Society of Exploration Geophysicists
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**2015 Near Surface Honorary Lecturer**

## *The curse of dimensionality in exploring the subsurface*

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The term "curse of dimensionality" refers to increases in the dimensionality of model spaces that result in undesirable increases in data sparsity, such that model parameters are no longer sufficiently constrained by the data. Although the term is usually employed in combinatorics, machine learning, and data mining, it is also directly relevant for many problems in exploration geophysics. The most obvious applications are 3D tomographic inversions, which typically include very large numbers of unknowns.

There is a further "curse of dimensionality" and related data sparsity that may impede many geophysical investigations: 3D surveys typically involve the acquisition of data using only a 2D array of sensors distributed across the Earth's surface. As a consequence, procedures for imaging the subsurface are missing data recorded in the third dimension, depth. Similar problems affect 2D inversions of (1D) profile data.

Computational problems that need to be overcome in large-scale tomographic inversions are additional issues associated with the "curse of dimensionality". In particular, the rapidly emerging field of realistic 3D full-waveform inversions of elastic and anisotroic data is hitting the limits of current computer facilities. Seemingly ever increasing computing power will undoubtedly be beneficial for such endeavors. Nevertheless, suitable model parameterizations that offer appropriate spatial resolution while keeping the inversion problem computationally tractable will continue to be critical elements of any high dimension inversion endeavor.

Because of the large computational costs and the difficulties to cover extensive areas with geophysical sensors in complicated terrain, many land surveys continue to involve data acquisition along profiles. Such surveys will play a significant role for the foreseeable future. When solving the associated 2D inversion problems, the "curse of dimensionality" strikes again. The underlying 2D assumption that subsurface properties and topography do not change in the third dimension, that is, perpendicular to the tomographic plane, is often unjustified.

The problem of data sparsity can be partially alleviated by employing optimized experimental design and optimized data parameterization approaches. These techniques identify experimental configurations and data representations that optimize data information content and resultant models in a cost-effective manner.

In this lecture, I will illustrate the "curse of dimensionality" by means of several examples from near-surface geophysics. I will present a variety of options for addressing the related problems, including experimental design techniques and optimized model parameterization strategies. I will also discuss problems and remedies related to out-of-plane features in 2D elastic full-waveform inversions

## Biography

**Hansruedi Maurer** is professor for exploration and engineering geophysics at ETH Zürich, Switzerland. His research interests span from algorithmic developments for geophysical tomography to innovative field studies concerned with natural hazards, storage of dangerous waste, exploration of deep geothermal reservoirs, cryosphere research and several other areas, where geophysical techniques provide useful information. A key aspect of his research is the tight coupling of latest developments in numerical modelling and inversion theory with the solution of problems that arise in field applications of magnetic, geoelectric, inductive electromagnetic, ground-penetrating radar and seismic methods. Moreover, he is one of the leading scientists in geophysical experimental design. His contributions in this relatively new research discipline were awarded with the Best Poster Award at the 1997 meeting of the Society of Exploration Geophysics and the 2004 Best Paper Award in Geophysics. He has served as an Editor for Geophysics, and he is an active member of several national and international scientific boards.