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Simulated **A**nnealing and **G**enetic **A**lgorithm Optimization using COMSOL Multiphysics: Applications to the Analysis of Ground Deformation in Active Volcanic Areas

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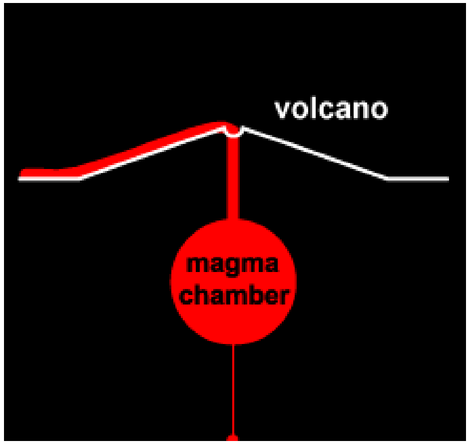
Outline

→ Intro: Volcano geodesy

→ SA and GA optimization within COMSOL

→ Application to Tenerife, Canary Islands

→ Summary and Future work



www.geo.ua.edu/

Surface displacement

Geodetic data

Optimization of Source parameters

Results

location, volume change, shape, etc.

Interpretation

Main problems

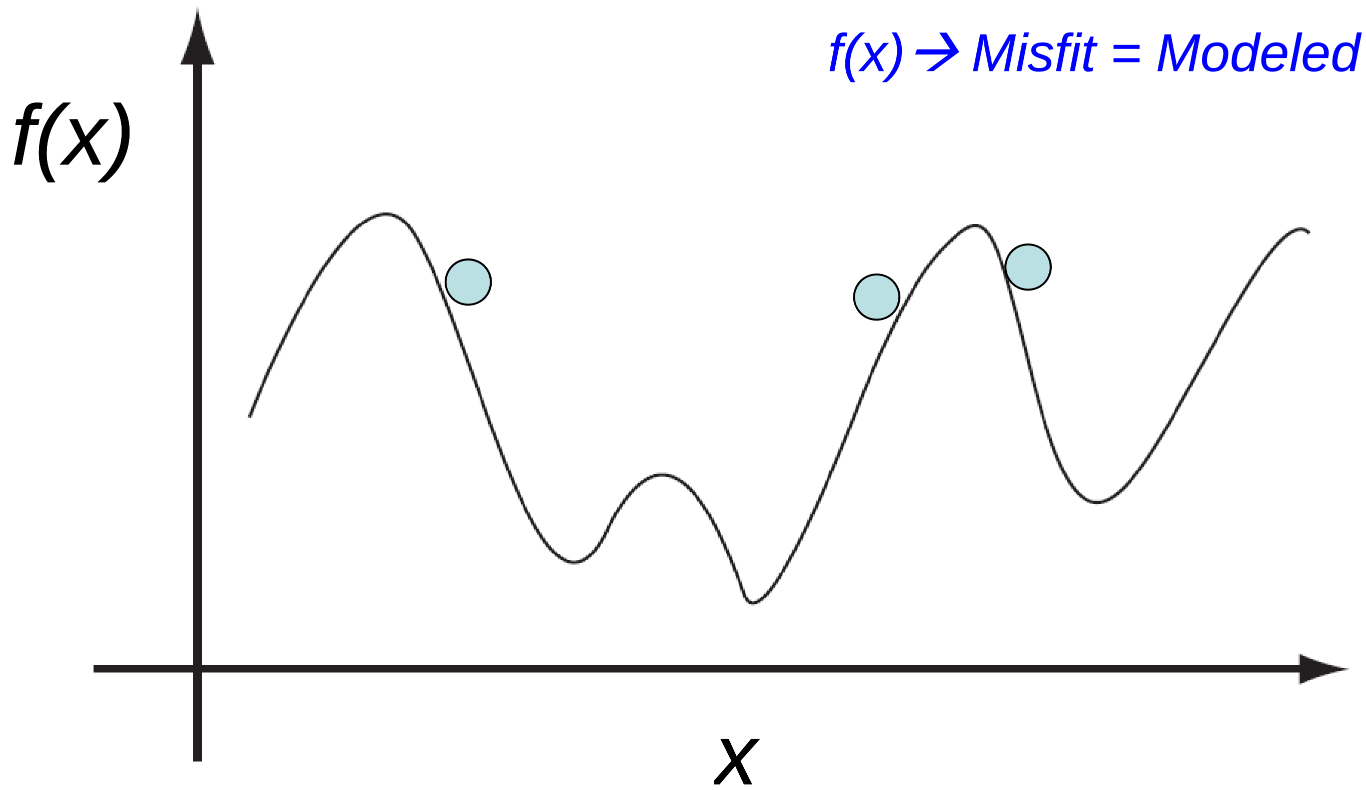
- **Opt. Algorithms:**

  GB, RS, SA, GA...

- **Forward model:**

  Analytical vs. FEM

Optimization with gradient-based algorithms

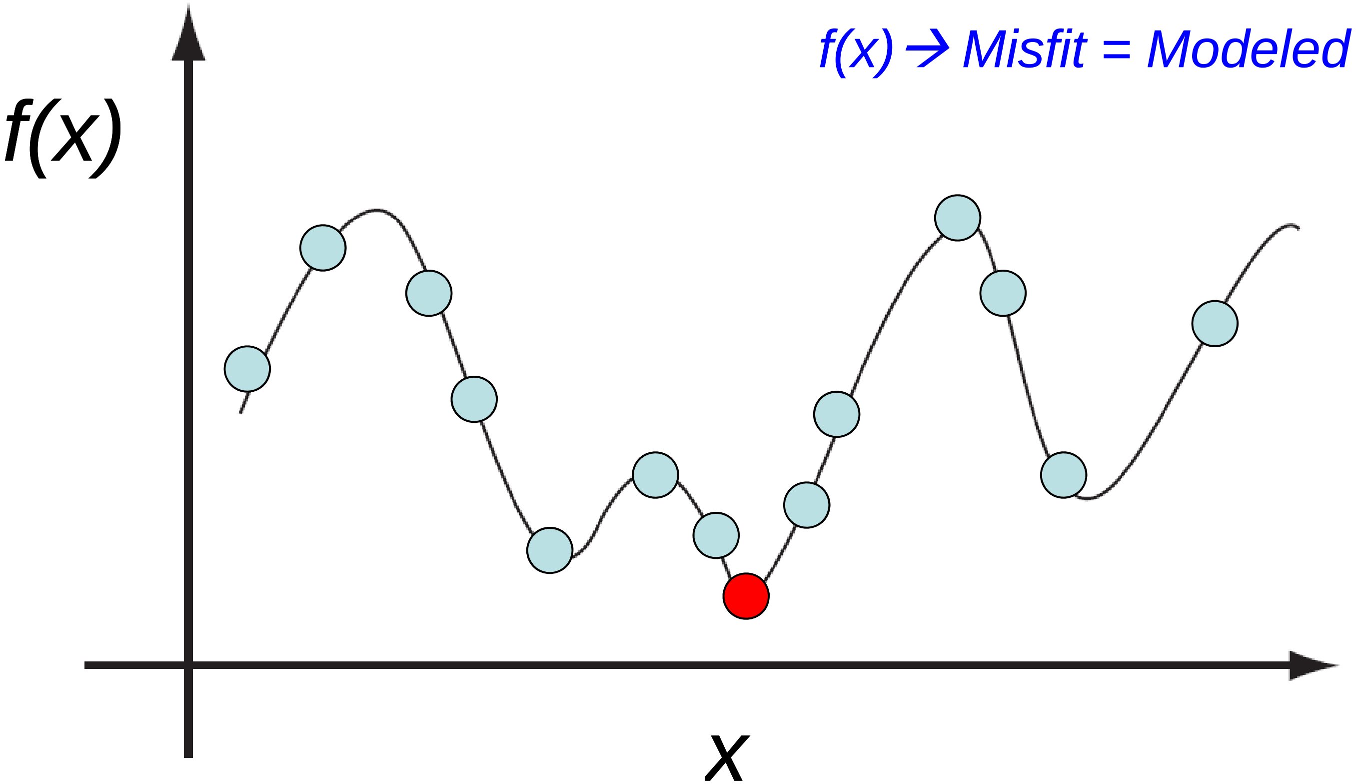


f(x) → Misfit = Modeled vs. Observed

Move down-hill → might be "trapped" in local minima

Solution depends on the initial guess → a priori constraints!

Optimization with Monte Carlo algorithms



f(x) → Misfit = Modeled vs. Observed

Randomness → allows “escaping” from local minima

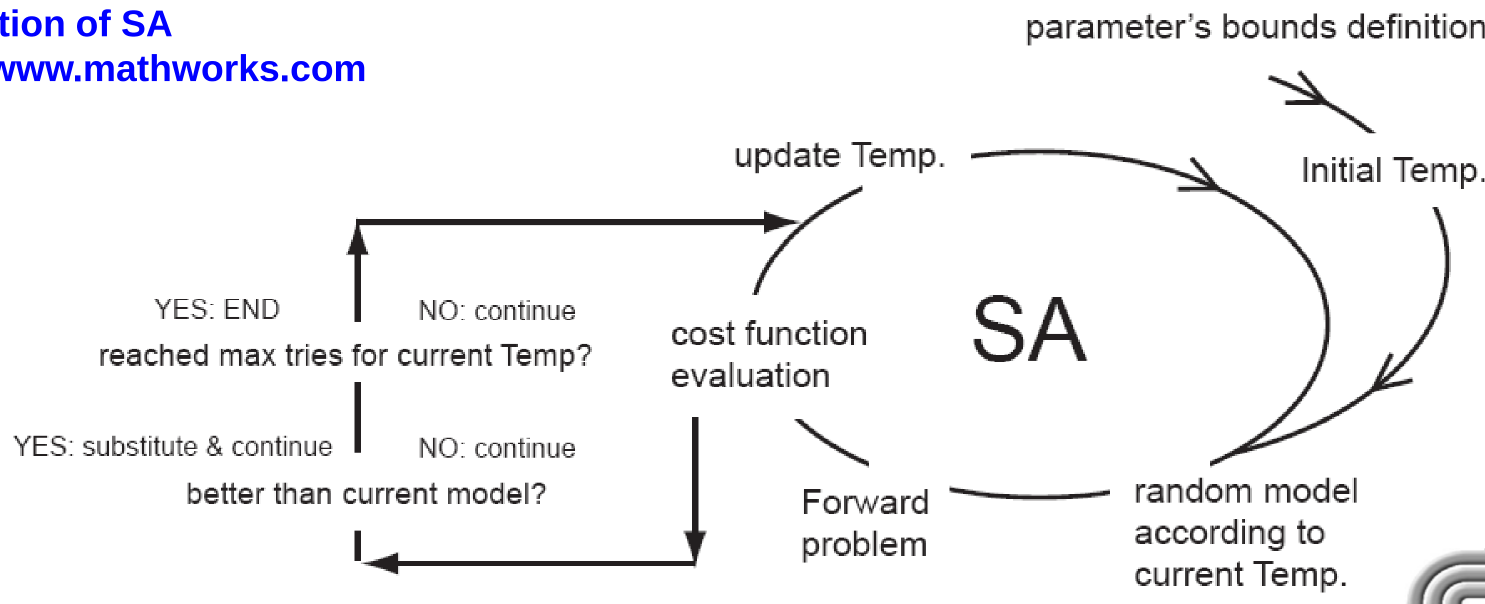
Simulated annealing and Genetic Algorithm belong to this class

Simulated Annealing (Kirkpatrick et al., 1983)

Based on analogy with annealing in metallurgy

Lowering Temp → solutions with lower cost are favored

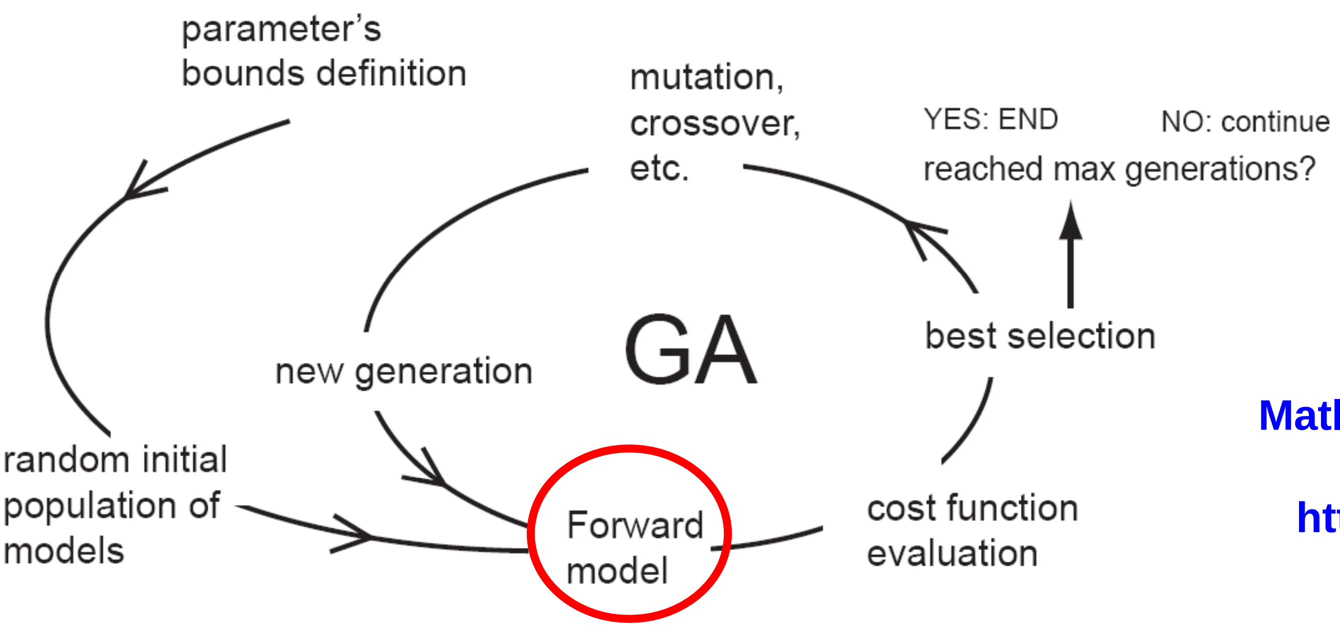
J. Vandekerckhove, (2006)
Matlab implementation of SA
available at http://www.mathworks.com



Genetic Algorithm (Holland, 1975)

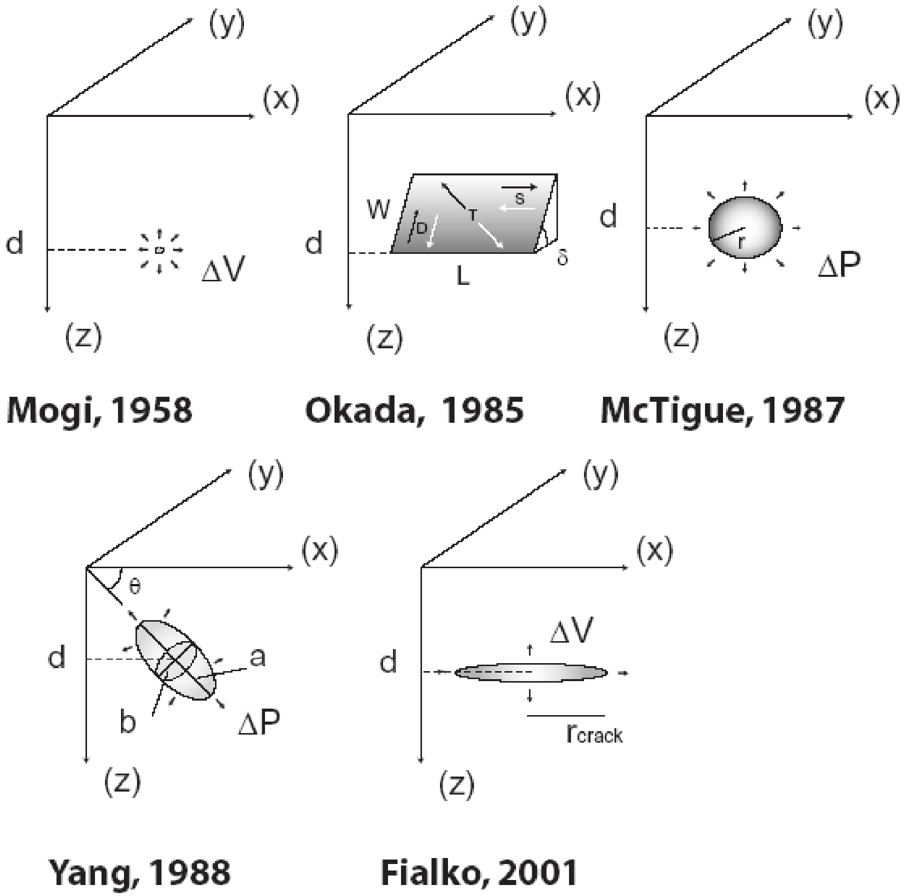
Based on analogy with biological evolution

Best-fit model → selection after max generations



K. Burjorjee, (2007)
Matlab implementation of GA
available at
http://www.mathworks.com

Standard forward models in Volcano Geodesy



→ Simplified geometry

→ Homogeneous half-space

→ Elastic material properties

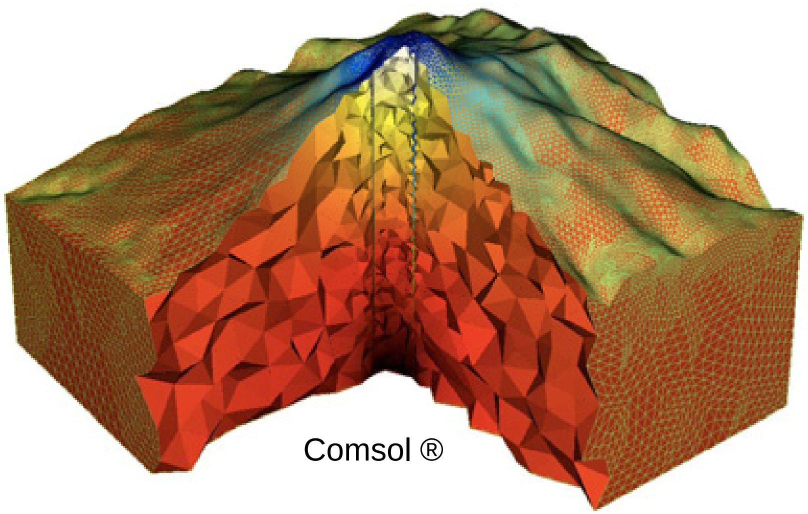
HOWEVER @ VOLCANOES…

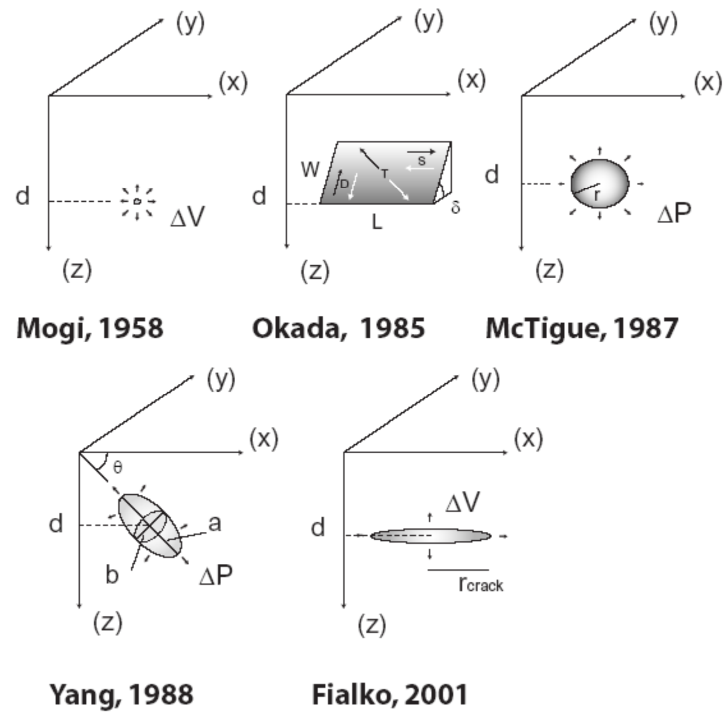
…Complex source‘s shapes

…Heterogeneities

…Time dependent material properties

FEM in Volcano Geodesy





Advantages:

→ Complex geometries

→ Material heterogeneities

→ “Multi-physics” simulation

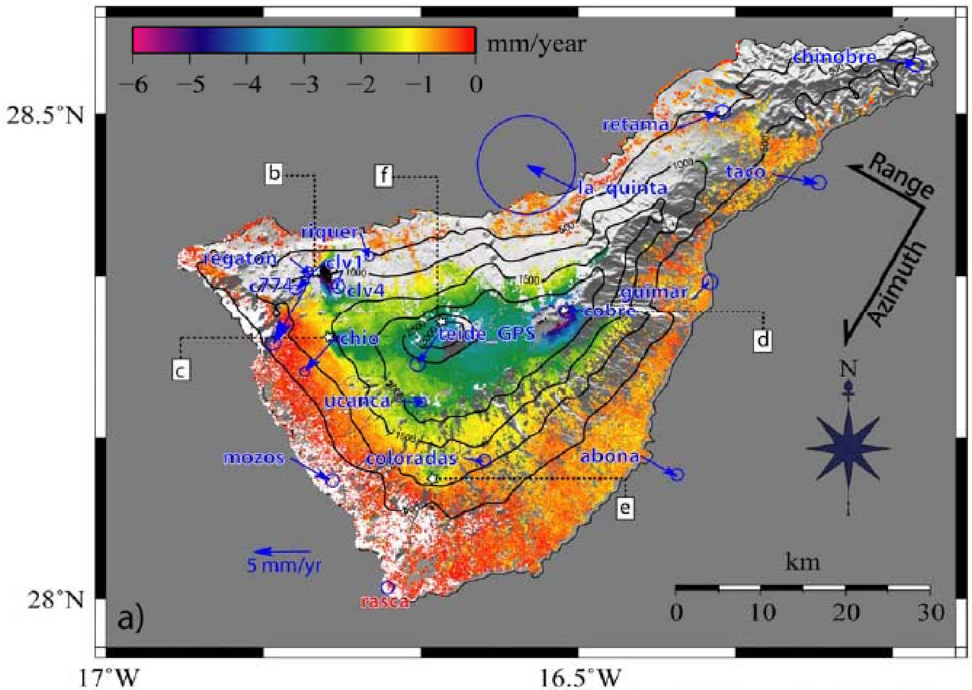
Disadvantages:

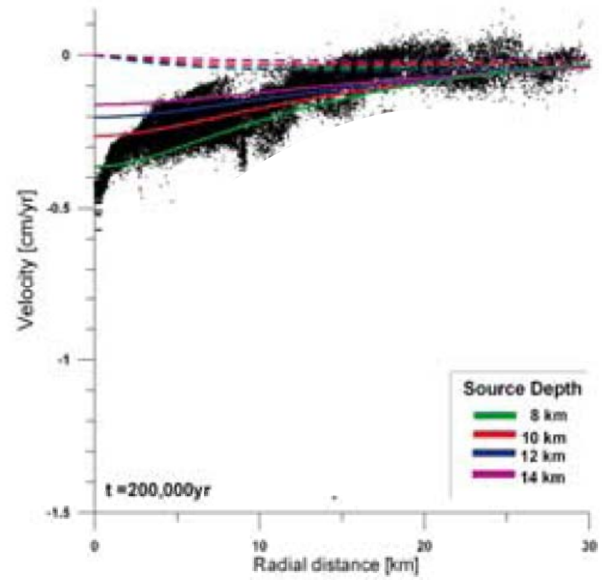
→ Computationally expansive

→ Poor constraints for subsurface properties

Application: Tenerife, Canary Islands

Fernandez et al., 2008



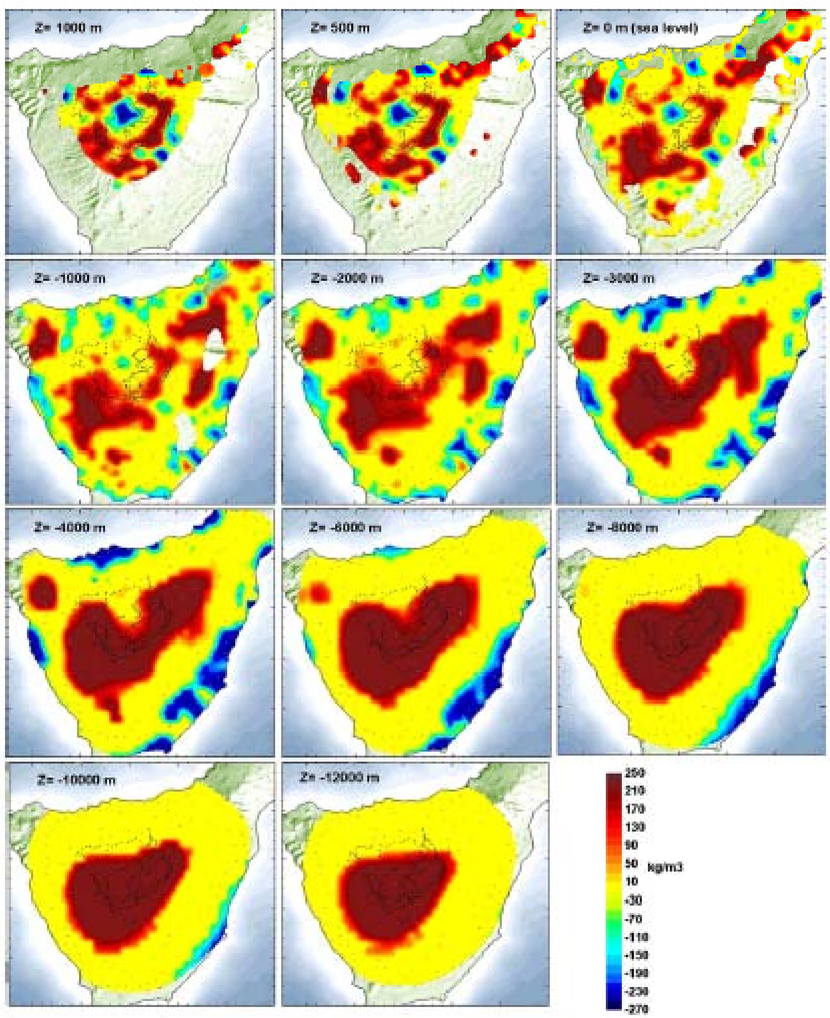


Surface deformation from space geodesy (1992-2006)

Interpretation: gravitational loading due to denser core

A priori information: Density structure

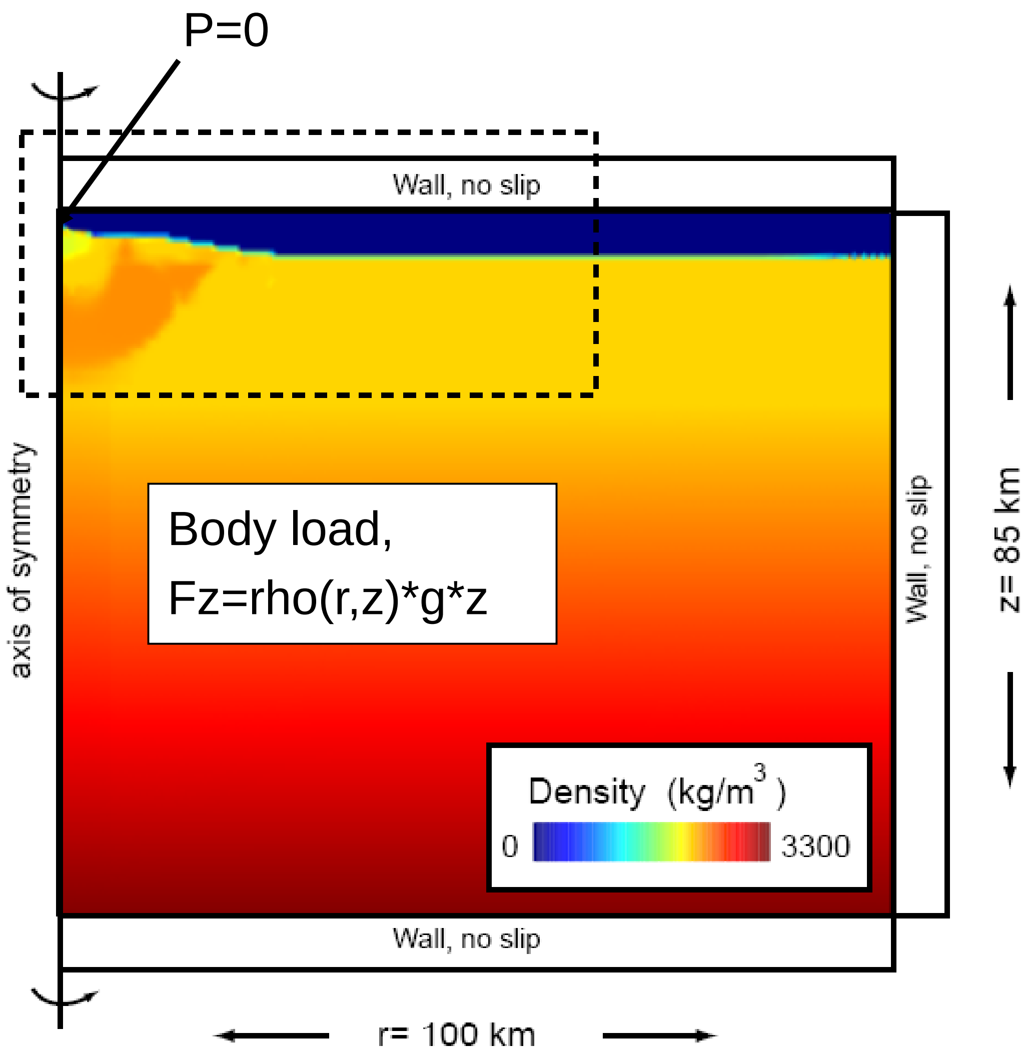
Gottsmann et al., 2008



Micro-gravity measurements
Constrain the inner structure

We can use this info to set up a FE model and optimize for the "best" distribution of viscosities explaining the observed deformation

COMSOL: Model setup



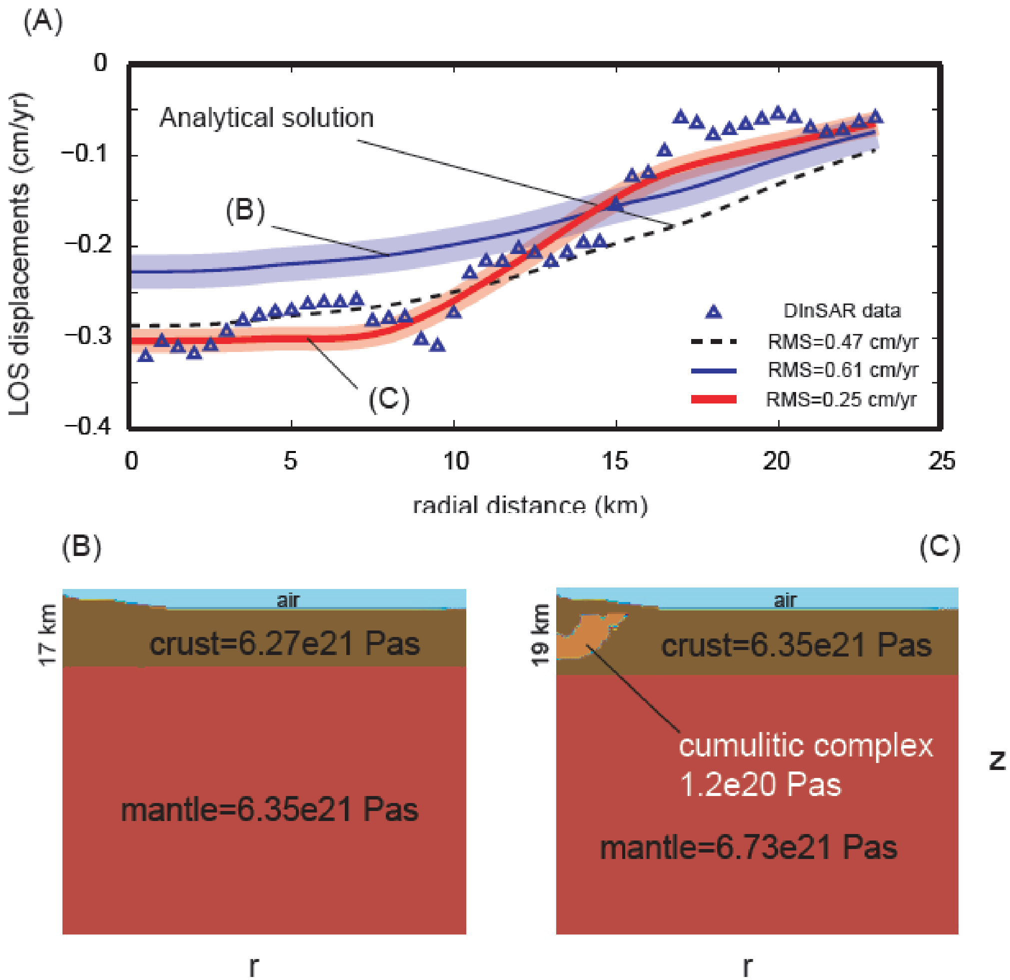
Fluid dynamics module

Incompressible Navier-Stokes

Density is a function rho(r,z), constrained by the microgravity measurements

Optimization of viscosity eta(r,z) with SA and GA

Results: Tenerife viscosity structure



Lateral heterogeneous viscosity distribution gives a better fit of the deformation data compared with homogeneous and/or layered structure!

Summary & Future work

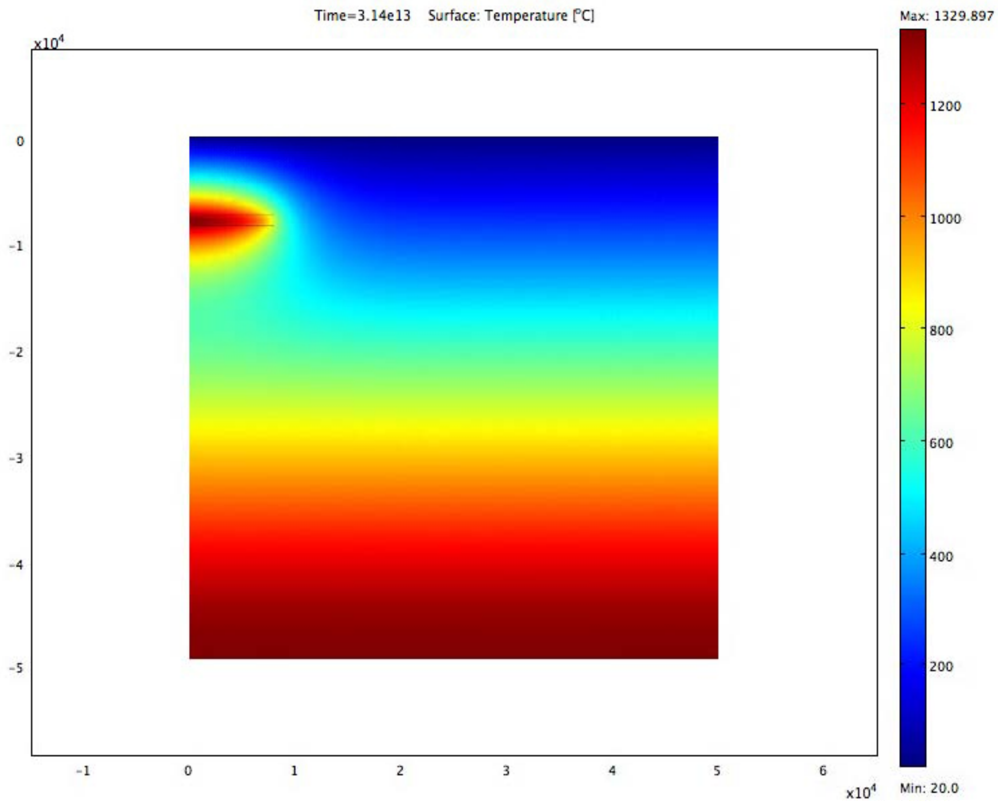
→ Implementation of optimization using SA and GA with *COMSOL*

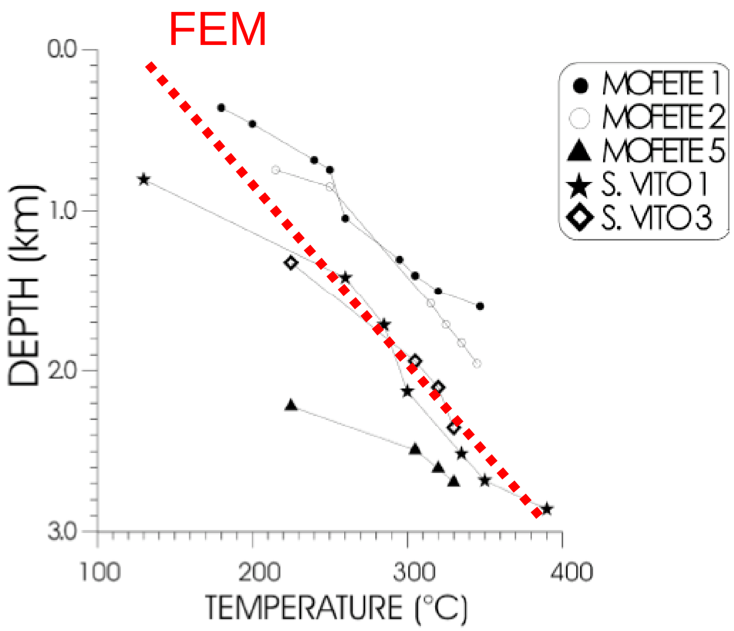
→ Possibility to use more complex forward models allows for a more accurate analysis of deformation at volcanoes: example of Tenerife

→ Same approach might be applied for other case-studies

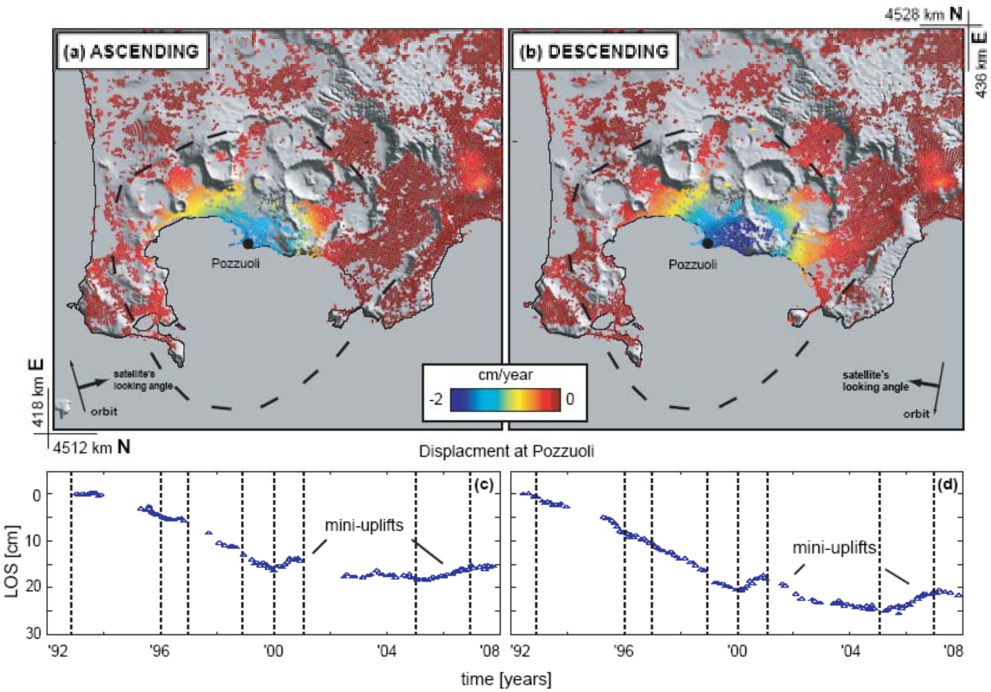
→ Straightforward extension to 3-D models

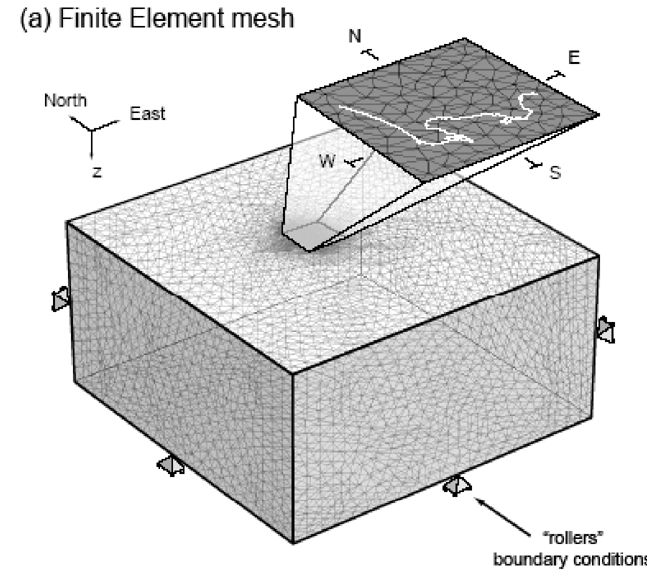
Thermal evolution of CF caldera

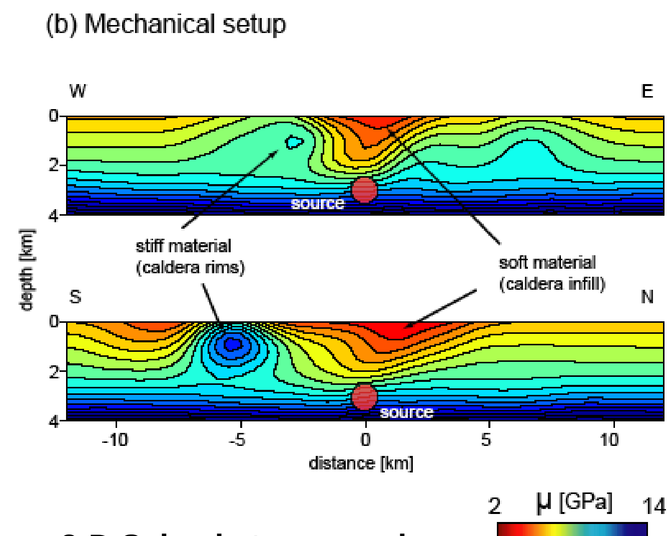




3-D Case: Campi Flegrei caldera



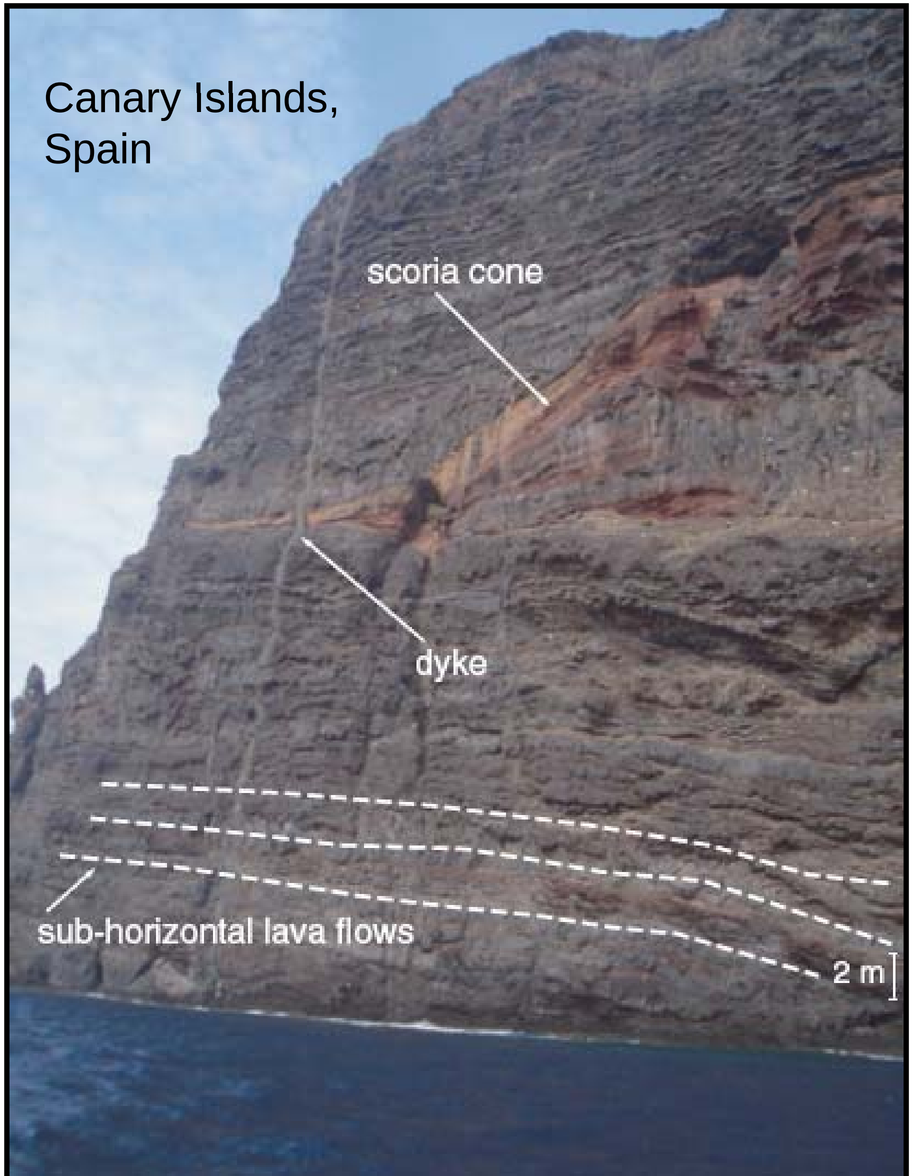




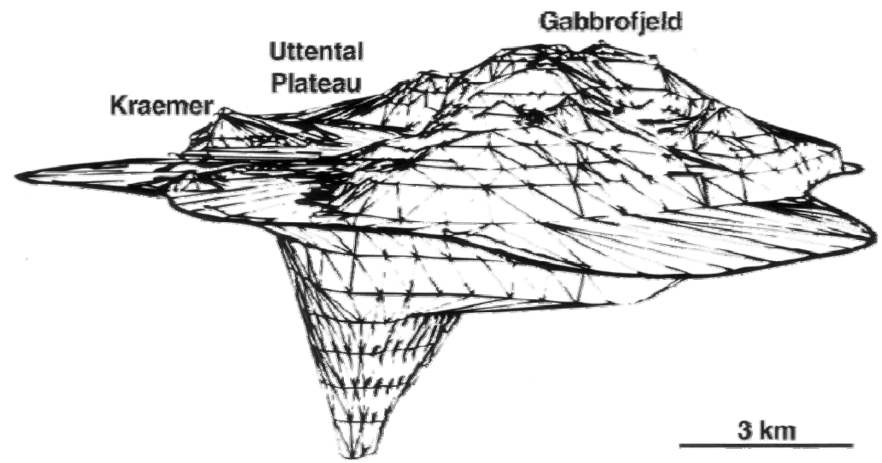
3-D Seismic tomography

Chiarabba et al., 2006

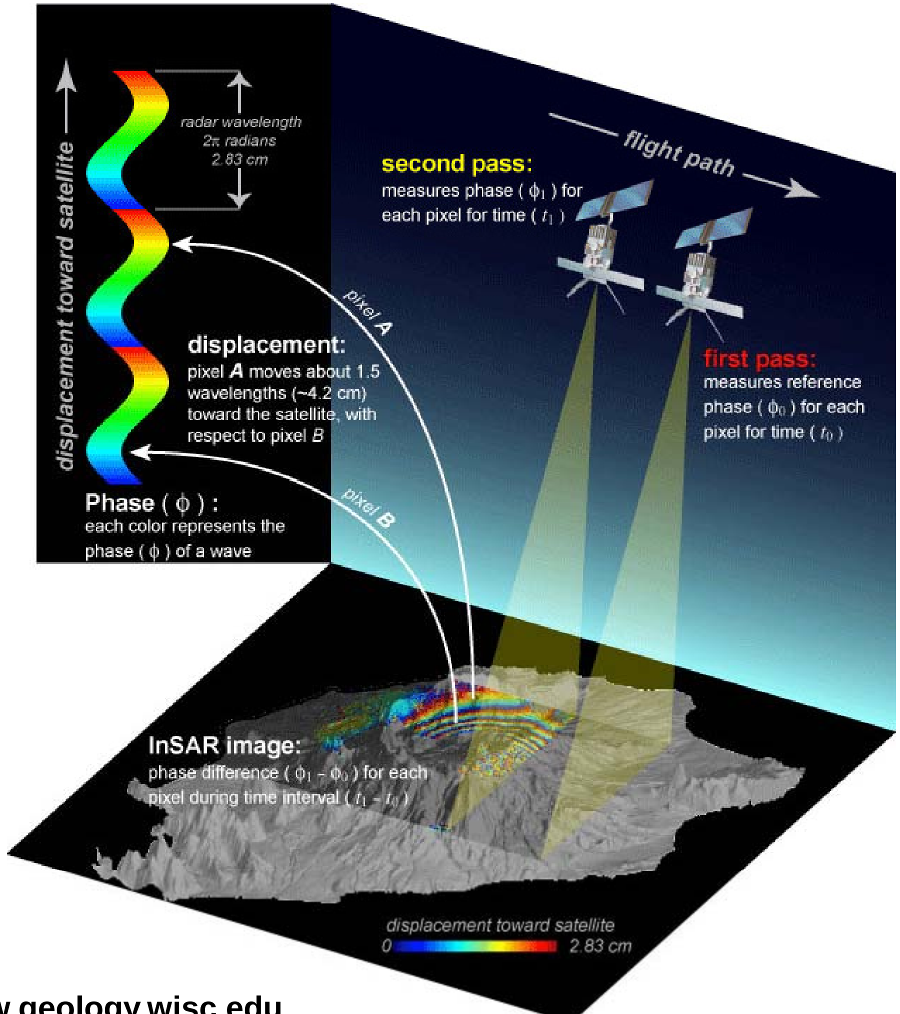
Complexities



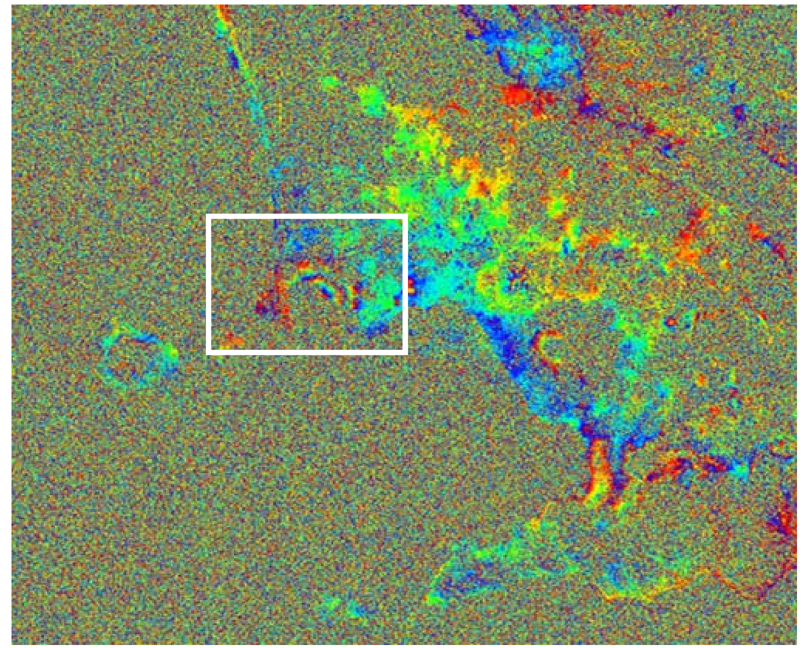
Skaergaard,
Greenland

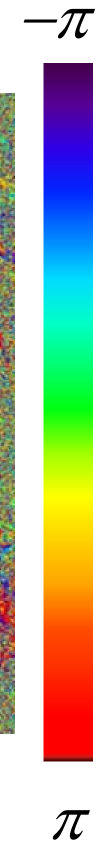


Satellite geodesy: DInSAR Scenario



www.geology.wisc.edu

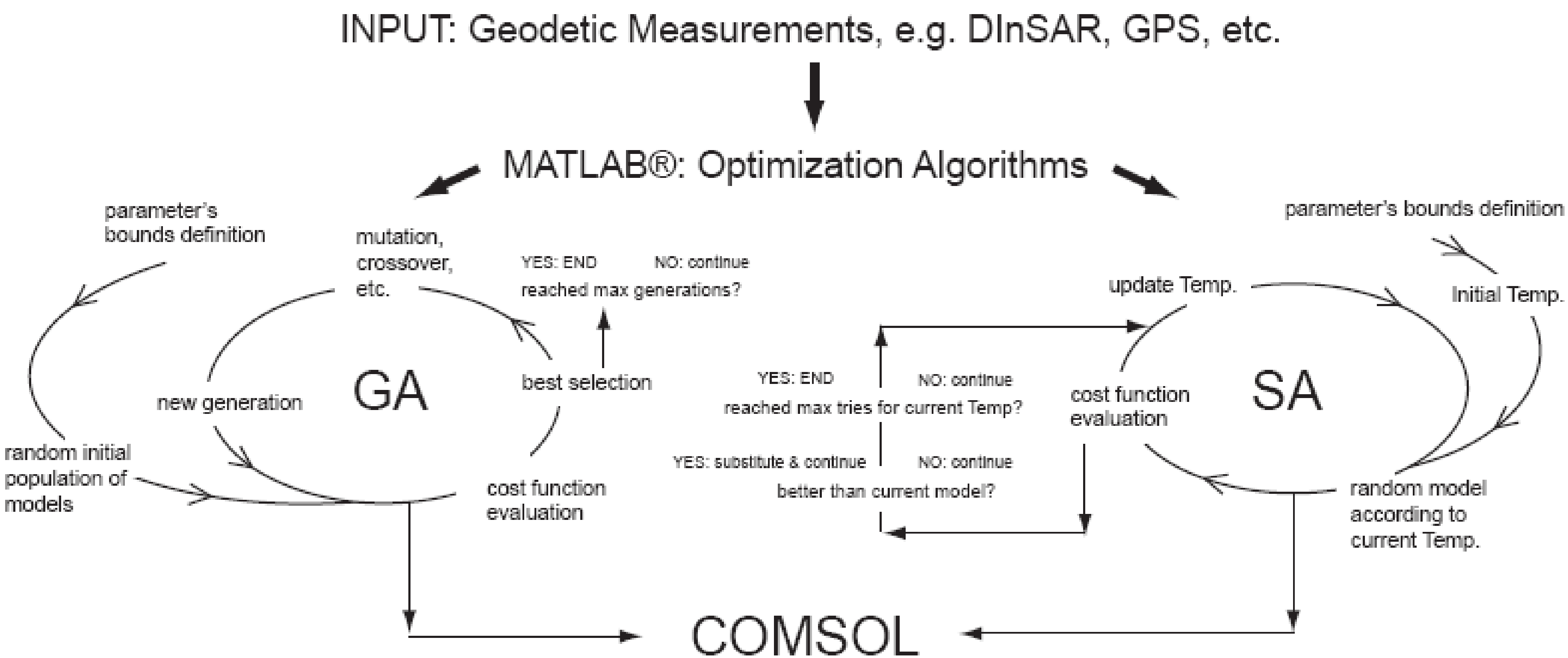




$$\varphi_d = 2\pi \;\rightarrow\; l_{d\_los} \approx \frac{\lambda}{2}$$

Centimetric displacements can be measured in over large areas!

Numerical inversion within FE models



Implementation of complex shapes, heterogeneities, time dependent effects, multiphysics environment