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High resolution tectonic temperature models for EGS and direct heat in sedimentary basins: a case study of the Netherlands

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Sedimentary Basin temperature models are very important for the modeling of the maturity of oil and gas and for forecasting the performance of geothermal energy systems. In the past decades much progress has been made in assessing and numerical modeling of the temperatures in basins. State of the art basin modeling techniques for hydrocarbon maturation for oil and gas exploration incorporate conductive and advective heat transport to predict temperatures in the sedimentary cover at various geological stages of the evolution. In this paper we define basin modelling, following conventions in E&P industry to be focussed on modelling of hydrocarbon maturation, migration and trapping in the sedimentary cover, and tectonic modeling to be focused on thermo-mechanical aspects of lithosphere deformation, driving basin (de)formationThe models are constrained by surface temperature and basal heat flow, which may vary over time. In most circumstances models behave fully conductive, although occasionally heat advection related to fluid flow can occur as a consequence of rapid compaction and temperature anomalies. The basin models are calibrated to temperature and maturity measurements in wells.
In geothermal exploration focus is towards assessing present day temperatures, instead of temperature predictions over geological timescales. Numerical models tend to focus on geo-statistical interpolation of temperature and temperature gradients measured from wellsand compilation of thermal gradients and heat flows in maps .Temperature interpolation in such models generally lack a physical underpinning, which can result in erroneous temperature predictions, as geostatistical interpolation results can differ significantly from model based approaches.

In this paper we will present a 3D modeling approach which overcomes this interpolation problem. We link the boundary conditions of this model, in terms of basement heat flow conditions, to a quantitative approach for lithosphere processes and thermal properties of the crust and subcrustal mantle underlying the sedimentary basins. This is particularly important for assessing temperatures at depth levels below sedimentary basins, which are relevant to industrial heat and electricity production for Enhanced Geothermal Systems. In the thermal model approach we incorporate non steady state effects on the lithosphere temperatures over geological timescales affecting temporal and spatial variation in subsurface temperatures. These effects include, among others a) surface temperature variations, in particular the effect of glaciation, b) sedimentary sedimentation and c) lithosphere deformation processes.

The impact of erroneous temperature interpretation can be very significant in geothermal exploration. For direct use applications, including spatial and greenhouse heating, one degree difference in production temperature results in a change in performance of up to 3%. The added value of the improved modeling of temperatures is illustrated by an application in the Netherlands.