Realistic 3D subsurface models – A new approach by integrating HEM, borehole and seismic data sets

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Introduction

Airborne electromagnetics (AEM) is a cost efficient technique for geophysical investigations of the shallow subsurface and has successfully been applied in various complex geological settings to analyze the depositional architecture. However, interpretation of AEM data integrated with geophysical and geological models is often missing.

The aim of AIDA sub-project SP5 (Model development and evaluation of results) is to provide a simple methodology for the interpretation of shallow subsurface data and the construction of more realistic geological 3D subsurface models. This will be achieved by the development of new inversion techniques, 3D modelling approaches and user oriented workflows.

The Cuxhaven tunnel valley was chosen as the first model area to demonstrate the procedures. This Elsterian tunnel valley has a complex Middle Pleistocene to Holocene fill. The database contains a dense helicopter-borne electromagnetic data set (HEM), 2D seismic reflection profiles and borehole data.

Workflow

The workflow includes (cf. Fig. 1):

A) Data preparation.

B) Construction of a geological 3D subsurface model (GOCAD®) based on borehole data and 2D seismic reflection profiles.

C) Geostatistical analysis and interpolation of resistivities based on 1D HEM inversion results to create a continuous 3D resistivity grid model.

D) Integration of the 3D resistivity grid model with the geological 3D subsurface model.

E) Testing of 3D resistivity grid model accuracy by comparison with borehole data and 2D seismic reflection profiles.

F) Adjustment of incorrectly interpolated areas of the geological 3D subsurface model by using the corresponding resistivity values.

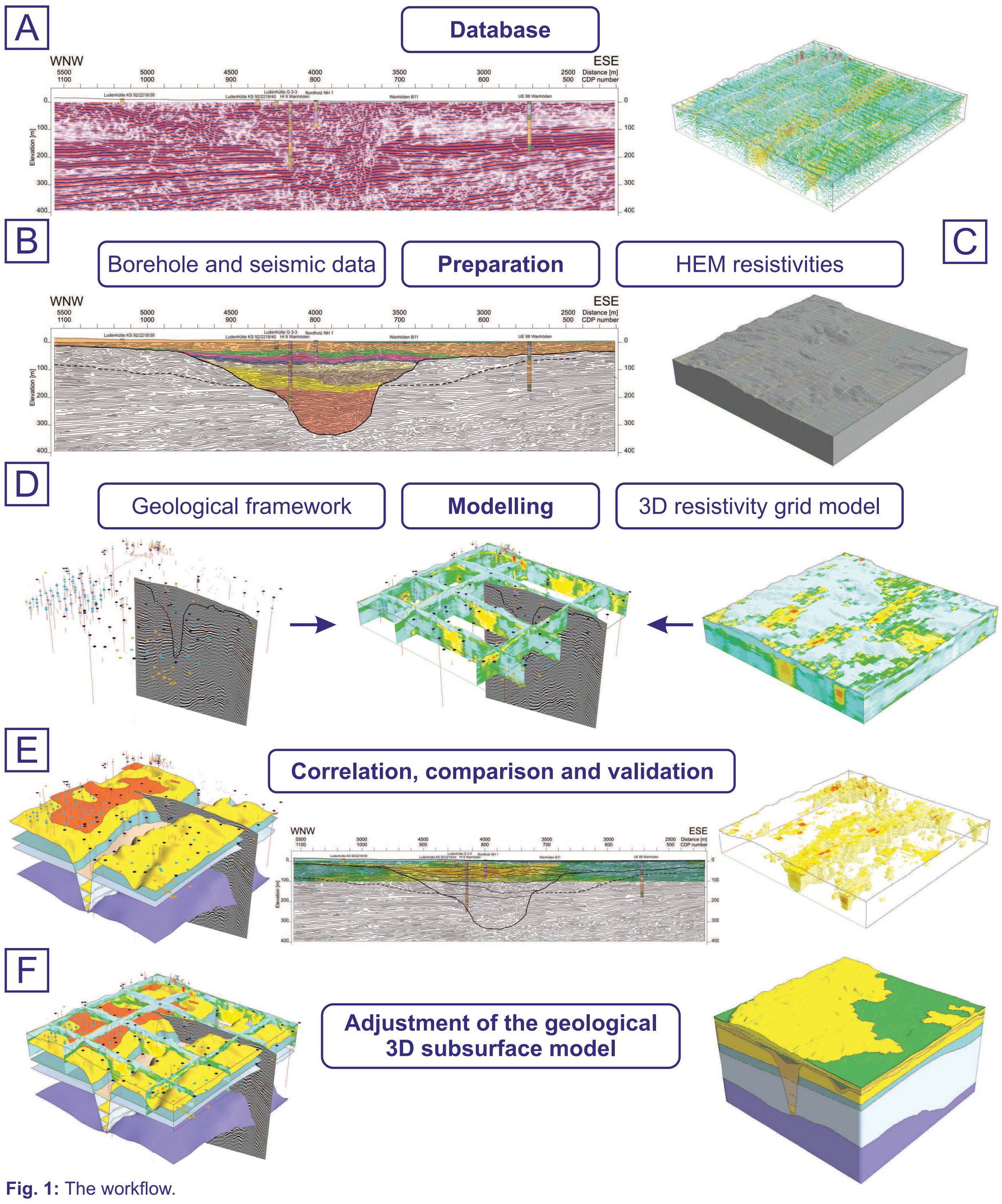

Fig. 1: The workflow.

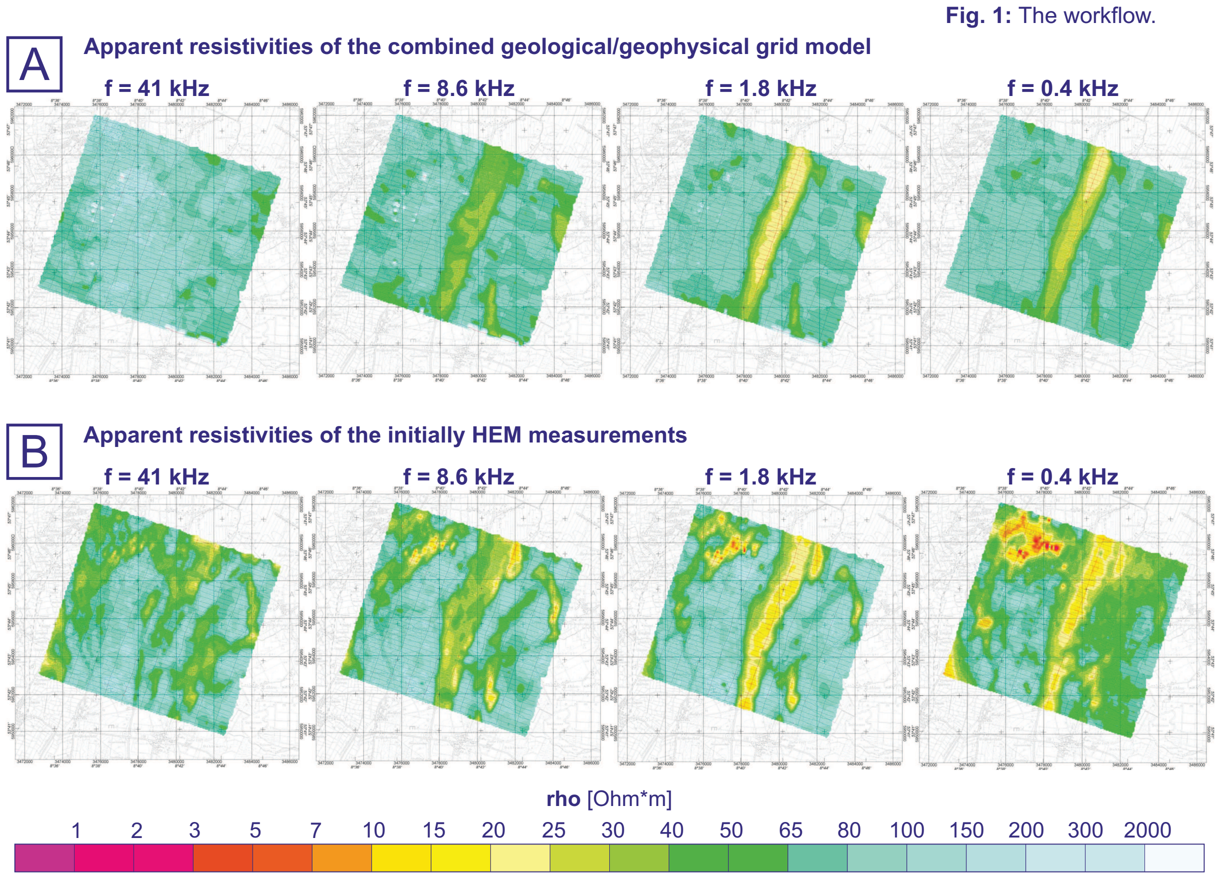

Fig. 2: Comparison between the apparent resistivities with decreasing frequencies from the shallow subsurface to the depth derived from (A) the final geological model and (B) the original 1D HEM measurements.

Verification of modelling results

The apparent resistivities derived from the final geological model (Fig. 2 A) were compared with the apparent resistivities of HEM data (Fig. 2 B) to identify the differences and uncertainties.

The comparison of the apparent resistivities generally displays a good correlation indicating a first good estimate of the depositional architecture of the shallow subsurface. The integration of HEM resistivities leads to a more realistic reconstruction of the sedimentary facies and depositional architecture with a high geometrical accuracy.

Results

The major result of the study is a high-accuracy geological 3D subsurface model with less geometrical uncertainties by integration of geophysical and geological data.

The 3D resistivity grid model based on geostatistical analyses and interpolation of 1D HEM inversion results provides a first good estimate of the depositional architecture.

However, uncertainties in the lithological interpretation of HEM data remain due to noise effects and the restricted resolution, and the heterogeneity of sediments with overlapping resistivity values.

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