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IGMAS+ a new 3D Gravity, FTG and Magnetic Modeling Software

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Abstract. Modern geophysical interpretation requires an interdisciplinary approach and software capable of handling multiple inhomogeneous data like seismic, FTG gravity, magnetic and magnetotelluric. We introduce the new IGMAS+ ("Interactive Geophysical Modeling Application System") geo-modeling software for realistic 3D FTG and magnetic modeling. The software is grid capable and allows extreme fast distributed calculations on normal hardware such as a network of PCs.

1. Introduction

Modern geophysical interpretation requires an interdisciplinary approach, particularly when considering the available amount of 'state of the art' information contained in comprehensive data bases. A combination of different geophysical surveys employing 3D seismic, gravity and electromagnetic, together with geological and petrological studies, can provide new insights into the structures and tectonic evolution of natural deposits and the lithosphere. Interdisciplinary interpretation is essential for any numerical modeling of these structures and the processes acting on them.

It is well known that 3D gravity and magnetic modeling appreciably improves the results of distinct depth imaging projects. This regards especially to areas of strong lateral velocity and density contrast and corresponding imaging problems. Typical areas where grav/mag modeling has been successfully used are sub-salt (for example [5], [6] and sub-basalt situations, for example [7], [8]). Recently, seismic depth imaging has become much faster. Instead of days or even weeks a 3D prestack migration can now often be carried out in less than an hour. More iterations to improve the velocity model are possible and the whole process has become interactive and more interpretative. Seismic processors are working closely together with seismic interpreters and structural geologists to find the best possible model fitting all available data and giving the best seismic image. Density models, which are physically closely related to seismic velocity models, may help improve seismic imaging constraining the parameter velocity through the independently measured gravity or gravity gradient field.

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2. Methodology

Three-dimensional (3D) interactive modeling with IGMAS+ ("Interactive Geophysical Modeling Application System") software provides means for integrated processing and interpretation of geoid, gravity and magnetic fields, their gradients (FTG, full tensor gravity) and invariants, yielding improved geological interpretation. The software is based on twenty years research and development (www.gravity.uni-kiel.de/igmas) but was redesigned from the scratch according to modern software architecture for optimal man machine communication and grid computing features (www.potentialGS.com). The analytical solution of the volume integral for the gravity and magnetic effect of a homogeneous body is based on the reduction of the volume integral to an integral over the bounding polyhedra; triangles in the case of IGMAS [1], [2]. Later the algorithm has been extended to cover all elements of the gravity tensor (Götze, personal communication) as well.

In order to achieve geologically realistic structures, IGMAS+ 3D models are constructed using triangulated polyhedrons and/or triangulated grids. Interoperability to widely used existing software like GOCAD, GeoModeller and Geosoft (Oasis Montaj, GMSys) is a key feature to integrate IGMAS+ into the modeling workflow at e.g. Statoil. Interactive modifications and inversion of model parameters (geometry, density, susceptibility, and magnetization), the access to the numerical modeling process, and a near real time visualization of calculated and measured potential fields allow the construction of realistic geological models as needed e.g. for offshore oil and gas exploration where geological constraints play an important role for the avoidance of method inherent ambiguities.

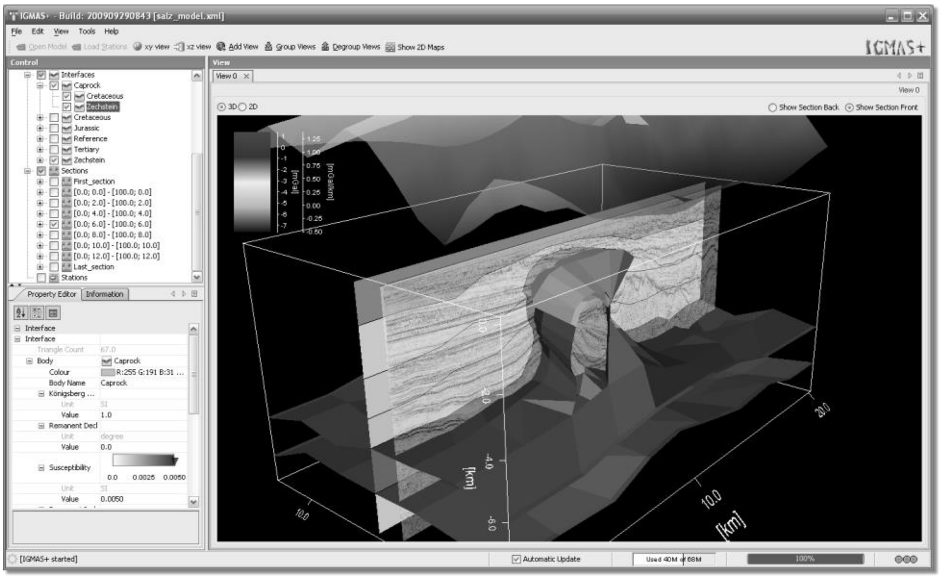

Figure 1: Easy construction of realistic geological models for FTG and magnetic forward calculation

The interpretation of potential fields by 3D modeling requires data from other independent sources. Different geophysical methods are used to interpret geophysical data, yielding a variety of different models – some 3D but most 2D and 1D. Examples include seismic 2D-raytracing models, 2D and 3D density and/or susceptibility modeling, 4D (time dependent) stress modeling, and 1D/2D magnetotelluric resistivity modeling. Even 3D and 4D geological models need to be respected. These models are often restricted to one single physical parameter or – in the case of geological model – are focused on a general picture. This is due to the historic development and due to the lack of an integrated approach and – in the past – limited hardware capabilities.

IGMAS+ comprises a fully linked multiple display graphics view designed for geologists and not for computer specialists. The aim of the design was always to set the geo-expert in the driver seat and allow the easy construction of complex geological models.

In summary this main focus areas for IGMAS+ are:

- Improvements in the user interface
- Improved model editing functionality
- Interfaces to other tools like Gocad and Geosoft
- Advanced density inversion using MMSE ([4], [3])
- Basic functionality for filtering and analysis
- More complex density functions for the currently homogeneous bodies

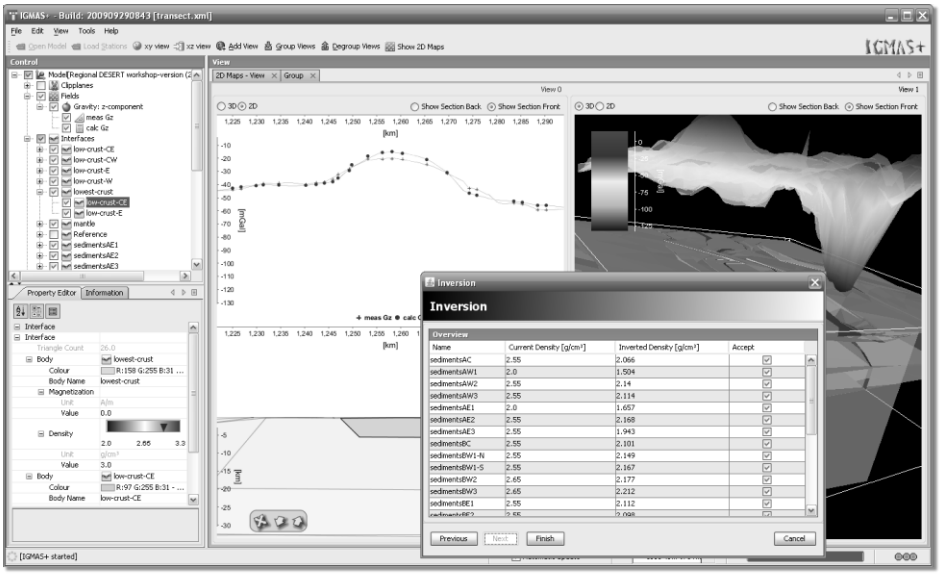

Figure 2: Multiple views of the model. All views are interlinked and table views to data give numerical insight

3. Model construction

Building a 3D model with possibly complicated topological structures is a time consuming and laborious task, which frequently does not fit into modern work flows demanding instantly quick answers and decisions. To comply with this, IGMAS+ is based on some special features:

- The geometry is defined on vertical parallel not equidistant vertical sections, which allows easy automatic triangulation as well as conventional "geoscientific" visualization in the form of cross sections.
- Semi- or fully automatic import of predefined models or information, resp. The import of seismically predefined horizons has been developed recently and will be described in more detail later.
- Easy to use and standardized formats data exchange formats. Modern interpretation of complex geoscientific data requires a variety of specialized computer software. Thus, sending the measured, interpreted or modeled data back and forth through a variety of import and output filters becomes increasingly important.

The amount of the irregularly spaced points of picked seismic horizons may be very high, compared to the gravimetrically naturally limited modeling resolution. If not down sampled, this fact will

- blow up the amount of the modeled data, requiring high computational resources, and in addition
- hide the methodological possible resolution of potential field modeling.

A down sampling may be achieved through a variety of procedures, many of them being developed especially for the high standards of graphical software systems around the “virtual reality” modeling. Their special task, however, is a bit different to ours: They try to maintain the original information content simultaneously reducing of data quantity, whereas we need an algorithm to down sample and at the same time generalize according to a given precision threshold. A possible procedure would have been to use a smoothing interpolation, but in order to make this step as fast as possible, we decided to apply a “Binned Average Values” algorithm: Within each cell of a grid covering the model area, the average of all points falling within the same cell is calculated for the x, y and z coordinate. The magnitude of generalization is easily controlled visually by the user changing the cell size of the filter.

As IGMAS+ needs the polygon geometry on all cross sections building later the 3D structure, each horizon surfaces has to be cut with vertical sections. The cutting algorithm is very fast, and may be applied to the Delaunay-triangulated surface directly, or after an intermediate step of gridding, which will produce a more generalized, smoothed initial model geometry.

Figure 3 shows the layered model geometry built automatically using very irregularly distributed initial seismically picked points (posted as medium gray circles) on top of the final model geometry, which has been gridded in this case.

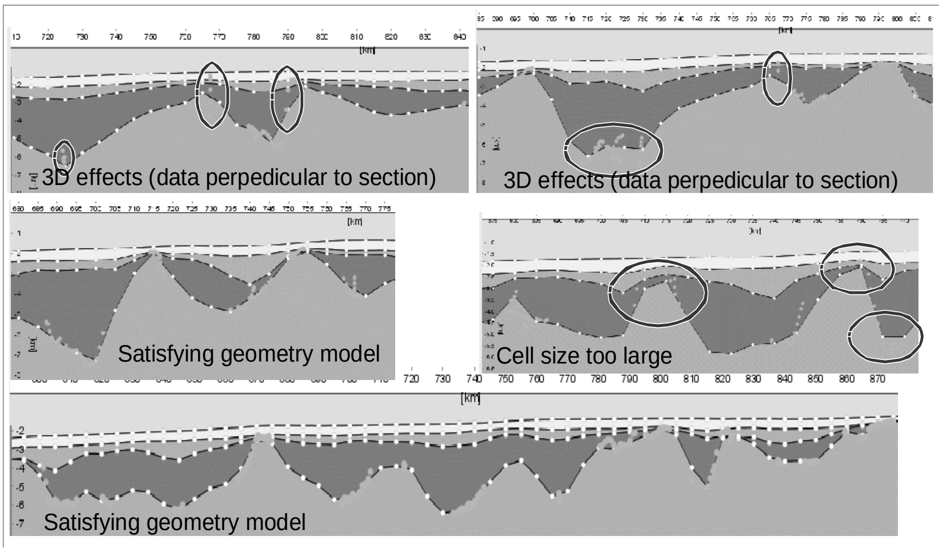

Figure 3: Automatically built 3D models using explicitly the geometry information of seismically picked points (medium gray circles). The layers have been generated through 1. binned average, 2. gridding and 3. triangulation.

4. Modeling results

Figure 4 shows two vertical west-east cross sections, with the measured (crosses) and calculated (circles) anomalies at the top, and the model geometry at the bottom. It is obvious, that there is generally a very good coincidence, especially the wavelengths and the phase are far better than one would expect of an initial model, which is constructed based only on seismic geometries. The amplitudes of some anomalies could be improved – in many cases the modeled amplitudes are too small. This could mean, that either the density contrast along the modeled horizons is not constant, or that the modeled structures should be located more superficially.

It should be emphasized, that the 3D model shown here has been built automatically within just some minutes, including the anomaly calculations. This easy-to-use-model construction enables the user to concentrate on the scientific outcome of the modeling, and to spend more time on interactive modifications, which are necessary in areas where the initial calculated fields do not satisfy the measured anomalies.

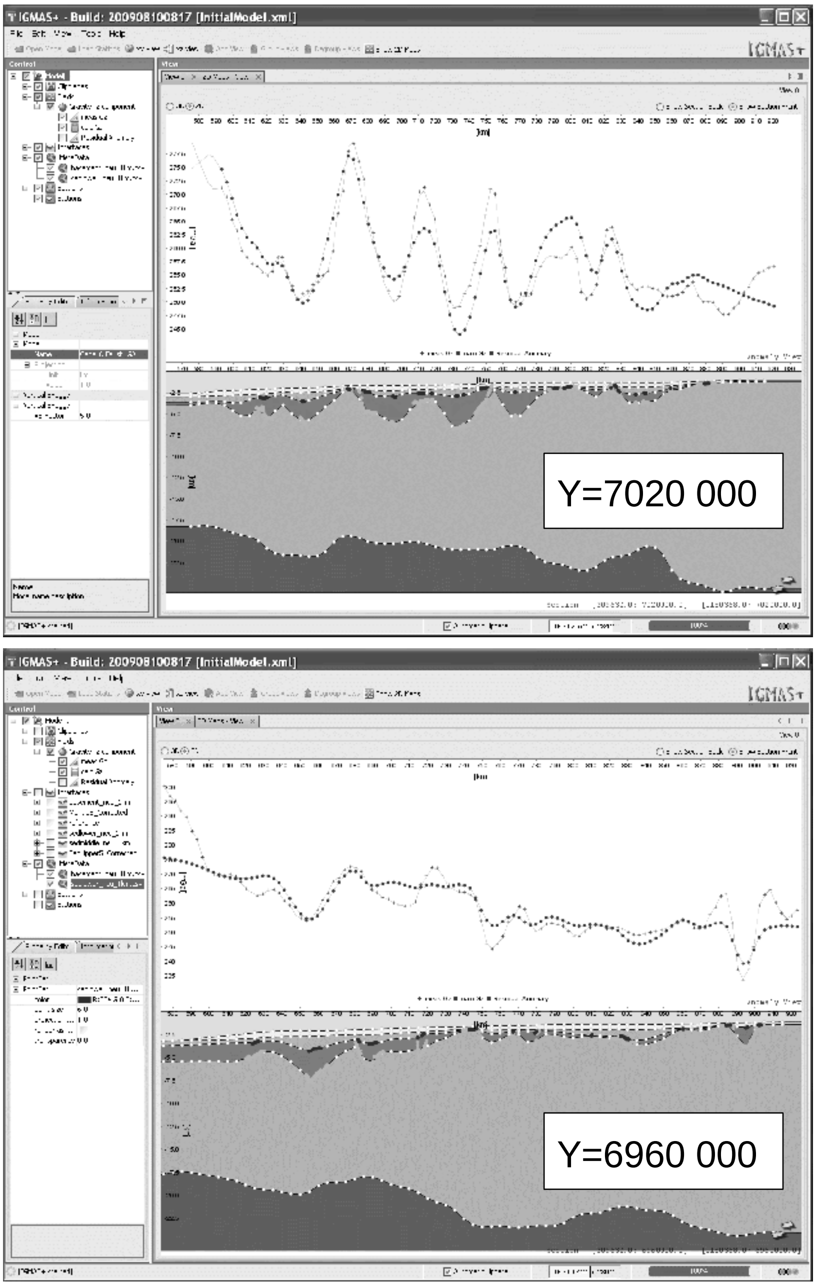

Figure 4: Initial, automatically built model. Circles in model: Down sampled picked seismic interpretation. Vertical exaggeration of model: 5

5. Acknowledgements

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