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The geothermal field below the city of Berlin, Germany: Results from structurally and parametrically improved 3D Models

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Abstract

The objective of this study is to analyze the influence of geological structure and parameterization of Cenozoic sediments on the geothermal field as calculated by 3D thermohydraulic numerical simulations for the subsurface of Berlin, Germany. The results show, that a mostly continuous Rupelian aquitard effectively hampers forced convective cooling of the deep subsurface ($\geq 1km$) but for localities where the unit is discontinuous. New parameterization methods for hydraulic conductivities lead to a stronger coupling of the hydraulic boundary condition and forced convective cooling. Newly derived thermal conductivities result in a stronger thermal blanketing effect for the Post-Permian sediments than previously estimated.

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Keywords: 3D geological model; Coupled fluid and heat transport; Sensitivity analysis; Boundary conditions; Urban future; Geothermal energy

1. Introduction

Understanding the present-day thermal and hydraulic configuration below major urban centers (e.g. Berlin) situated in sedimentary basins becomes increasingly more important as renewable energy resources (e.g. geothermal energy) contribute to reducing CO_2-emissions [1]. Hence, understanding the different coupled physical processes involved and their interrelation with the respective parameters is essential even with respect to possible future model scenarios (e.g. anthropogenic forcing). The major contributors to the thermal field are diffusion of heat by conduction and convective heat transport driven by circulating groundwater. The latter can include topography-driven flow, overpressure flow, or flow induced by buoyant forces within the fluid. Each of these processes and their respective effect on the present-day geothermal field is mainly controlled by the local hydrogeological setting which is represented in new detail in this study.

Despite a relatively flat topography (Fig. 1a) and no recent tectonic activity in the Northeast German Basin, latest 3D numerical investigations of coupled fluid and heat transport indicate a regional hydrothermal regime which

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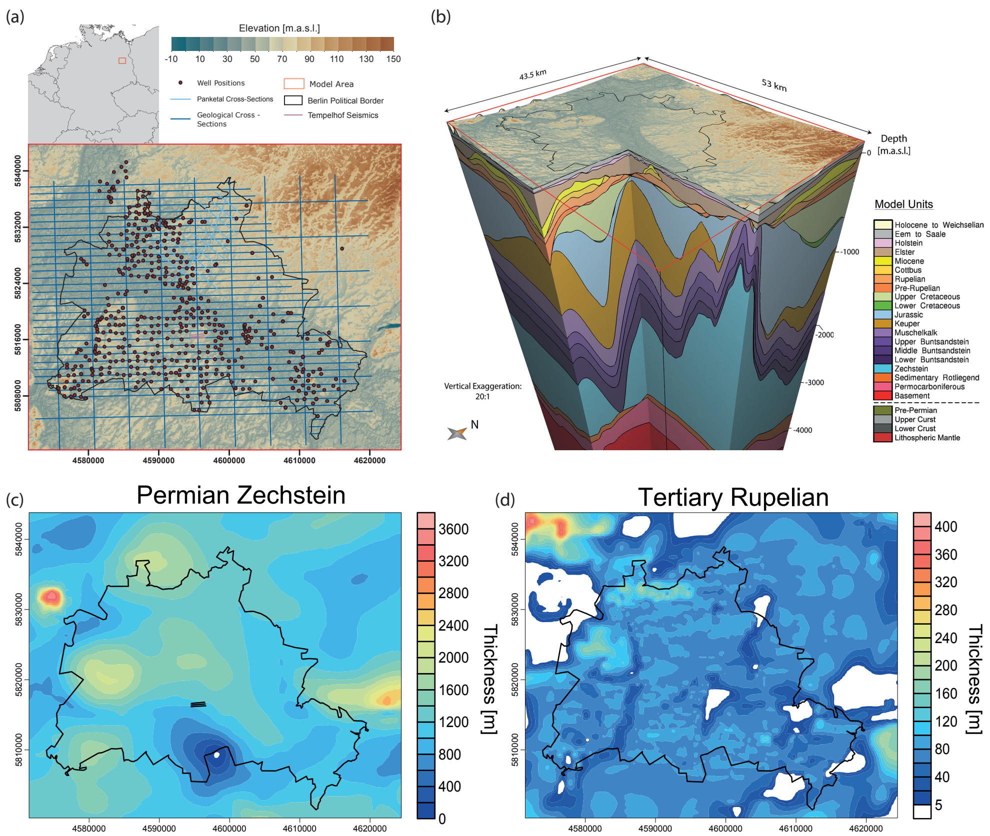

Fig. 1. Database and new structural model of the subsurface of Berlin, Coordinates are in Gauß-Krüger DHDN Zone 4. Black line indicates political border of Berlin. (a) Location of the model area in central Europe and database (b) 3D structural model as used for all thermal simulations. Depicted on top is the elevation distribution of the uppermost layer (see a). Model units and vertical extent of models for the different modeling methods as indicated in Section 3. (c) Thickness distribution of the Permian Zechstein salt unit. Black lines in the center indicate the location of the Tempelhof seismics, (d) Thickness distribution of the Oligocene Rupelian clay. (c,d) White areas represent discontinuities. Database provided by Senate Department for Urban Development and the Environment of Berlin (SenStadtUm) and Berlin waterworks (BWB).

is largely influenced by conductive heat transport additionally overprinted by a regional component of pressure (topographically) driven groundwater flow extending to variable depths [2,3]. Predicted temperatures reproduce the available measured borehole temperature measurements only to a certain degree showing a local and systematic misfit. This misfit is predominantly evident at shallower depth levels (< 3km), where modeled temperatures are generally colder than measured values. Two different causes for the observed discrepancies have been suggested [2]: (1) a lack of accuracy in representing the surface thermal and hydraulic boundary conditions, (2) insufficiently detailed representation and diversification of the shallow Tertiary and Quaternary aquifer complexes.

This study is part of ongoing activities aiming at investigating and quantifying the relative impact of the aforementioned parameters on the present-day thermal configuration of the subsurface of Berlin, capital city of Germany. The objective of the three models run (M1-3), is to analyze the influence of the geological structure and the model unit parameterization on the geothermal field. Since model units physical parameters like thermal or hydraulic conductivities are rarely well constrained by measured data, we opt in a new method, where we parameterized youngest model units in accordance with their lithological and/or grain size distributions (see Section 3). We followed a two-step approach where (1) a new structural model has been built according to newly available data, (2) Numerical thermal and hydraulic simulations have been carried out based on (1) (see Sections 2 and 4).