

The interaction between Web technologies and High Performance Computing for the Earth Sciences

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W.I.S.A. Web Interface for Seismological Applications

DOiT Data Optimization integrated Tool

What is W.I.S.A. ?

W.I.S.A. is a Web-based user interface to simulate elastic wave propagation in 2D heterogenous and dissipative media with complex layer interfaces and irregular topography.

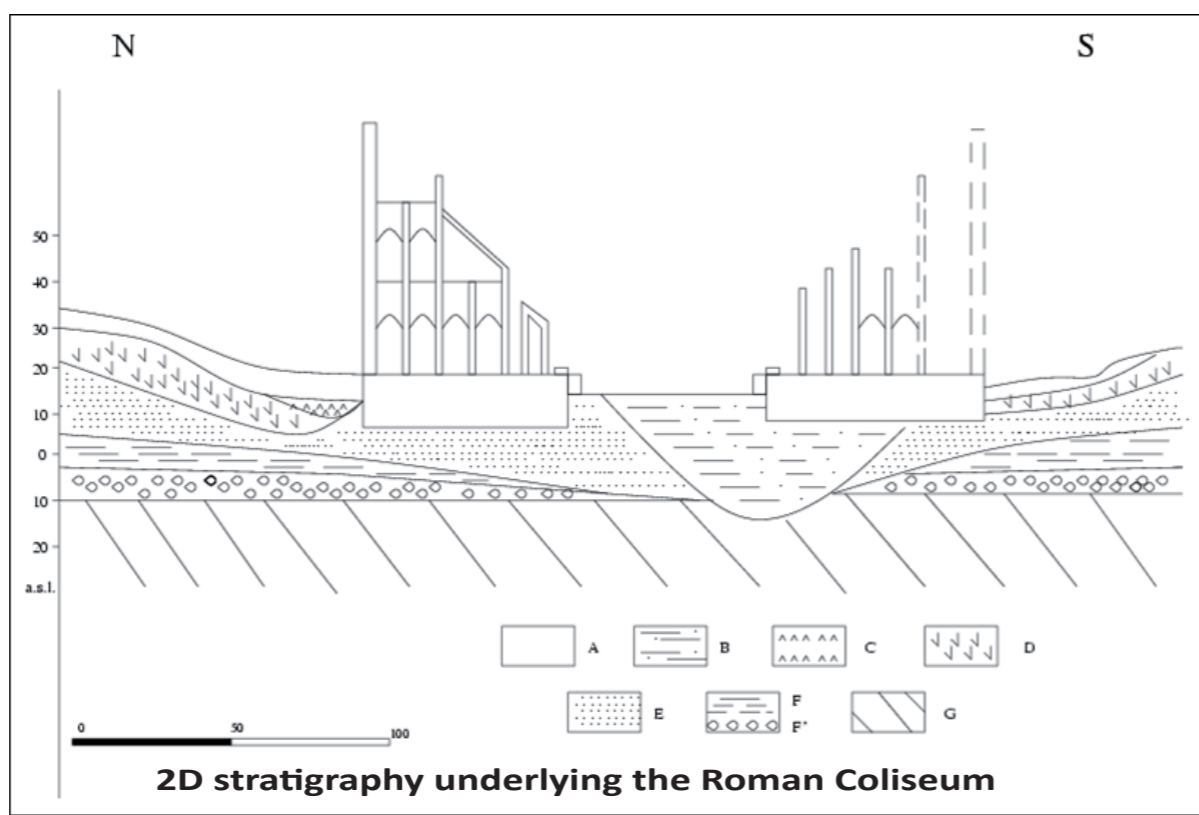
Features

- Entirely developed at CASPUR
- End-user is not required to have knowledge of numerical simulations and HPC skills
- Apache/Perl CGI platform with C modules and GD Library for rendering

Physical Problem

An important contribution to assessing interaction between nearsurface geology and seismic radiation arises from studies involving the so called site effects.

It would be more useful to know the site characteristics of the ground motion before an earthquake occurs. Numerical modelling is a powerful approach for such aim as well as to estimate parameters commonly used for earthquake engineering purposes. This is particularly true in urban areas.



Mathematical Model

The initial boundary value problem which represents the elastic dynamics driving 2D elastic wave propagation is presented in displacement formulation.

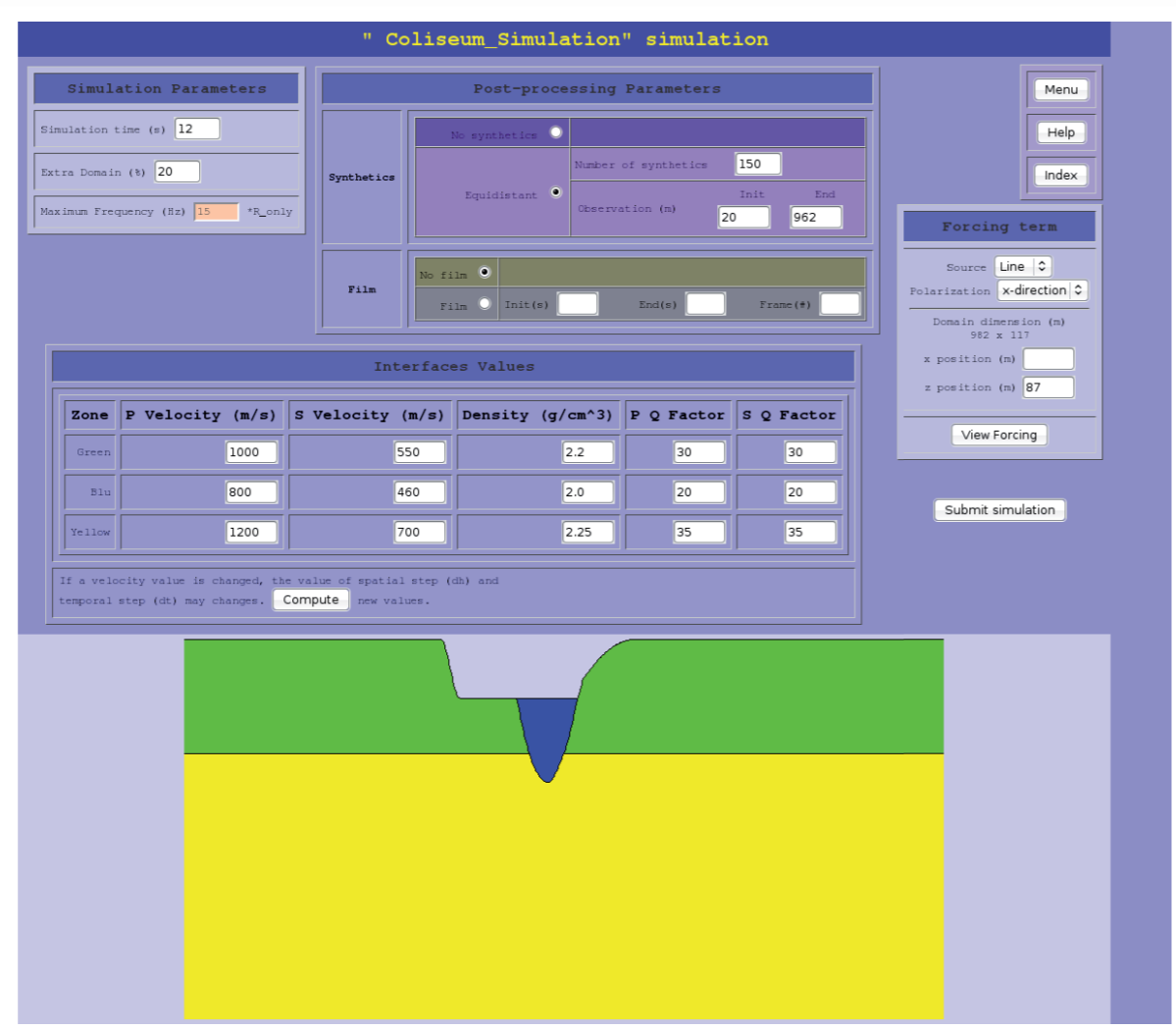
The discretization schemes are based on finite difference or finite elements method (FD, FEM).

$$\begin{cases} \frac{\partial^2 u}{\partial t^2} = \frac{1}{\rho} \frac{\partial}{\partial x} \left[(\lambda + 2\mu) \frac{\partial u}{\partial x} + \lambda \frac{\partial w}{\partial z} \right] + \frac{1}{\rho} \frac{\partial}{\partial z} \left[\mu \left(\frac{\partial u}{\partial z} + \frac{\partial w}{\partial x} \right) \right] - \frac{1}{\rho} \sum_{j=1}^n \xi_j^u(x, z, t) \\ \frac{\partial^2 w}{\partial t^2} = \frac{1}{\rho} \frac{\partial}{\partial z} \left[(\lambda + 2\mu) \frac{\partial w}{\partial z} + \lambda \frac{\partial u}{\partial x} \right] + \frac{1}{\rho} \frac{\partial}{\partial x} \left[\mu \left(\frac{\partial u}{\partial z} + \frac{\partial w}{\partial x} \right) \right] - \frac{1}{\rho} \sum_{j=1}^n \xi_j^w(x, z, t) \end{cases}$$

$$\begin{cases} \frac{\partial \xi_j^u}{\partial t} + \omega_j \xi_j^u = \omega_j \left[\frac{\partial}{\partial x} \left(\kappa Y_j^k \frac{\partial u}{\partial x} + \lambda Y_j^k \frac{\partial w}{\partial z} \right) + \frac{\partial}{\partial z} \left(\mu Y_j^k \frac{\partial u}{\partial z} + \mu Y_j^k \frac{\partial w}{\partial x} \right) \right] \\ \frac{\partial \xi_j^w}{\partial t} + \omega_j \xi_j^w = \omega_j \left[\frac{\partial}{\partial z} \left(\kappa Y_j^k \frac{\partial w}{\partial z} + \lambda Y_j^k \frac{\partial u}{\partial x} \right) + \frac{\partial}{\partial x} \left(\mu Y_j^k \frac{\partial w}{\partial x} + \mu Y_j^k \frac{\partial u}{\partial z} \right) \right] \end{cases}$$

Pre Processing

The main difficulty in preparing the input data to numerically simulate the dynamical response of near-surface geological structures is to digitize the domain of integration of the elastodynamics equations. W.I.S.A. helps the user in digitizing a 2D vertical section representing the geological stratigraphy of the site under study. The result of the preprocessing phase is the digitized 2D geological profile ready to be used, with the values of the elastic and anelastic parameters.

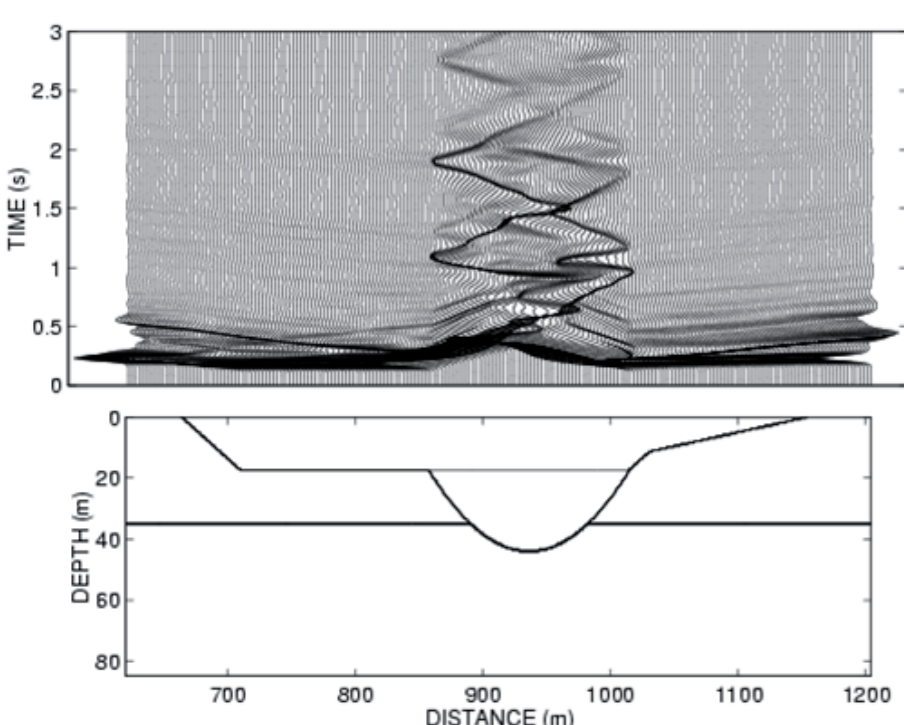


Processing

The great drawback to model realistic site dynamics is the impressive computational requirements needed for numerical simulations (gigabytes of memory, performances at gigaflops rate, ...). We simulate ~ 10 seconds ground shaking for a total of ~ 10.000 time-steps. A problem of millions unknowns is solved at each time-step. We develop a parallel code, based on OpenMP, suitable for shared memory architectures installed at CASPUR. A parallel multiblock approach for the solution of linear system related to the problem has been used.

Post Processing

Analysis & Visualization of results is done by using specific software (f.e. MATLAB). Post-processing parameters can be set via W.I.S.A. frames in a user-friendly manner.



Bibliography

Caserta A., Ruggiero V., Lanucara P., 2002. Numerical modelling of dynamical interaction between seismic radiation and near-surface geological structures: a parallel approach. *Computer & Geosciences* 28, 9, 1069-1077.

Trasatti, E., et al. (2008), The 2004–2006 uplift episode at Campi Flegrei caldera (Italy): Constraints from SBAS-DInSAR ENVISAT data and Bayesian source inference, *Geophys. Res. Lett.*, 35, L07308, doi:10.1029/2007GL033091

Hardware

The parallel machine used to perform the numerical simulations is an IBM SP5 with 168 processors Power5 working at 1.9 GHz clock. The cluster is composed of 21 SMP-nodes, each one of them equipped with 8 CPUs, interconnected with an IBM High Performance Switch.

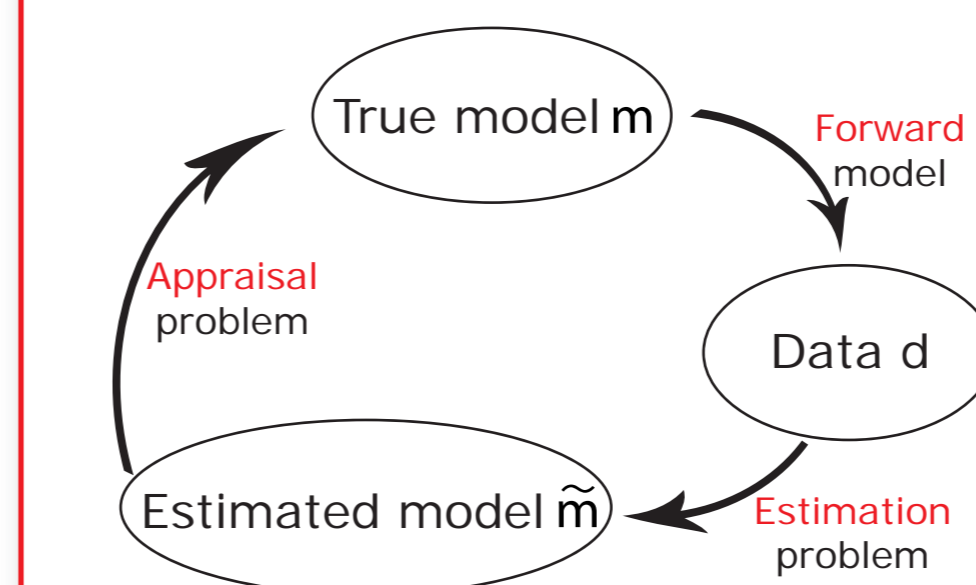
What is DOiT?

DOiT is a Web-based user interface to perform optimization of geodetic non-linear inverse problems

Features

- Global optimization based on the neighbourhood algorithm (Sambridge, 1999)
- MPI implementation to deal with large scale search of multi-dimensional spaces
- Transparent execution on distributed computing environments
- High portability and security
- Modular architecture for easy expandability
- Open structure based on AJAX Web 2.0 (XML & Javascript) and PHP integrated with C/C++ and Fortran 90 modules

The Problem



The general realistic problem can be represented by the equation

$$d = G(m) + \epsilon$$

data ← d ← G(m) ← model
 ← error ← ε ← physical-link (non-linear in general)

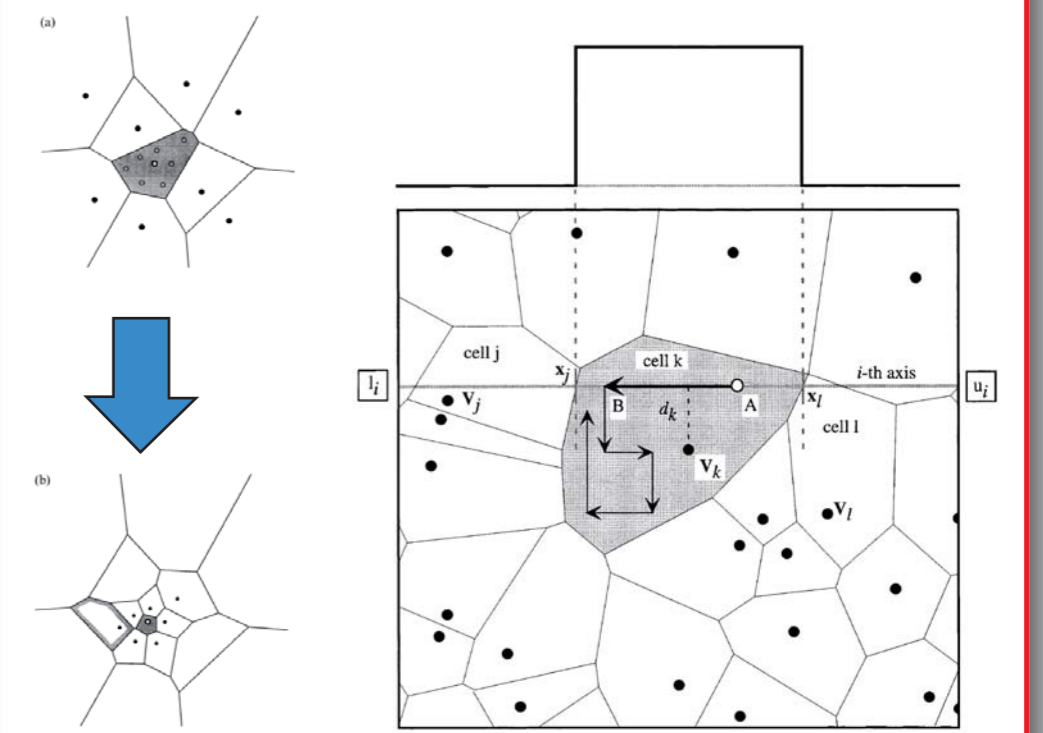
In a Bayesian fashion the solution is the posteriori probability density

$$PPD(m | d) = k \rho(m) L(m | d)$$

← likelihood function that contains predictions from the model
 ← prior probability distribution

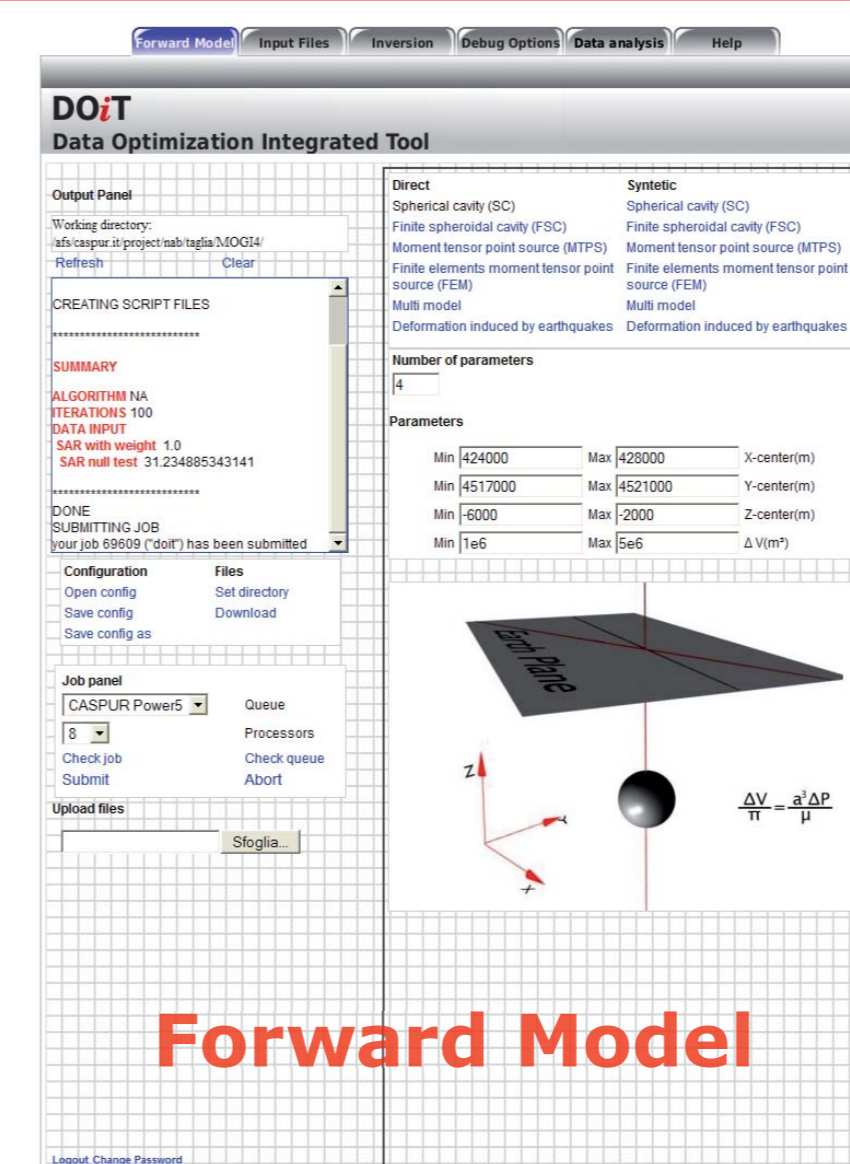
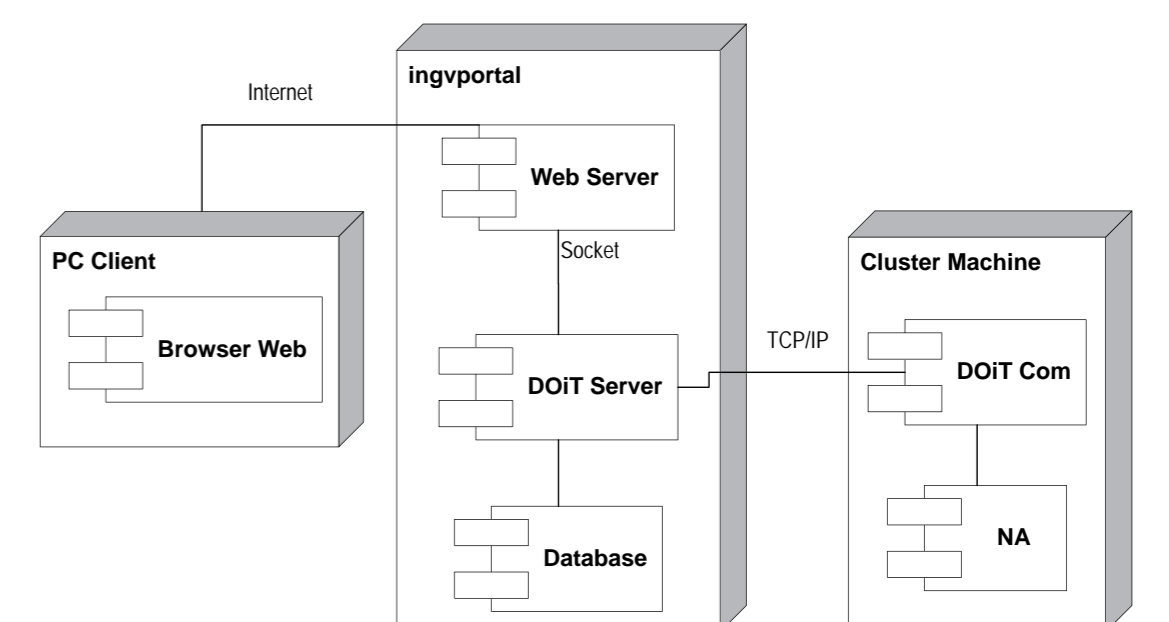
The solution using NA

- (1) Generate an initial set of n_i models uniformly in the parameter space;
- (2) Calculate the misfit function for the most recently generated set of n_i models and determine the n_i models with the lowest misfit of all models generated so far;
- (3) Generate n_i new models by performing a uniform random walk in the Voronoi cell of each of the n_i chosen models;
- (4) Go to step 2.

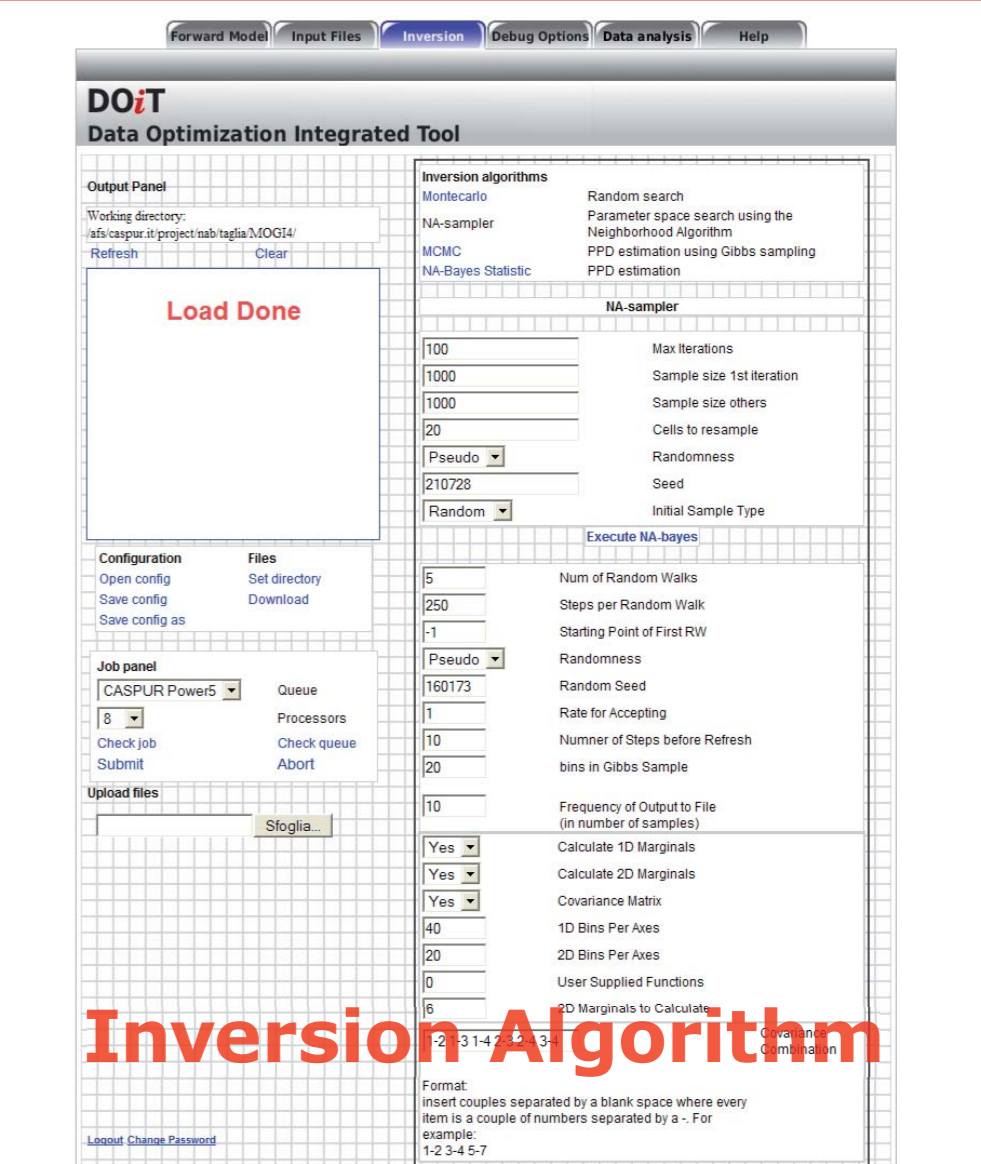


DOiT structure

- Very modular structure with independent parts
- All the complexity is transparent to the end user
- Several thousands of code lines



Forward Model



Inversion Algorithm

DOiT has been used in:

