As part of my first year of PhD, I have first undertaken an extensive literature review on different aspects of the research : 1) approaches for modeling groundwater flow and heat transfers in coal mines, 2) heat extraction from borehole heat exchangers, 3) solar fluxes, 4) climate disturbances on geothermal gradient, 4) radiogenic heat production in sedimentary areas, together with an extensive review on the geology of Scotland / geological structure of the Midlothian Coalfield.

During my placement at the Coal Authority, I had the opportunity to look at all the available data to get familiar with them, their methods of acquisition, their limitations, and how they could contribute to my research. Temperature/Flow rate data, mine plans and GIS data have been collected and made available through an Academic license. I moreover gathered climate data from the Meteorological Offfice website, as well as newly released geothermal data from the Glasgow UKGEOS Observatory.

The three main research questions of my PhD are the following:

- What are the main heat sources and heat transfer mechanisms in abandoned flooded coal mines in the UK?

- What is the footprint of past mining activities on the heat distribution in coal mines ?

- What are the key mine features influencing the heat exchange rates in mines?

Together with an analysis of the mine-water temperatures available throughout the UK, numerical modeling will allow solving for advective-dispersive heat transfers in coal mines. The first step was to decompose the overall processes occurring in complex mine systems into smaller/simpler problems. I have created a conceptual model of mine workings (RQ1) to identify the different materials, the potential heat/water recharge areas, and their evolution through time. To verify the ability of the finite-element numerical modeling software OGS to deal with heat transfer processes, we started to benchmark the diffusive-advective heat transport within a horizontal porous layer. From their, I have undertaken a sensitivity analysis on the effect of material thermal/hydraulic properties on the rate of heat transfer between a porous coal layer embedded in an undisturbed host rock, for different boundary conditions. In parallel, I have evaluated the amount of surface heat flux required to reproduce change in surface temperature in Scotland, without imposing a constant temperature boundary in numerical models. This has been done for the purpose of submitting a first paper on the sustainability of heat extraction from borehole heat exchanger. This paper will focus on heat extraction from shallow depth, aiming at calculating the footprint area required to provided the required energy to a single-house in the UK, and showing the necessity to bring artificial recharge to the ground in order to maintain sustainable production. Calculating the surface heat flux appeared to be closely related to the current state of the geothermal gradient. I have therefore created a python script allowing to simply calculate the surface and bottom heat fluxes along an unsteady-state temperature gradient in heterogeneous ground, based on the output from OGS.

As part of the RQ2, I started to create 2D simple models of mines composed of 3 worked coal seams, for which I have simulated a long-term water extraction (i.e. mining period), followed by recovery of water originating from different sources (i.e. 50 years). This preliminary analysis showed that perturbations of the geothermal gradient in mines might be permanent.

As part of RQ3, I I looked at the overall change in energy content within simple 2D models with similar properties and boundary conditions, based on the geometry of the worked coal beds. Results indicated that the spacing between coal beds might influence on the overall heat capacity of a mine. In addition, I have processes available GIS shapefile for futur utilization as input to the meshing software GMSH.