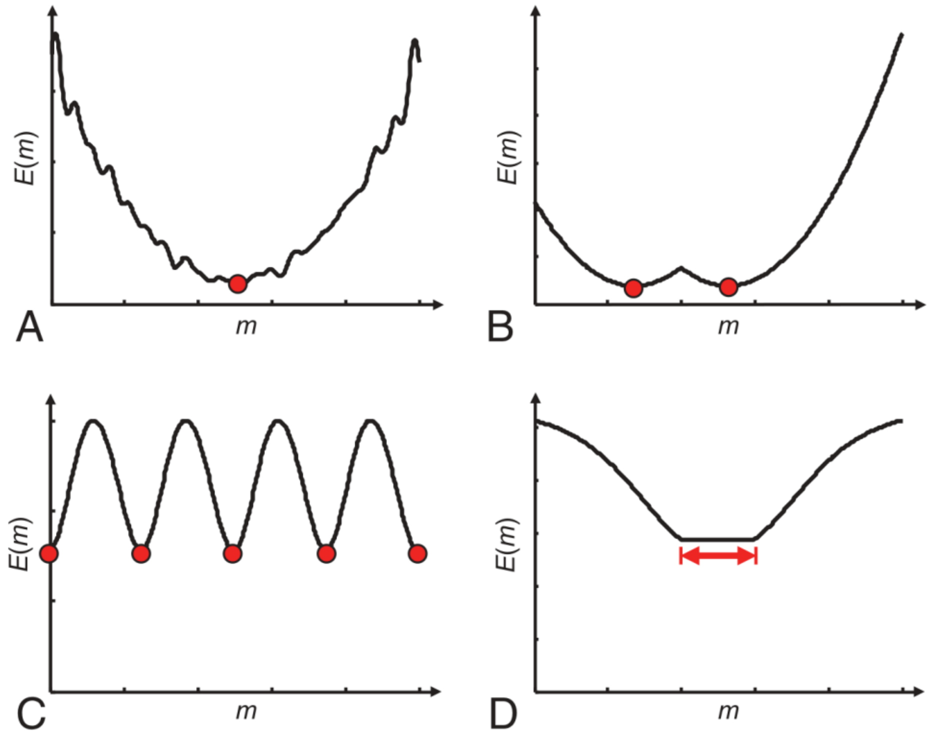
$\mathbf{d} = \mathbf{Gm}$



Clear minimum

Non-linear

Undulated $\mathbf{d} = \mathbf{G}(\mathbf{m})$ Similar models

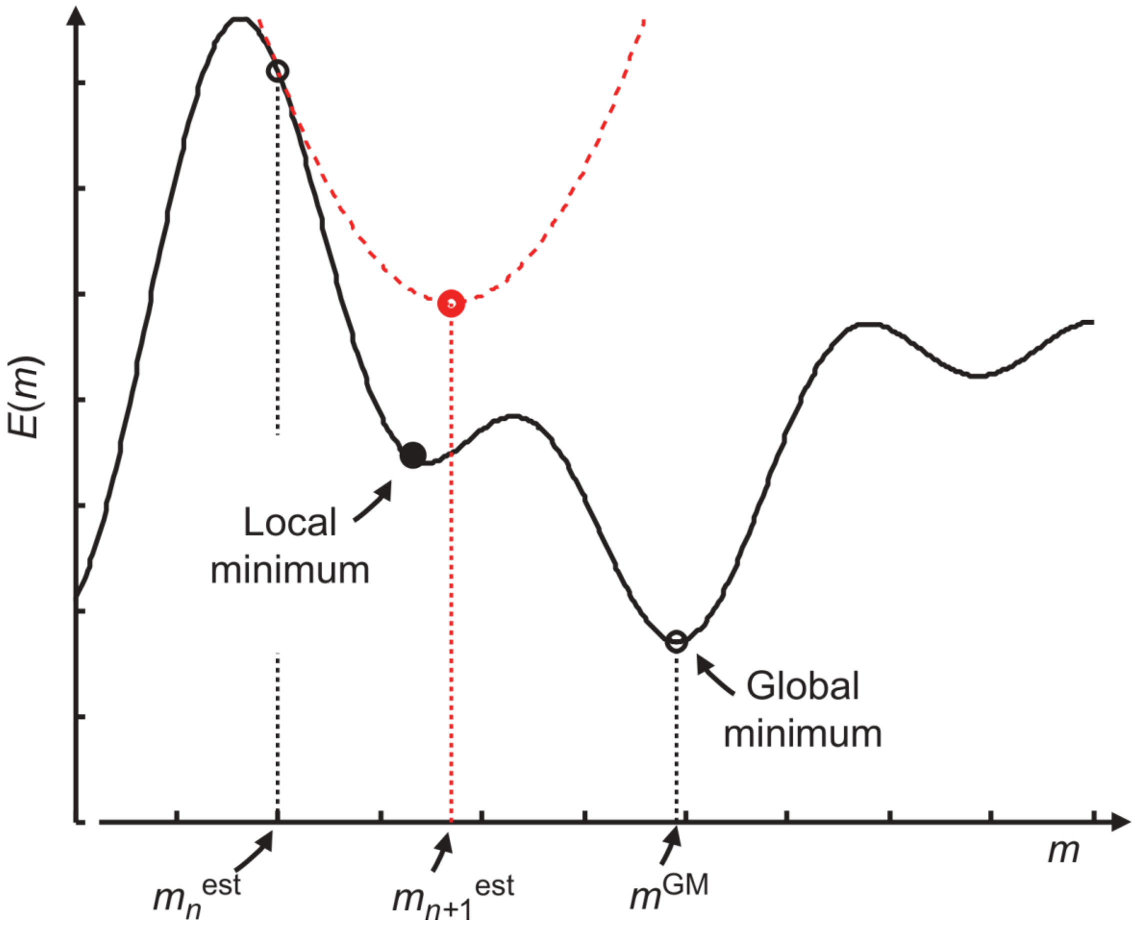


Periodic: modes

Broad minimum

Additional constraints on valid model parameters

Iterative minimization by gradient methods



Choice of simplicity