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Inversion of thermal layering data through genetic algorithms assisted numerical modelling

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Various experiments dedicated to the investigation of the thermal properties of subsurface materials are under study in our institutes. Some are already in space (MUPUS, on board Rosetta), other are under development for future use in space (HP^3) or on Earth (EXTASE).

All share a common configuration and working principle: long, thin probes, equipped with sensors and heaters, are placed in the material that they heat for a finite period of time, while recording the heating and cooling curves at all the different levels.

Depending on the exact method used, theories allows the correlation of these curves with thermal properties. Unfortunately, the realization and practical implementation of the experiments introduce a high number of additional parameters and errors that make the properties determination by analytical means very complex and prone to failure.

To overcome these problems, another approach has been implemented: the process done by the probes is simulated with a thermal numerical model and the results are compared with the experiment. The error of the fit is then evaluated. The entire process from the guess of the parameter set to determination of the error is very fast and does not require excessive resources.

Due to the high number of parameters, the high non linearity of their interconnections, and the absence of previous knowledge on the material (e.g. comet surface), it is necessary to have a way to select, in the least time, the optimum set of values which fit the experimental data.

Genetic Algorithms (GA) are the method we selected. They are applied to the numer-

ical modelling to explore the parametric space and search for the optimal combination of values that minimize the fitting error.

A GA module is devoted to the creation of model sets that are run and fit against the experiment by a simulation module containing the thermal model.

Starting from a pseudo-random set of parameters, the GA module generates a set of initial models that are passed to the simulation module. As a result the corresponding error is passed back to the GA, where Aritmetic Crossover is used to mix properties of different models and Tournament Selection is then used to generate the successive set of models.

In this paper, the results from terrestrial experiments (EXTASE) are used to verify the procedure and prepare the method for future space-applied uses.