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Research Interests: Inverse theory, geomagnetism, spectral analysis, electromagnetic induction.

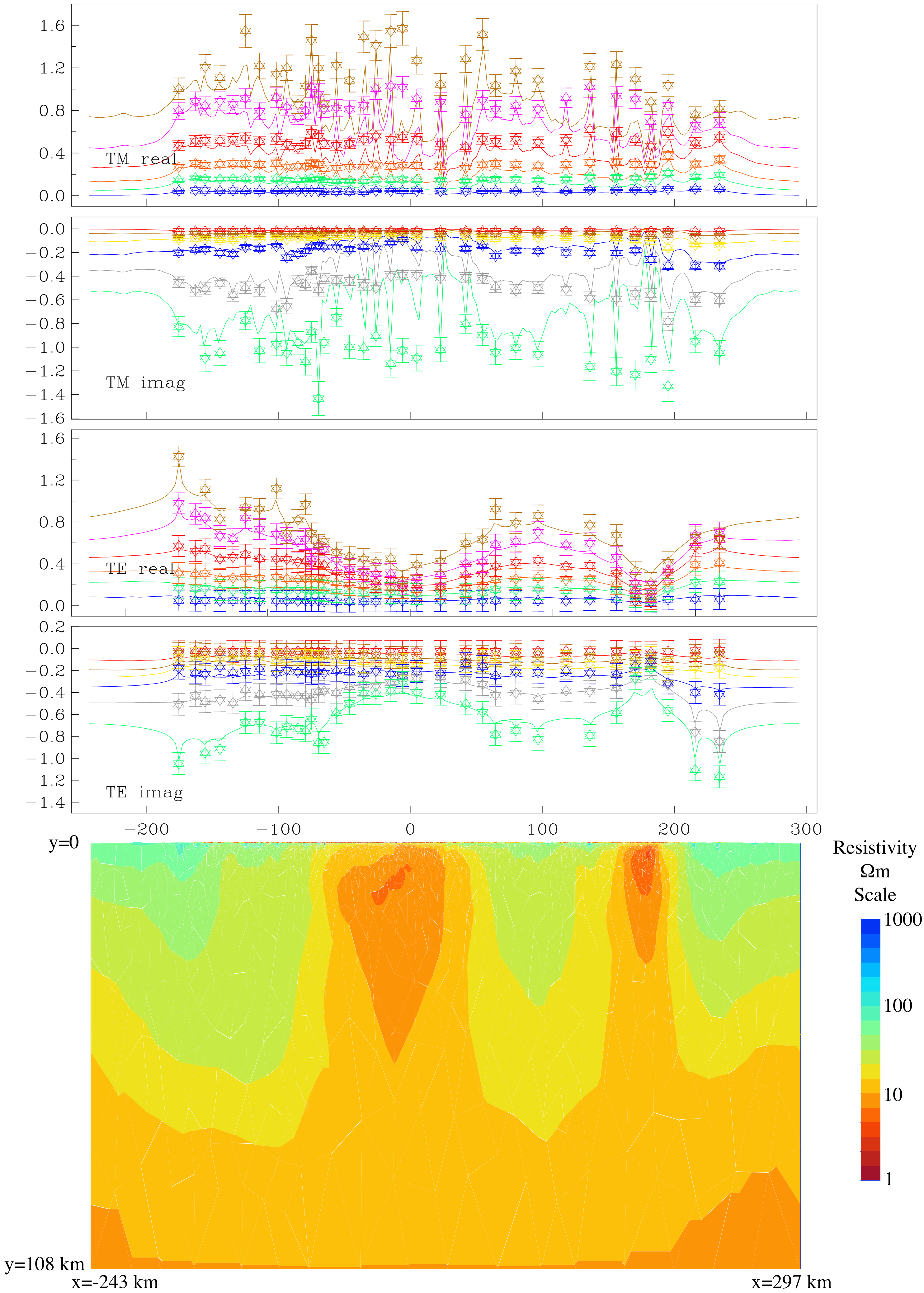
The past year has been occupied with bringing to publication work that was the subject of Ashley Medin's PhD project. In collaboration with Prof Steve Constable in IGPP, and two colleagues in the UCSD Mathematics Department, Profs Randy Bank, and Philip Gill, Bob Parker and Dr Medin (now Ashley Van Beusekom) have been pursing a radical approach to the numerical solution of large-scale inverse problems, applying the ideas to the 2-dimensional magnetotelluric (MT) inverse problem. MT sounding consists in the simultaneous measurement of electric and magnetic fields on an array of instruments at the Earth's surface, relying on naturally generated time-varying fields from the ionosphere and magnetosphere to provide a driver for electromagnetic induction. As readers of the Annual Report will be aware, electrical methods have risen to prominence as powerful tools for exploring the Earth, particularly beneath the seafloor. The observational techniques have made enormous strides in the last decade, with IGPP leading the way. New theoretical methods are needed to deal with the volume of data and the demands for higher resolution.

As a first step in this direction we have adopted a strategy for the solution of the 2-dimensional MT problem embedded within a numerical optimization program. In the conventional approach to nonlinear inverse problems like this one, we begin with a model structure and compute its response and thus predict the observations that would be obtained; this is the solution of the forward problem. Naturally, at first these predictions fail to match the actual values, and so the discrepancies are used as a basis for a calculation seeking perturbations to the model that will bring predictions and observation into better accord—the inverse problem. The response of the modified model is computed and the process repeated. In this traditional scheme optimization plays an important part in the second phase to minimize undesirable features of the new solution (like excessive short-wavelength undulations).

The new technique places the whole process under the control of an optimization algorithm, by including the solution of the forward problem as well as the matching of the observations and the stabilization issues into a single objective function, symbolically:

$$P = w_1 \cdot [\text{PDE violation}] + w_2 \cdot [\text{data misfit}] + w_3 \cdot [\text{model roughness}]$$

The solution the forward problem entails the numerical solution differential equations derived from Maxwell's equations, and that process is framed as minimizing an error function; this avoids solving the forward problem to needless accuracy and high resolution in the early stages. To realize these ideas we adopted a general-purpose, multigrid optimizer, PLTMG, created by Prof Bank.


TM real
TM imag
TE real
TE imag
−200
−100
0
100
200
300
y=0
y=108 km
x=-243 km
x=297 km
Resistivity
Ωm
Scale
1000
100
10
1

The plot illustrates the solution based a standard 2-dimensional MT data set employing both transverse and transverse magnetic responses. Among the advantages of the optimization method developed here is the ability to include inequality constraints on the model, in addition to, or instead of common regularization penalties. Inequalities in inverse problems have been one of Bob Parker's obsessions: they provide a means for extract reliable information from an inverse problem, something lamentably absent in most cases. A paper covering the work described here is under review with Geophysical Journal International.

Recent Publications

Parker, R. L., Can a 2-D MT frequency response always be interpreted as a 1-D response?, *Geophys. J. Internat.,*doi: 10.1111 /j.1365-246X.2010.04512.x 181, pp 269-74, 2010.