

Introduction: On comparableness of magnetotelluric processing methods

The aim of magnetotellurics is to provide information about the magnitude and distribution of the electric conductivity in the Earth. This is achieved by measuring variations of natural electric and magnetic fields at the surface. Transfer functions between the electric and the magnetic field, or between magnetic fields recorded for certain different orientations or locations, respectively, contain information about the conductivity of the subsurface insofar as they are connected by an induction process. So the first important task the worker is confronted with after measurements is to derive reasonable, good-quality transfer functions from the data that will enable him to solve the subsequent problem, i.e. to find a conductivity model of the subsurface. Performing that task is not trivial for at least two reasons: First, since magnetotellurics is a passive method, one has very little control over the signal-to-noise ratio in the records. In ill-conditioned cases, this can lead to very scattering results. Second, even if there have been derived smooth transfer functions, they are reasonable in terms of magnetotellurics only if the so-called far-field condition is fulfilled. This is not the case in the proximity of sources of artificial electromagnetic signals, e.g. electric pasture fences, corrosion-protected pipelines, or railway lines, especially if they are run with direct current. Thus deriving transfer functions between any measured quantities is not straightforward in modern methods, but there are applied additional techniques in order to take into account the difficulties mentioned above.

In general, the problem addressed first is tackled using a number of steps to reduce the influence of outliers in the data, e.g. time series preprocessing, robust statistics, weighted stacking over spectra during averaging, and smoothing over the results of adjacent frequencies, referred to as “procedures independent of conditional equations” in this thesis. The second one is evaded by reference to data of another site situated beyond the sphere of influence of the artificial signal. It is called remote reference

technique (RR). A third method often successfully applied to noisy data is selection, i.e. rejecting data segments that do not fulfill certain significant criteria of natural magnetotelluric signals.

There is a notable number of processing methods containing several of the mentioned techniques by some means or other. E.g., the algorithm after Egbert and Booker (Egbert and Booker [1986]) connecting robustness with the possibility to apply RR, is rather popular in the author's surrounding. Ritter et al. (Ritter et al. [1998]) propose a method including robustness, RR, and selection schemes, and Weckmann et al. (Weckmann et al. [2005]) describe a selection technique within a robust single-site processing. Larsen's code (Larsen et al. [1996]) is also robust and especially known for its time series preprocessing. It uses a remote site for a signal-noise separation solving somewhat different equations than in the classical RR. This method has been expanded by Oettinger (Oettinger et al. [2001]) by means of a second reference station. Egbert (Egbert [1997]) developed a robust code using multiple reference stations in yet another way, and Varentsov et al. (described in Ernst et al. [2001]) use several references and robust procedures, as well. In each of the enumerated works, there are cited further processing methods.

Thus, there exists a rich variety of solutions for the problems mentioned above. In such a case, of course, the question is raised up which of them is the optimal one, either in general, or at least if the data possesses certain properties. Comparisons of transfer functions obtained after different authors have been made (e.g. Müller and Haak [2004]), but there must be doubts that such approaches are able to make reliable statements about methods in general and not only for the dataset treated in the given case. The crucial point is that comparisons have to take place (except for the feature under investigation) under exactly the same circumstances. This means, if there has to be made a decision which equation for getting transfer functions is most meaningful, the entire treatment of the data before and after solving the given equation has to be the same. This is not satisfied if the full processing codes are used, since the compared algorithms perform the steps summarized by the term "procedures independent of conditional equations" each in a different way. ¹

The need for "procedures independent of conditional equations" arises from qualitative and quantitative deficiency of data. Those procedures fight something difficult to describe, and it is not obvious to estimate whether a single representative of these

¹The situation is even worse (of course, from a methodical, not from a practical point of view), if selection is applied, because the criterion for acceptance of a data segment differs with the dataset and has to be chosen by the user as the case arises (Weckmann et al. [2005], Ritter et al. [1998]).

“shortcuts through statistics” does this in a good or bad way. If magnetotelluric data was perfect, applying “procedures independent of conditional equations” were unnecessary and without any effect on the transfer functions. If the data amount was infinite (or very large), the least square treatment involved in the equations’ solution removed the effect of statistical noise without “procedures independent of conditional equations”, too. Nevertheless, a “procedure independent of conditional equations” does have an impact on transfer functions obtained from real data with limited quantity and quality. It will improve their smoothness and diminish scattering and error bars. Different “procedures independent of conditional equations” will result in transfer functions “beautified” (i.e. looking more reasonable) to different degrees. Hence, it will be impossible to conclude from smoother curves to better conditional equations, if two codes differ in equations and “procedures independent of conditional equations”, since an interference of the latter has to be taken into account.

In the framework of this thesis, the problem of comparableness has been solved by reprogramming different processing methods in a uniform way. The developed code does not include neither time series preprocessing, nor robust procedures, nor weighting or averaging over neighboring frequencies, nor smoothing. It bases solely on a least square solution of the given equations. There have been implemented the single-site solution, the Remote Reference technique, Larsen’s signal-noise separation method (Larsen et al. [1996]), and Oettinger’s extension of the latter (Oettinger et al. [2001]). The single-site processing and the general properties of the code will be described in the first chapter. There will also be given an overview over the different types of noise and the problems they may cause in such a “historic” approach.² The second chapter is dedicated to the Remote Reference technique that is able to deal with many of the features causing difficulties in the single-site method. It will be tried to explain its effectiveness in an illustrative way. In the third chapter, the signal-noise separation after Larsen et al. [1996] will be considered. It provides the possibility to estimate and examine transfer functions for the correlated noise (i.e. the electromagnetic signals emitted by artificial sources) simultaneously to the MT relevant ones. The question whether these MT transfer functions are in essential terms different from RR obtained ones belongs to the central issues of this work and will be investigated. Finally, in the forth chapter the extension of Larsen’s method will be described that has been made by Oettinger et al. [2001] via introduction of a second reference site, and it will be discussed whether Larsen’s method can be improved by it.

²cf. the approach of Swift [1967]

In addition to synthetic data, also measured ones served as test objects for the abilities of the enumerated methods. They stem from a profile through the Northwest of Poland and East Brandenburg (Germany) and from the geomagnetic observatories Belsk and Niemegek. The profile is a part of the EMTESZ Pomerania project which aims at the investigation of the conductivity structure beneath the Teisseyre-Tornquist Zone, an issue that is not addressed in this work.³ The dataset is a very good target for processing methods that promise to be able to deal with difficult data containing correlated noise to a big percentage, since the profile crosses four main lines of the Polish railway network (see fig. 1), that are run with direct current (DC) and therefore emitting especially fatal disturbing signals.

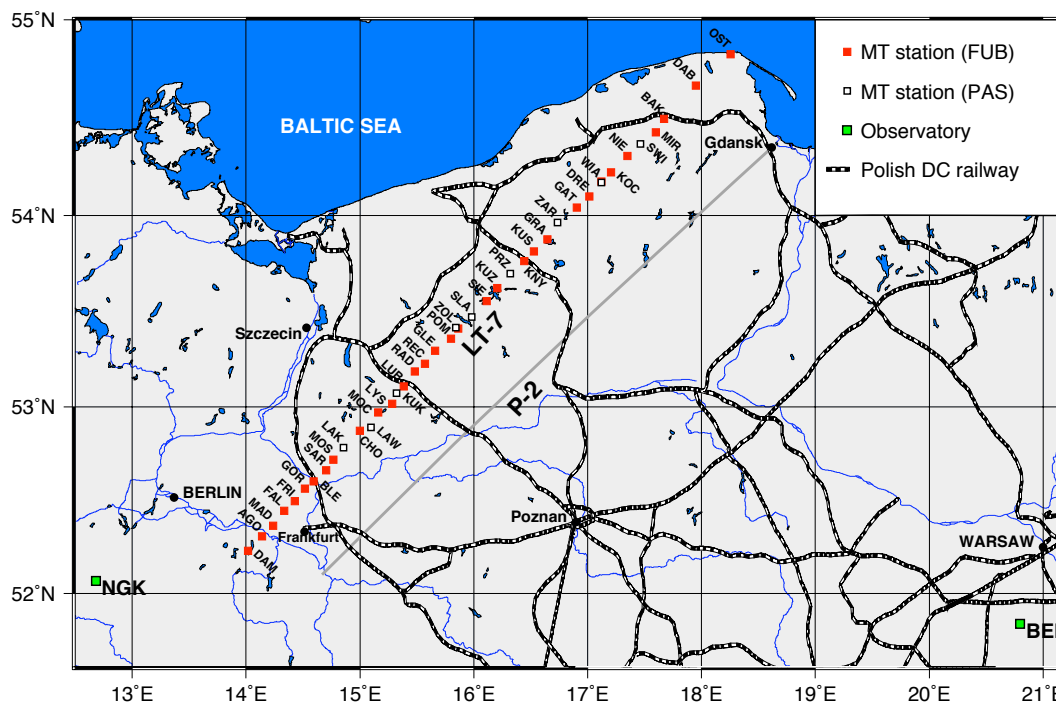


Figure 1: Magnetotelluric sites on profile LT-7 in NW Poland and NE Germany measured by the Free University of Berlin (FUB) and the Polish Academy of Sciences (PAS). The profile crosses four DC railway lines. The geomagnetic observatories Belsk (BEL) and Niemegek (NGK) play an important role as remote sites.

³but see Brasse et al. [2006]