Dispersion and Heat Conduction in a Simplified Geothermal Doublet

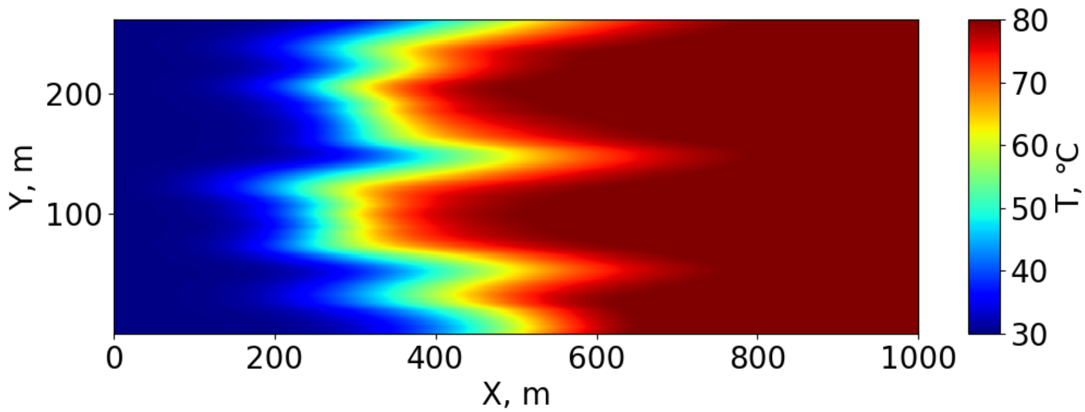

Figure 1: Temperature distribution of a geothermal reservoir after 15 years

AESB3400 Bachelor Thesis

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July 6, 2021

1 Summary

The goal of this study is to test out the accuracy of the upscaling approach (Jinyu Tang, 2021) for a geothermal doublet. This approach tries to simulate the physical thermal dispersion. When modeling in a geothermal reservoir it would be easy if a lot of layers can be upscaled. However, when doing upscaling one can not just take an average of the layer properties. This results in a very inaccurate representation of reality. That is where the upscaling comes in. First, some other points need to be considered. The reservoir is simulated in DARTS (Wang, Voskov, Khait, & Bruhn, 2020). This simulator uses numerical methods to model the reservoir. Before starting on modeling geothermal reservoirs first a 1D case is evaluated to check for numerical dispersion that comes into play. With that evaluation done the 2D cases were simulated. The full reservoir has 91 layers, these can be upscaled into 9 layers eventually. To start building up to that scenario first 2 other scenarios are evaluated. First, an upscaled section of the first block of upscaled layers is evaluated. This was originally 10 layers and now upscaled to one layer. This one layer was first simulated in a fine grid simulation and then a single grid simulation. These results are compared to a simulation of the original layer properties and a simulation of an arithmetic average of the reservoir properties. This is also done on a second scenario with 2 upscaled groups and eventually the full 9 layer reservoir (originally 91 layers). With these scenarios evaluated the upscaling shows to give a better simulation of the reservoir compared to using an average for the layer properties. This is all compared with a simulation of the original layer properties.

To give a visualization the figures below show the fine grid simulations of the second scenario. The figures show a 2D plot of the temperature distribution in the reservoir after 15 years. The reservoir is modeled to have a breakthrough of the cold front at the production well after 30 years, 15 years is roughly halfway in. Figure 2 shows a simulation of the original reservoir properties. Figure 3 is the fine grid simulation of the upscaled reservoir and figure 4 is a fine grid simulation with average layer properties. What is visible is that the upscaled reservoir has a better and more realistic spreading of the cold front when compared to the average simulation. What is also visible is that the upscaled reservoir has its issues as well when compared to the original reservoir simulation. All these results are further discussed in this thesis.

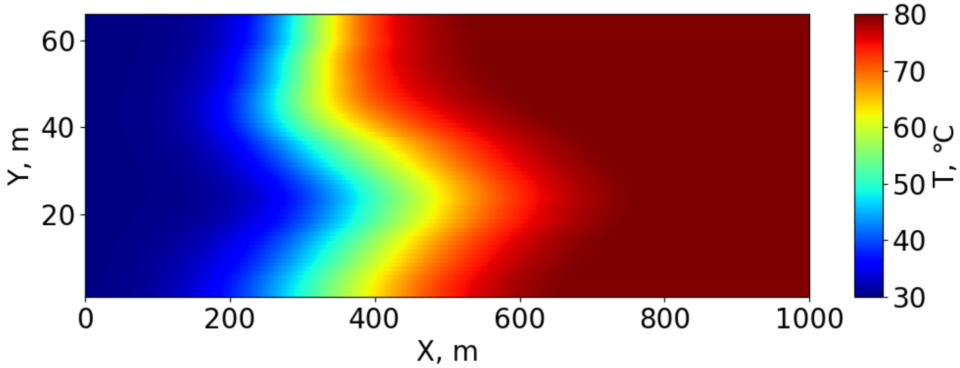


Figure 2: Case 6

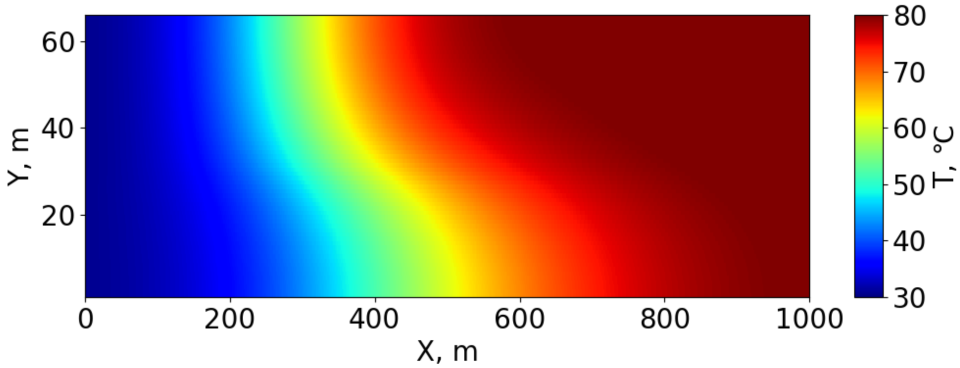


Figure 3: Case 7

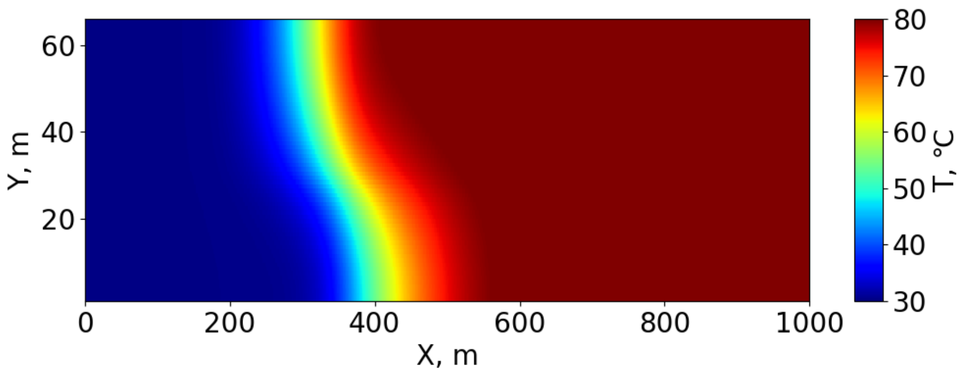


Figure 4: Case 9

2 Introduction

In geothermal wells, the cooling of a production well is critical, when a reservoir cools down and the temperature of the production well drops with a tiny fraction that immediately implies a lower energy delivery of the geothermal well. Therefore it is very important in modeling to have good predictions of the breakthrough of a cold front of a geothermal reservoir.

It can be convenient to model a geothermal reservoir using numerical methods. However a reservoir, depending on the geologic setting, can be highly heterogeneous. This results in a lot of different layers with different properties which are not convenient when modeling. Therefore it would be convenient to be able to upscale the layers to more uniform blocks that can be easily modeled. Also, the cooling of a reservoir will lead to more convection and a more spread out front with a higher diffusivity.

To be able to correctly model a reservoir a model was developed to see the effect of the spreading of temperature in a reservoir resulting from the heterogeneity and heat conduction between layers (Jinyu Tang, 2021). The reservoir in this case is a reservoir with 91 layers with a total thickness of 261 meters. This reservoir has been upscaled to 9 layers, as said before it's important to look at what this means for the temperature at the production well after several years. This case will not directly be evaluated but before doing that several other things are checked as well.

If one is looking for dispersion and heat conduction in a reservoir using numerical methods it is important to account for numerical dispersion. When numerical dispersion occurs the simulation has a higher diffusivity than the real-life situation. This can be a problem for modeling in geothermal reservoirs and therefore to start with there will be several 1D cases where the numerical dispersion is evaluated.

With that done there will be several 2D cases where the upscaled model of the reservoir will be compared to the original properties of the reservoir and an arithmetic average of the reservoir properties. In addition, a different number of grid blocks in the z-direction will give a good overview of the accuracy of the upscaling approach. The DARTS simulator is an appropriate tool to address these issues therefore the reservoir will be simulated using DARTS (Wang et al., 2020). The reservoir properties for this reservoir came to form a well log for a geothermal project (Bredesen, Dalgaard, Mathiesen, Rasmussen, & Balling, 2020).

3 Methods

The main goal is to get a feeling of what is possible with the upscaling of reservoirs and what the spreading of a cold front in a reservoir does when that happens. In a working geothermal reservoir the immediate question that rises is for how long is this going to work, and how long it takes before the temperature of the water at the production well drops to a level that is too cold for energy supply. An accurate simulation of a reservoir is therefore important.

The way the problem is modeled is using DARTS Geothermal Simulator (Wang et al., 2020). To be more precise the Geothermal 2D package is used. With this simulator, a simple 2D reservoir can be modeled and Temperature distribution along the reservoir and at wells are monitored. In this way, the outcomes can be used for the evaluation of the results. The reservoir has one production and one injection well. The reservoir itself is modeled as 1000 meters long in the x-direction, 1 meter wide in the y-direction, and in the z-direction, the thickness depends on the simulation.

The simulator doesn't allow for anisotropic thermal diffusivities, which will become more important on a larger scale. The numerical method the simulator uses is an Implicit Backward Difference scheme, this can later be used for calculations of the truncation errors.

3.1 1D cases

To get an idea of the numerical dispersion that comes into play when using numerical methods to solve for the spreading of the cold front in a geothermal doublet several 1D cases are evaluated.

To start 1D cases with the heat conduction of the rock and water turned on and off will be evaluated. The simulations are run with a set of different lengths of grid blocks to get an idea of the numerical dispersion that comes into play. Those cases can be evaluated to get a good number of grid blocks where the numerical diffusion is not significant to be used in the 2D simulations. In the 2D simulations, the number of grid blocks can also maybe more reduced since the diffusion of heat can become greater.

For modeling the 1D cases the reservoir is taken as a 1m thick reservoir with homogeneous properties along all axes. The aim is to have a breakthrough of the cold front after 30 years. With these parameters in place, the superficial velocity of the reservoir can be determined, and depending on the other parameters the injection rate can be set. A breakthrough of a cold front is defined as a temperature drop of 10% at the production well.

The parameters of the 1D simulations are as follows:

	Q, m3/D	hm	Φ	K m2	k$_x$ KJ/(D.m.K)	k$_z$ KJ/(D.m.K)	ρC_p KJ/(m3.k)
With Conduction	3.4483E-02	1	0.19	8E-14	235.84	235.84	1816.83
Without Conduction	3.4483E-02	1	0.19	8E-14	0	0	1816.83

Table 1: Input variables for 1D numerical dispersion evaluation

3.2 2D cases

With having an idea of the numerical dispersion a good length of grid blocks can be set to be used in 2D simulations. To evaluate the effectiveness of the upscaling methods and the spreading of the cold front different cases with different properties are compared. The 2D simulations are evaluated in 3 scenarios, each divided into 5 cases. All scenario properties are derived from a wireline logging that was done for a potential geothermal reservoir (Bredesen et al., 2020). All the different layers from the original properties can differ in thickness but are all by 1-meter increments.

Each scenario builds on the previous, starting with scenario 1 where it's simple. There are 10 different layers for a total reservoir thickness of 35 meters. Those layers can be upscaled into 1 group. The first case however is a simulation of the original reservoir with different properties for different layers. Continuing onto the second case the upscaling is done and all different layers in the first case now have the same properties. Still, this is a fine grid simulation where every block is still 1 meter thick. Case 3 is a one-grid simulation with 1 thicker grid block in the z-direction for the upscaled group. This is done to see if it's possible to use only one grid block for an upscaled group. The fourth and fifth simulations are done by using an arithmetic average for the layers. Again case 4 is a fine grid simulation with individual layers and case 5 is one thicker layer. All these cases can then be compared to each other. The main things to look at are the diffusion of the cold front and most important the temperature at the production well.

Continuing onto scenario 2 where another 10 layers are added below the ones from scenario 1, resulting in a 20 layer reservoir with a thickness of 66 meters. These layers can be upscaled into 2 groups. But again to give a baseline, first case 6 is a simulation with the original layer properties. Case 7 is a fine grid simulation with 2 upscaled groups and case 8 is again a case where the 2 upscaled groups use one grid block each. Again this is compared to using an average for the properties in cases 9 and 10. Case 9 is a fine grid simulation and 10 uses 1 grid block per group.

Scenario 3 is the total reservoir of 261 meters thick. 91 layers in total can be upscaled to 9 layers. Case 11 is again the original properties of the reservoir with 91 layers. Case 12 is a fine grid simulation of the 9 upscaled layers and case 13 uses 1 grid block per upscaled group. Case 14 and 15 are again cases using the averages per upscaled group. Where 14 is a fine grid simulation and case 15 uses 1 grid block.

An overview of all the simulations is given in table 2. All these simulations are done to check the model from (Jinyu Tang, 2021) for the spreading of a cold front due to the heterogeneity of a reservoir and the heat conduction in a reservoir. The different cases are there to compare what happens with averaging and using fewer grid blocks. All the outcomes of these simulations are discussed in the results chapter.

Case	layers	properties	simulation	total thickness
1	10	original	fine grid	35
2	10	upscaled	fine grid	35
3	10	upscaled	1 grid	35
4	10	average	fine grid	35
5	10	average	1 grid	35
6	20	original	fine grid	66
7	20	upscaled	fine grid	66
8	20	upscaled	1 grid	66
9	20	average	fine grid	66
10	20	average	1 grid	66
11	91	original	fine grid	261
12	91	upscaled	fine grid	261
13	91	upscaled	1 grid	261
14	91	average	fine grid	261
15	91	average	1 grid	261

Table 2: Summary of layer properties in 2D cases

4 Results

4.1 1D results

Before modeling the 1D case we need some baseline to compare the results to verify everything went right and the results are realistic. For that, the formula for the advance of the thermal front in a geothermal reservoir, neglecting heat conduction and interaction with overburden and underburden from the AESB2320 (PTP) course is used as stated below.

$$\frac{\Delta x}{\Delta t} = \frac{Q}{HW} \frac{\rho_f C_{pf}}{\Phi \rho_f C_{pf} + (1 - \Phi)\rho_g C_{pg}} \quad (1)$$

The properties for the 1D simulation are filled in the formula and with a heat capacity of water of $4181 Jkg^{-1}K^{-1}$ and a density of $1000 kg/m^3$. The properties for rock are stated in table 1.

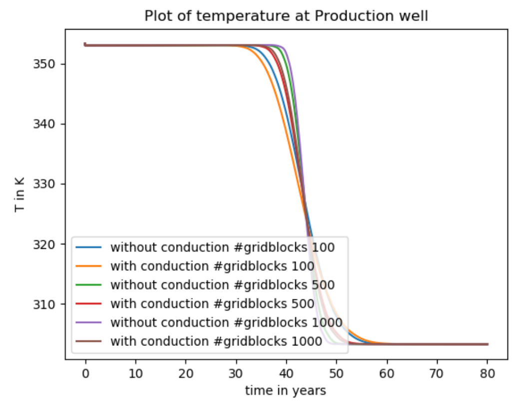
With this, we get a velocity of the cold front ($\Delta x/\Delta t$) with filling a time of 30 and 40 years the cold front is at 696 and 929 meters respectively. Looking at 1000 meters the front will take 43 years to break through. This will come more important later as we define a breakthrough of a cold front to be as a 10% loss in temperature of the production well. However, this formula considers the middle of a cold front in a very simplified geothermal doublet, in this way the cold front can seem to be not there yet while in the criteria set it can already be set, this will be discussed later in the results.

The 1D cases are modeled with and without conduction. With help of the formula for diffusivity from the curve for unsteady conduction between semi-infinite slabs in contact to get diffusivity α in m^2/day (AESB2320). With this and the truncation error calculated from (Lantz, 1971) the 1D cases are evaluated. Darts simulator uses time in days and length is in meter. The simulations evaluated together with the results for the 1D simulations are shown in the table 3. Note that in table 3, the α with are the calculated diffusivity constants with the conduction of rock and water. α without are the diffusivity constants without the conduction of water and rock.

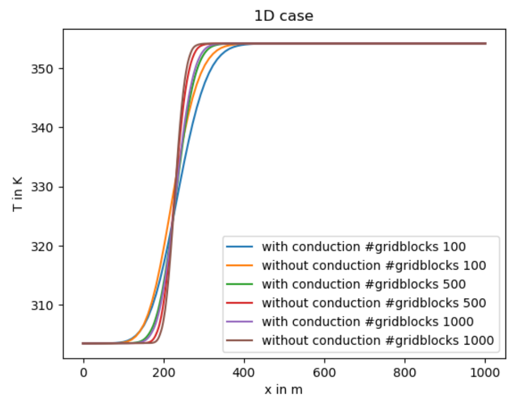
Case	No. grid_x	dx	dt	α without	α with	difference	Truncation error
1	10	100	10	0.5872	0.5872	0.0000	0.0513
2	50	20	10	0.1238	0.1783	0.0545	0.0113
3	100	10	10	0.0594	0.0776	0.0182	0.00636
4	500	2	10	0.0172	0.0323	0.0150	0.00236
5	1000	1	10	0.0100	0.0263	0.0163	0.00186
6	2000	0.5	10	0.0069	0.0241	0.0172	0.00161
7	5000	0.2	10	0.0052	0.0226	0.0174	0.00146
8	10000	0.1	10	0.0046	0.0046	0.0000	0.00141
9	100000	0.01	10	0.0041	0.0041	0.0000	0.00137

Table 3: 1D cases evaluation

With all the 1D scenarios evaluated the number of grid blocks in the x-direction is set at 1000. This gives low significance for numerical dispersion keeping in mind not to use too small grid blocks due to the run times of the software. Also when starting on 2D cases the physical dispersion can be bigger making the numerical dispersion less significant. To further illustrate the numerical dispersion the temperature along the reservoir is plotted together with the temperature at the production well against time. One would expect that when the conduction of rock and water is turned off that the plot would have a vertical transition between cold and warm. This however is not the case as shown in figure 6b. Figure 5b shows the numerical dispersion reducing as the number of grid blocks goes up. Also, the breakthrough time of the cold front for 1000 grid blocks for these simulations lay at 43.6 years for a 50% drop in temperature and at 41.1 years for a 10% drop in temperature. This complies with the previous calculation for a simplified geothermal doublet.

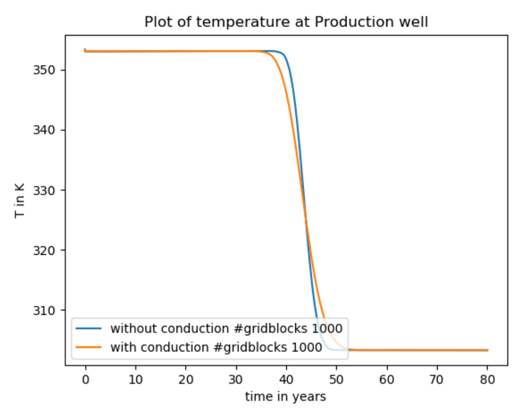


(a) Temperature at production well

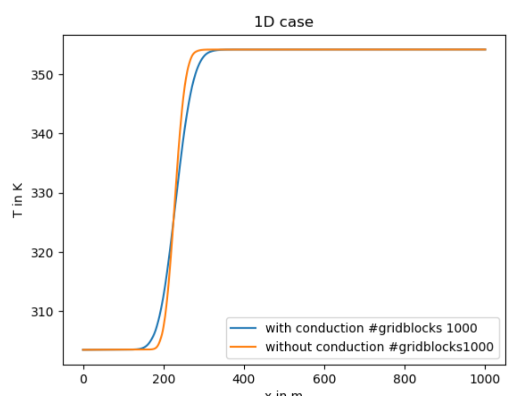


(b) Average temperature against x in reservoir

Figure 5: 1D simulations cases 100, 500 and 1000 grid blocks



(a) Temperature at production well



(b) Average temperature against x in reservoir

Figure 6: 1000 grid blocks

4.2 2D results

As explained before the 2D cases are divided into 3 scenarios each scenario will be discussed here. The scenarios are evaluated with 1000 grid blocks in the x-direction. This comes from the analysis for 1D simulations. The amount and thickness of the blocks in the z-direction depends on the simulation

4.2.1 Scenario 1

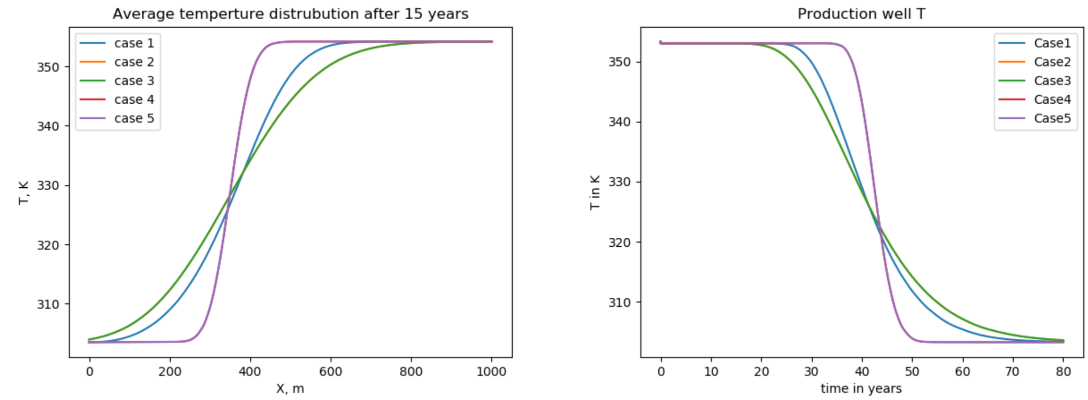
In scenario 1 10 layers were lumped together. Again case 1 is the original reservoir properties in place. Case 2 and 3 are the upscaled reservoirs with case 2 being a fine grid simulation and case 3 using one grid block in the z-direction for the simulation. Cases 4 and 5 are simulations done using an arithmetic average for the thermal properties, also case 4 is a fine grid simulation and 5, just as 3, uses 1 grid block for the upscaled group.

The results for the simulations are given in figure 7. What should be noted here is that cases 2 and 4 are not visible in figure 7. These lay below 3 and 5 respectively. These were the cases with a fine grid simulation and using 1 grid. In this case that does not matter since the layers are upscaled into a single property for all layers. Also in table 4 the different calculated properties are given. α (in m^2/day) is here again calculated the same as in the 1D simulations. Also, the breakthrough time is calculated by looking at the temperature in the production well. A breakthrough is again defined as a 10% loss in temperature at the production well. Due to the bigger diffusion of the cold front in these simulations, the front will break through faster. As shown in the table case 1 has a breakthrough of 31 years. However, this cold front is way more spread out (as can be seen in figure 8). Therefore the middle of the cold front is still behind, when looking at a 50% drop at the production well a breakthrough of 40 years is still seen. Still, all the values from the simulation are as expected from equation 1 and there are no weird outliers.

More important is looking at the upscaling and how the dispersion is simulated in this way. An important note to start with is that the values in the tables are from the averages in the reservoir. For cases 2 till 5 this does not make any difference since all the rock properties are the same but for case 1 the temperatures can differ along the z-direction. For the first scenario, the upscaled reservoir has a higher thermal diffusion constant than the original. This means a bigger spreading of the cold front. However, with using an arithmetic average the diffusion constant becomes way smaller. What also stands out is that the upscaled reservoir has an earlier breakthrough time in this case. Still, it is only 10% compared to the original case (1) which is not small and insignificant but way better than using an average which gives around 24% difference in breakthrough time.

case	α	breakthrough time	difference	percentage
1	2.949	31.205	0.000	0.000
2	5.101	27.822	-3.384	-10.843
3	5.118	27.849	-3.356	-10.755
4	0.335	38.712	7.507	24.056
5	0.335	38.740	7.534	24.144

Table 4: Scenario 1



(a) Average temperature against x in reservoir (b) Temperature against time of production well

Figure 7: Scenario 1

Below are the 2D interpolated plots of the temperature in the reservoir at 15 years in. These are cases 1,2 and 4. Cases 3 and 5 give the same results as 2 and 4 but do not have a color plot since it is only in 1D and the color plot cant be generated. There is however a graph of the temperature against the x-axis of the reservoir in the appendix.

The reason for showing these figures here is that it gives a good example of the spreading in the cold front. Figure 8 is the original 10 layers in place with all individual properties. Figure 9 gives the upscaled reservoir. It is visible here that the reservoir is a bit overestimated here since the cold front is more spread-out as in the first case. However, when looking at figure 10 the reservoir is way less spread out and this gives an underestimation of the reservoir. This also has been seen in table 4 where the diffusivity constant (α) is roughly 10 times smaller for the average reservoir compared to the original properties and α for the upscaled reservoir is less than 2x as big.

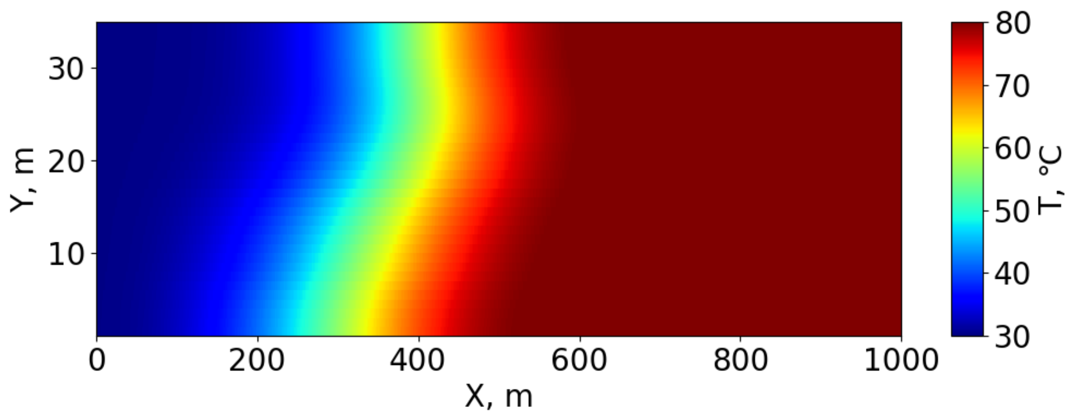


Figure 8: Case 1

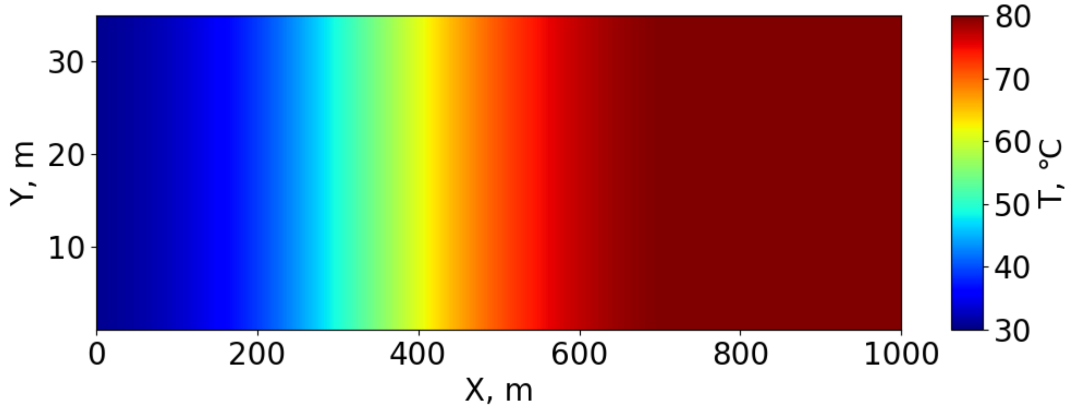


Figure 9: Case 2

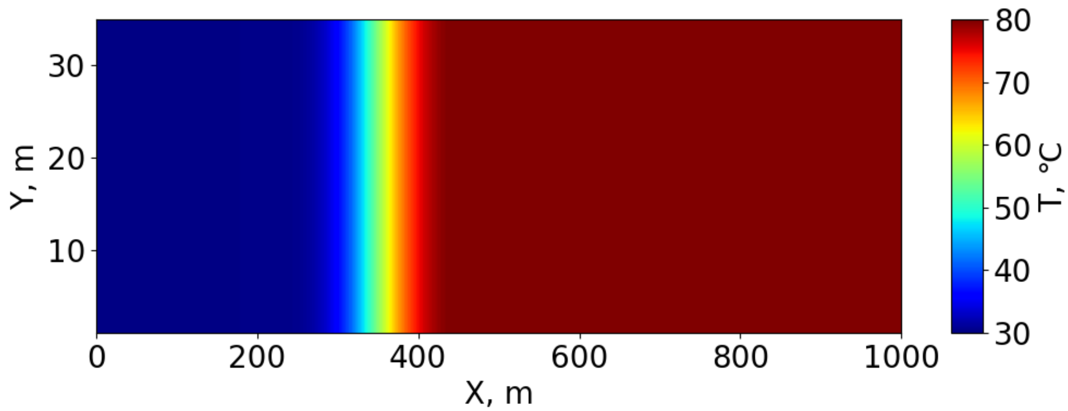


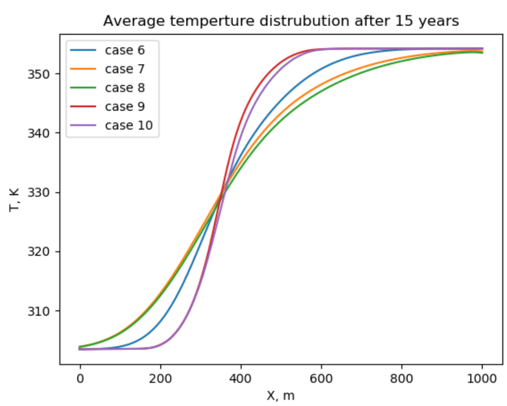
Figure 10: Case 4

4.2.2 Scenario 2

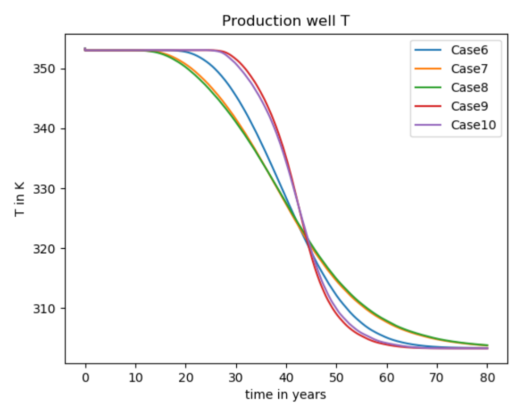
For the second scenario the original properties are upscaled to 2 layers. As said before all the values in the table are now averages for the whole reservoir. With these properties in place, the upscaled version has a 14% faster breakthrough than the original properties, the 1 grid block simulation also is a bit more off. The average is pretty close in this simulation. Again as in scenario 1, the upscaled reservoir overshoots the original scenario a bit and the average reservoir undershoots a bit. However, the average is also close in this case. Again figure 11a shows an average temperature along the reservoir. In this case it is true for all the graphs since all simulations have different properties along the z-direction. The upscaling in this case is a bit more off due to the bigger spreading of the cold front. The average simulation almost does as good of a job as the upscaled simulation. These results can be seen in the figures in figure 11 and in the values for a breakthrough in table 5

case	α	breakthrough time	difference	percentage
6	1.652	27.740	0.000	0.000
7	3.027	23.603	-4.137	-14.914
8	3.391	22.836	-4.904	-17.679
9	0.499	33.425	5.685	20.494
10	0.605	32.521	4.781	17.235

Table 5: Scenario 2



(a) Average temperature against x in reservoir



(b) Temperature against time of production well

Figure 11: Scenario 2

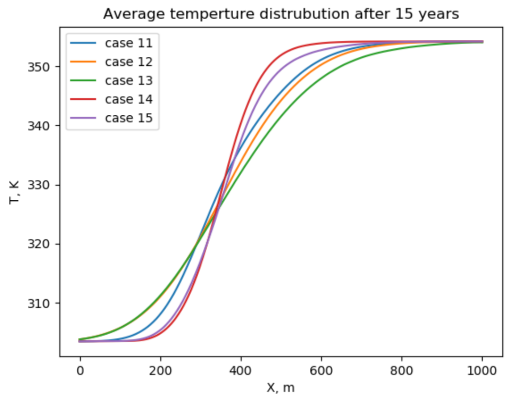
4.2.3 Scenario 3

Lastly, the final simulation is the simulation with the total reservoir, it was possible to upscale this to 9 different layers. Here as well the upscaled version does better than an average, however in this case the upscaled is better than before. The average simulation is more off in the full reservoir. Also, the 1 grid simulation in the previous scenarios was pretty close to the fine grid simulation. While in this scenario the 1 grid simulation is more off. Also in the graphs of figure 12a is again an average temperature over the reservoir. Since this is a 261-meter thick reservoir the average temperature says less over the situation. However, this is always good for checking the simulation. The breakthrough of the reservoir is set on 30 years, figure 12b is the temperature at the production well till 80 years, one would expect that all heat is out after those years which is indeed the case. Also figure 12a shows the temperature in the reservoir after 15 years, the integral below all curves also should give the same values which is indeed the case. When simulating some parameters in DARTS were set wrong, this resulted in graphs where some heat was 'missing' and the curves did not all gave the same integral. This problem was spotted by examining those graphs and the mistake was fixed.

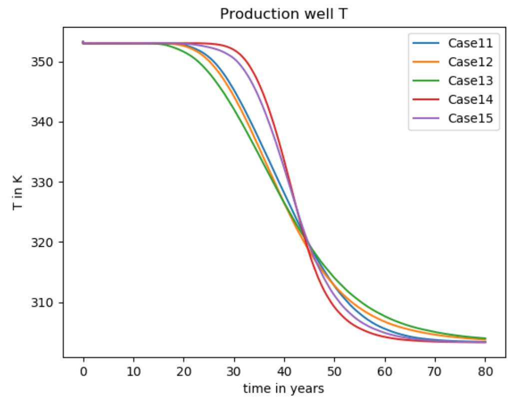
Overall what stands out is that the upscaled reservoir overshoots the thermal diffusivity and the average undershoots it. However, the upscaled is way closer in simulating the reservoir. Interesting is that the 1 grid simulation is more off in here. This is also seen in figure 15. This is the 1 grid block simulation of the 9 layers total reservoir. This figure also shows the difference in thickness of the different upscaled layers well. But what is especially interesting is that the layer that was already more spread out in the fine grid simulation (figure 14) now becomes even more spread out. This results in lower accuracy of the upscaling with only using 1 grid block per upscaled group. Next to these figures, figure 12 shows the accuracy of the upscaling even better. The graphs for cases 11 and 12 (original and fine grid simulations) almost coincide with each other. Both in the temperature log of the production well (12b) and the average temperature of the reservoir at 15 years (12a). The inaccuracy between the fine grid and 1 grid simulation probably comes from the conduction between layers in the z-direction, in the fine grid simulation all the layers are very thin and can therefore interact with each other more. In the simulation with 1 grid block per upscaled group, the layers are thicker and there is less conduction between the layers resulting in an overshoot in certain layers. This results in a bigger overshoot in breakthrough time.

case	α	breakthrough time	difference	percentage
11	1.594	27.822	0.000	0.000
12	2.259	27.027	-0.795	-2.856
13	2.847	25.027	-2.795	-10.044
14	0.588	33.890	6.068	21.812
15	0.841	32.384	4.562	16.396

Table 6: Scenario 3



(a) Average temperature against x in reservoir



(b) Temperature against time of production well

Figure 12: Scenario 3

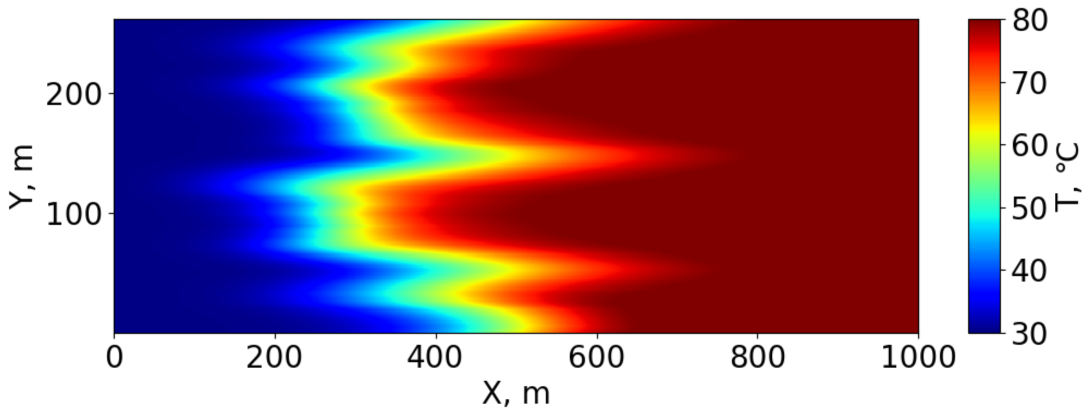


Figure 13: Case 11

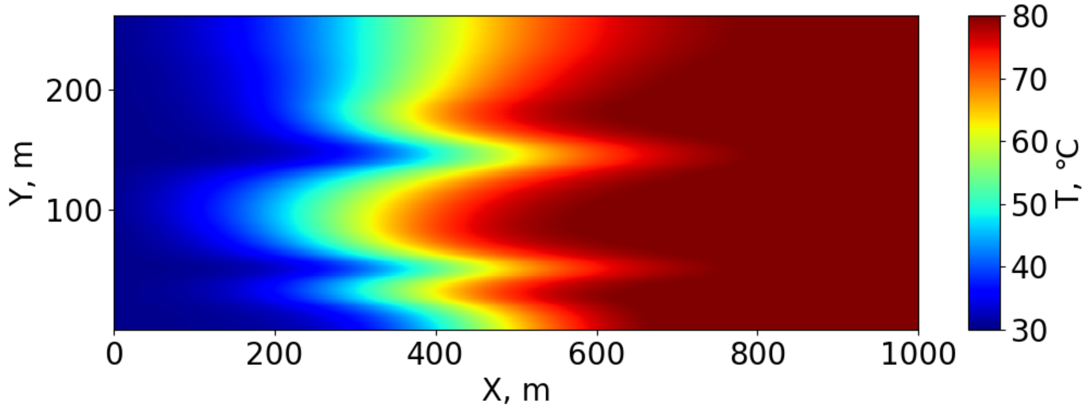


Figure 14: Case 12

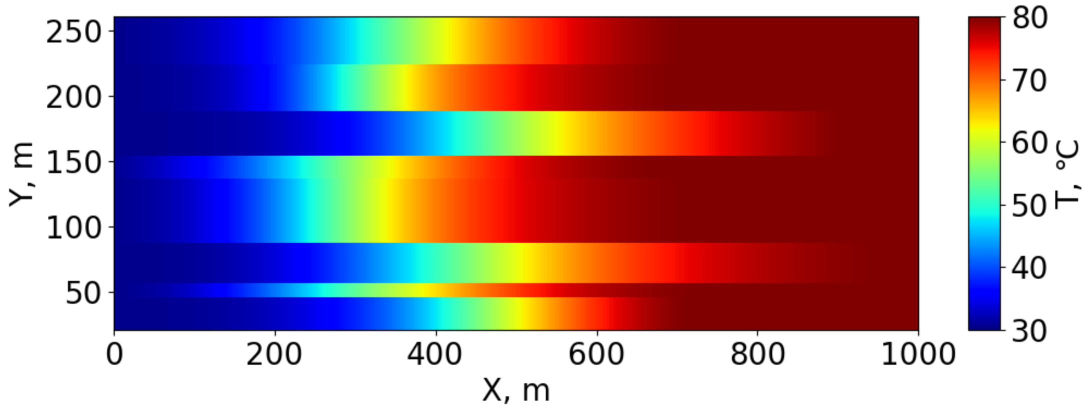


Figure 15: Case 13

5 Discussion

The different scenarios provided a good overview of the upscaling approach for the spreading of a cold front. A straightforward conclusion from the 3 scenarios is that using an arithmetic average for the reservoir properties is not the way to go. This gives a very unrealistic vision of the reservoir. However the upscaling also comes with its complications. Depending on the simulation or situation the upscaled reservoir is never perfectly accurate but can get very close.

However, in the upscaled simulations, there is a big difference as well in doing a fine grid simulation and keeping the same layer thickness or doing a simulation with 1 thicker grid block per upscaled group. Using 1 bigger grid block gives a significantly worse result for the upscaled 9 layer reservoir. This is inconvenient since using 1 grid block per upscaled group reduces the run times for simulations a lot.

However, the more upscaled groups used, the more accurate the upscaling gets. Comparing scenario 1 with 3 gives a good image. The front in the upscaled reservoir in case 2 (figure 9) shows a more spread out front compared to case 1 (figure 8). Compare this to cases 11 and 12 (figures 13 and 14), here the cold front is very well simulated in the upscaled reservoir. Overall, there are some flaws of the upscaling in using less upscaled blocks. However, it does a good job at simulation the spreading of the cold front in the reservoirs at 9 upscaled layers.

6 Conclusion

Overall the upscaling gave a good approach to the spreading of a cold front. Nonetheless, it has its complications. To start with the 1D simulations gave a good insight into the numerical dispersion. With a good grid block length set where the numerical dispersion is not significant the 2D cases were evaluated. This gave a good baseline to see how the upscaling did its job. The upscaling does a significantly better job at simulating the original reservoir properties when compared to using an arithmetic average. Overall the upscaling gives an overestimate of the reservoir as the cold front has a faster breakthrough at the production well. The average simulations give overall a bigger underestimate of the reservoir and have a slower breakthrough of the cold front. Depending on the scenario this results in a less accurate result for the upscaled groups, the bigger simulations give a more accurate result than the simulations with less upscaled groups. To conclude the testing with upscaling was good and gives a better result than using an average. However, one should always test the upscaling and compare the spreading of the cold front in a reservoir to the original properties to validate the upscaling.

7 Appendices

7.1 All 2D cases plots at 15 years

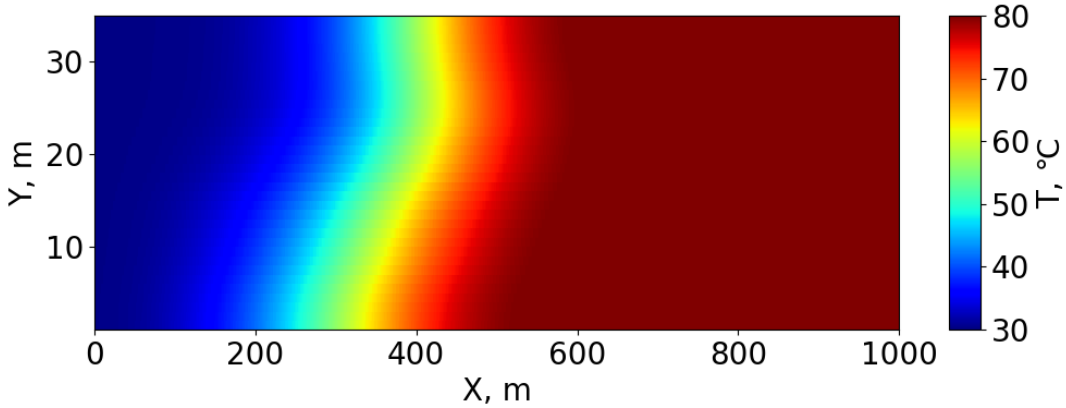


Figure 16: Case 1

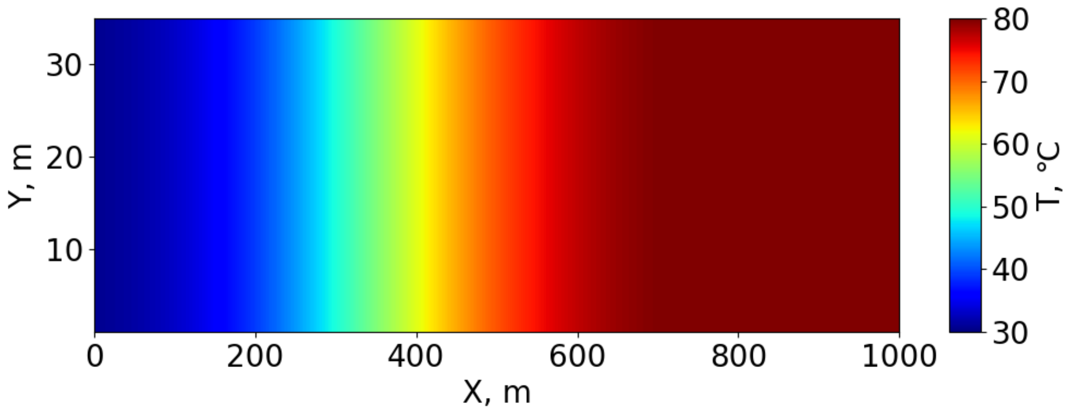


Figure 17: Case 2

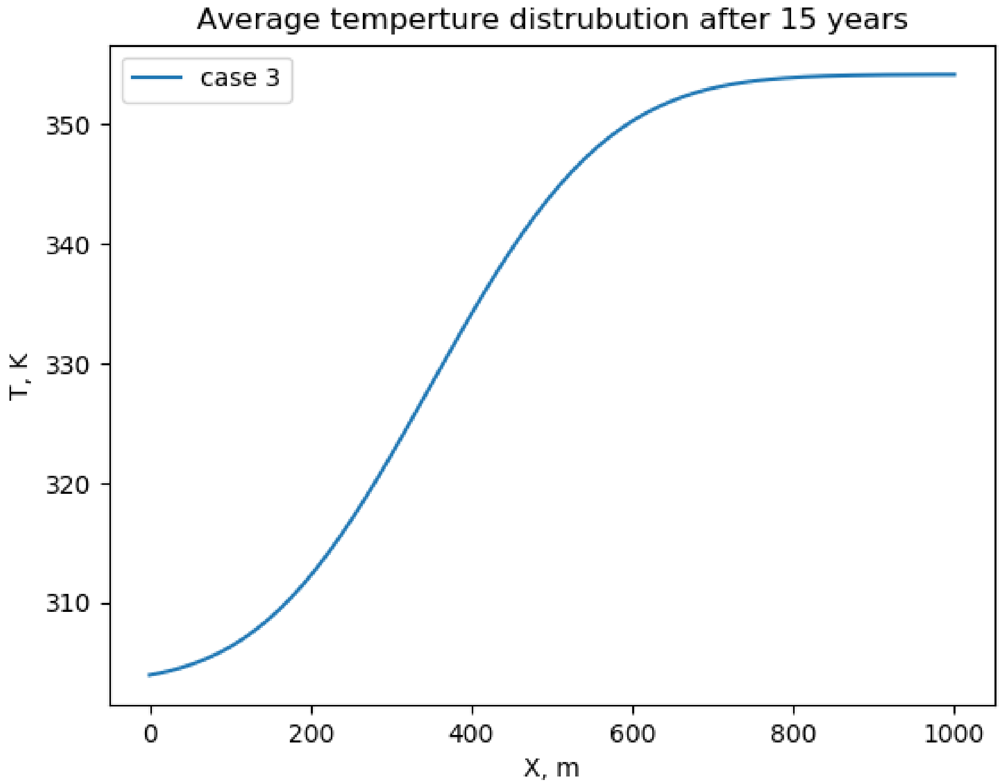


Figure 18: Case 3

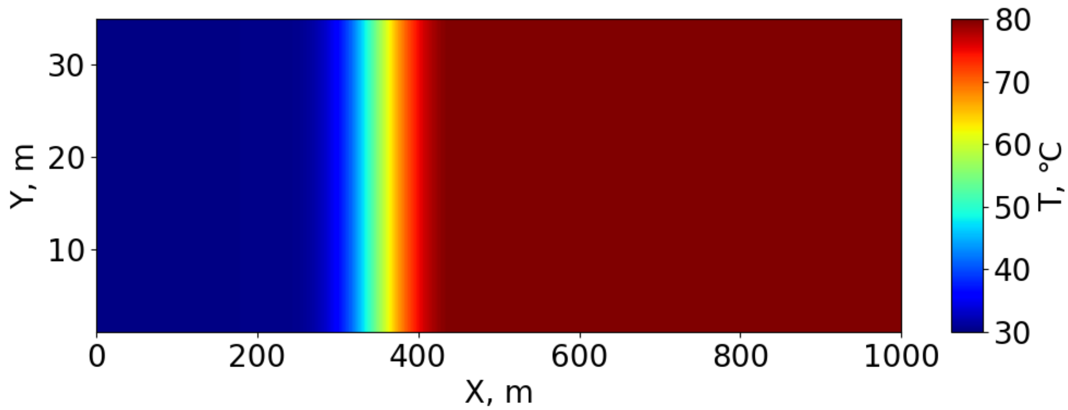


Figure 19: Case 4

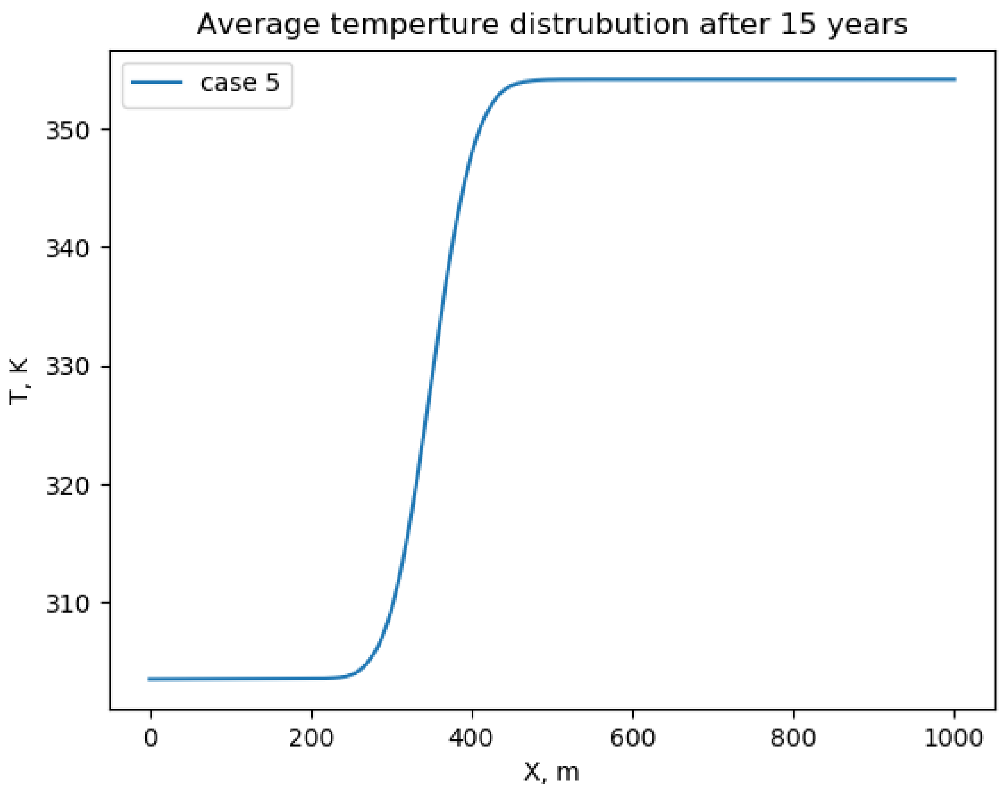


Figure 20: Case 5

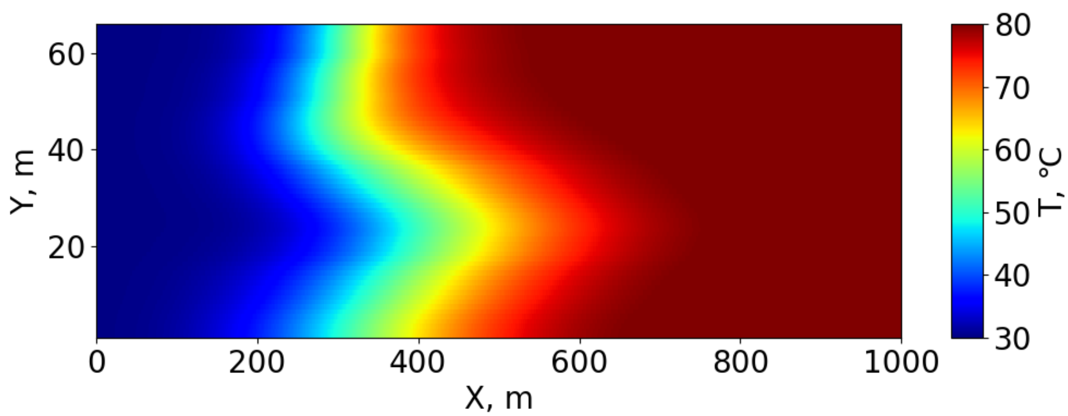


Figure 21: Case 6

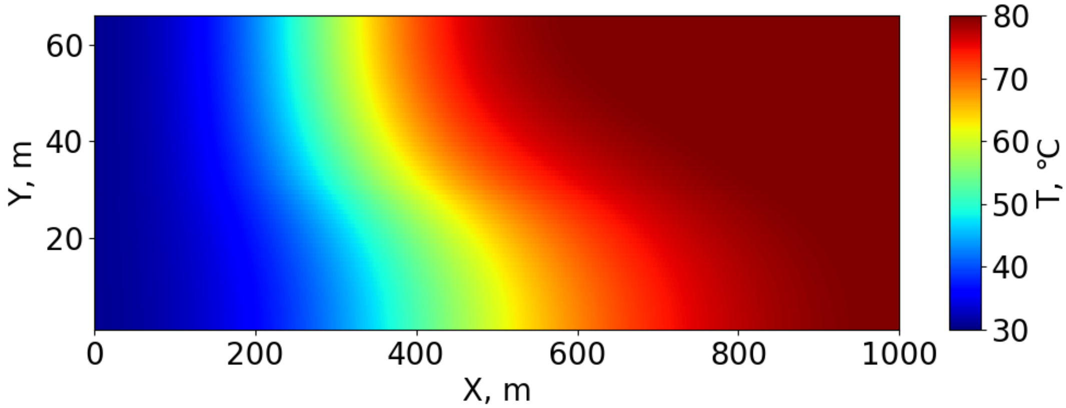


Figure 22: Case 7

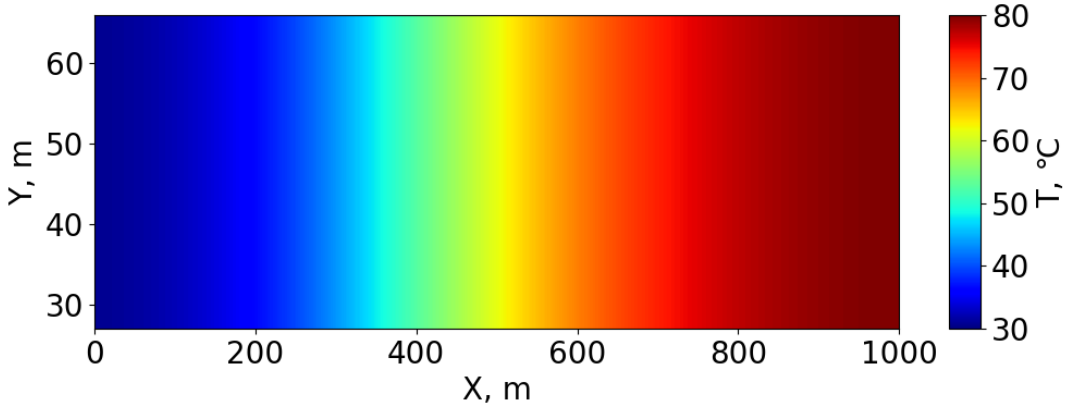


Figure 23: Case 8

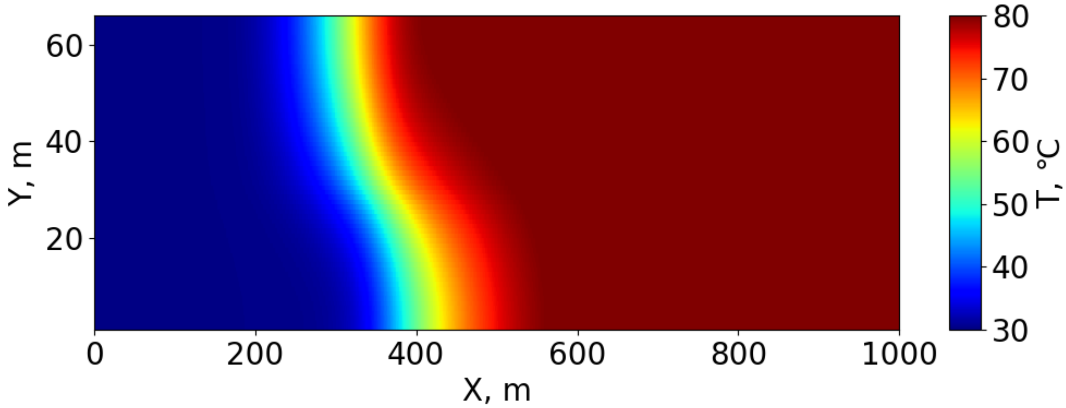


Figure 24: Case 9

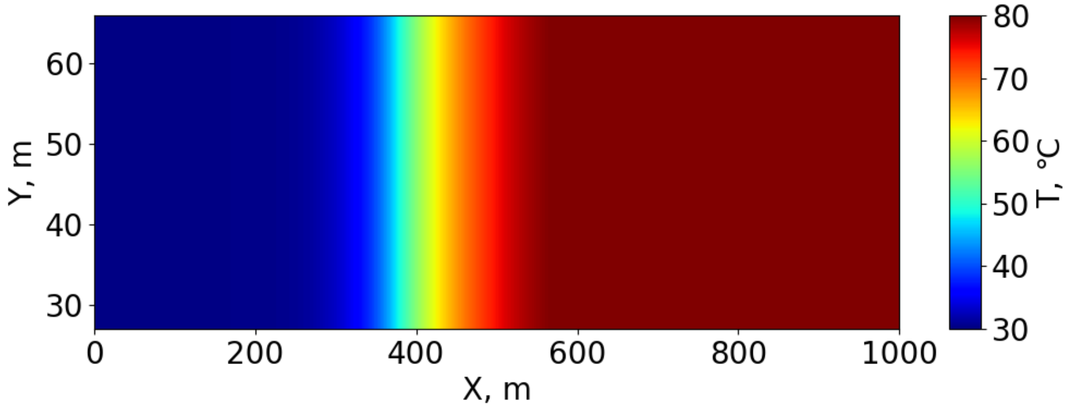


Figure 25: Case 10

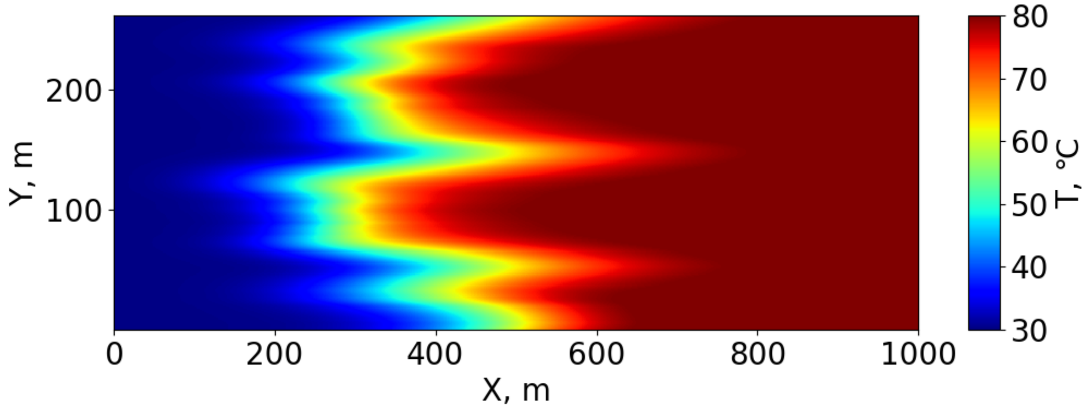


Figure 26: Case 11

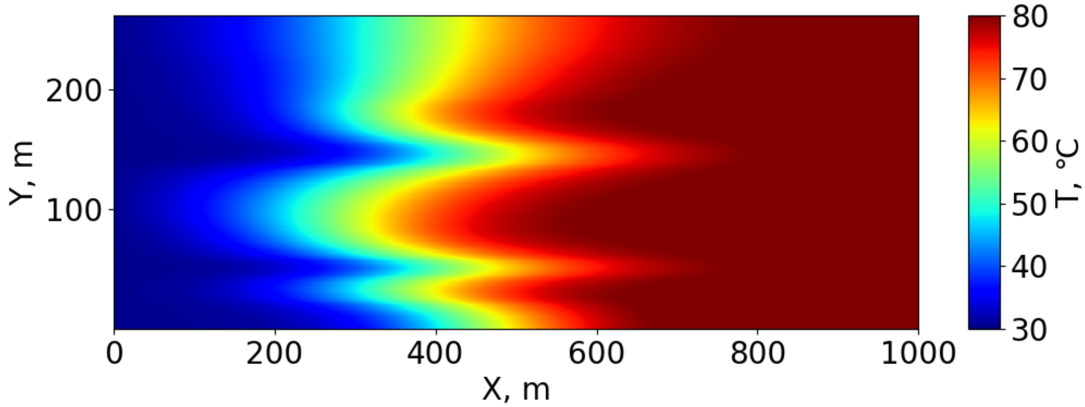


Figure 27: Case 12

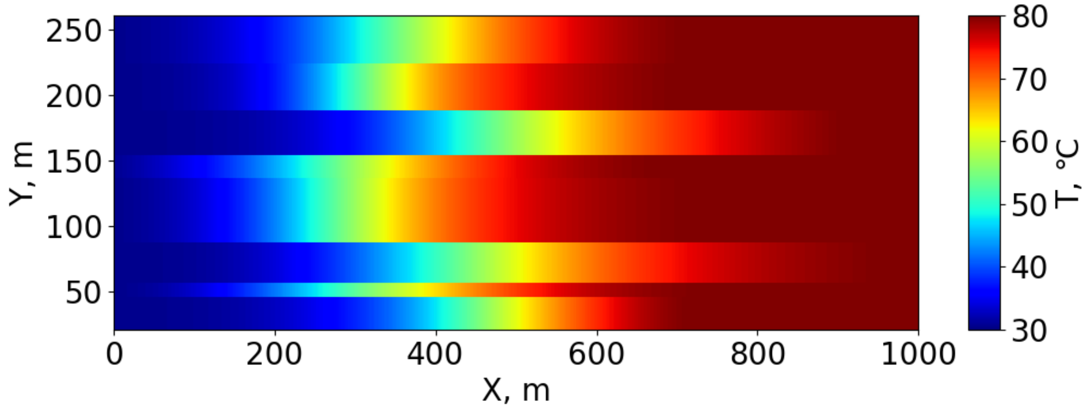


Figure 28: Case 13

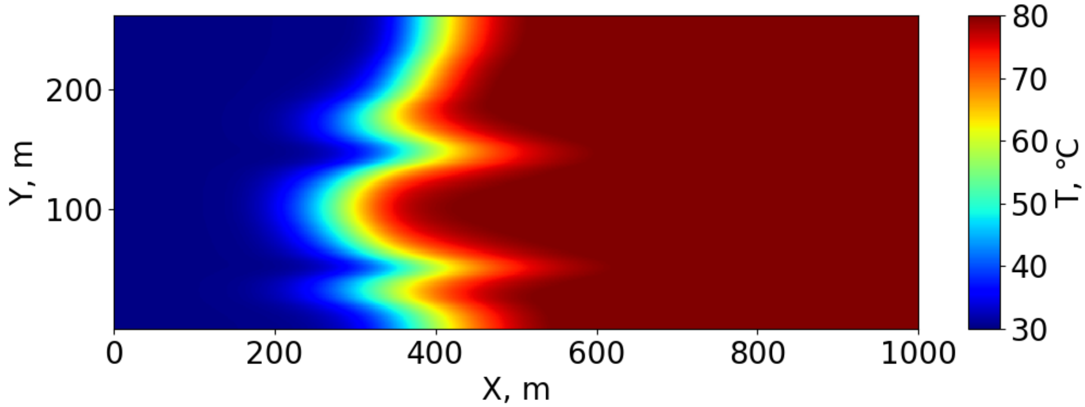


Figure 29: Case 14

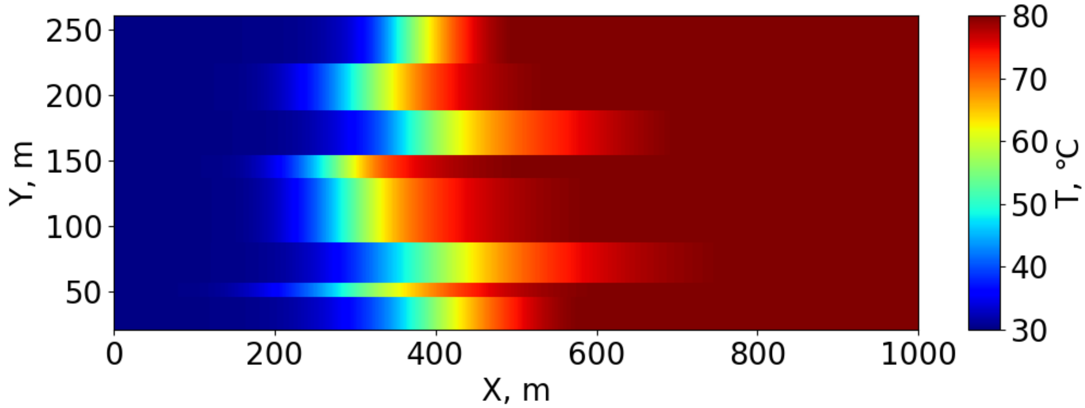


Figure 30: Case 15

7.2 All 2D cases plots at 30 years

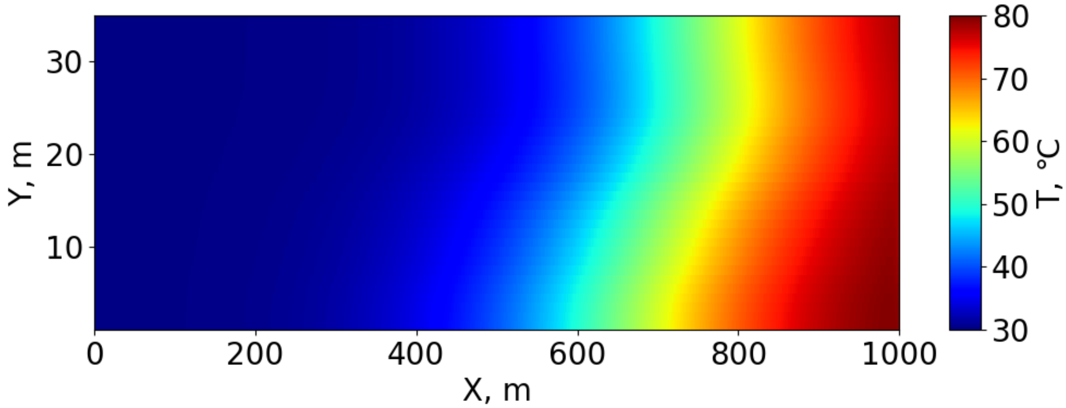


Figure 31: Case 1

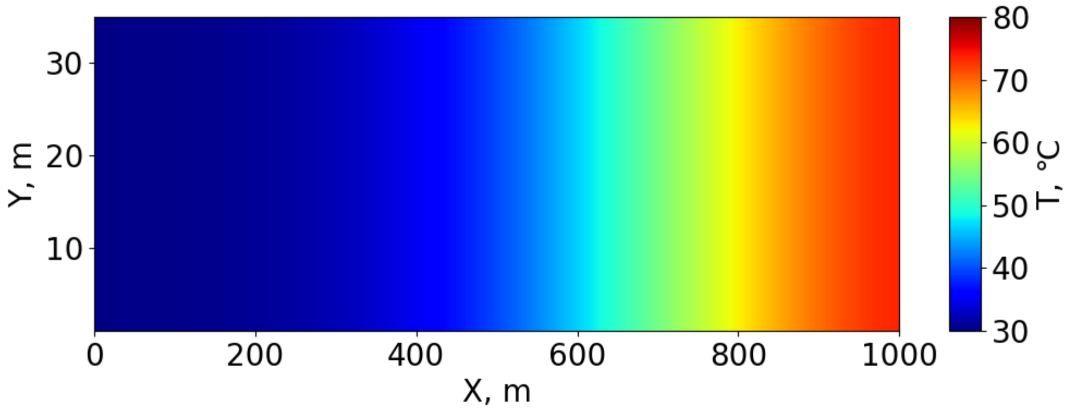


Figure 32: Case 2

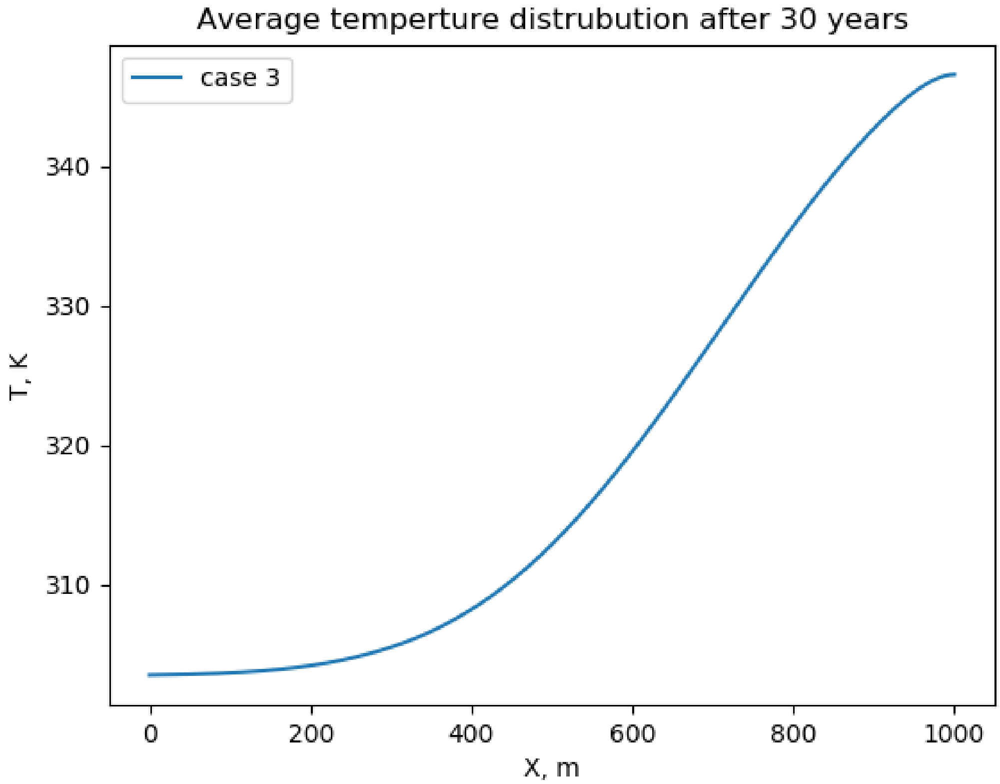


Figure 33: Case 3

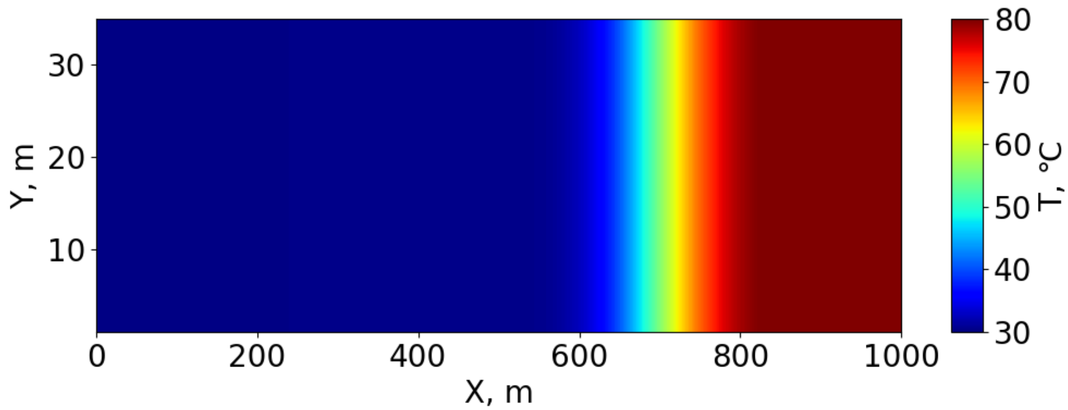


Figure 34: Case 4

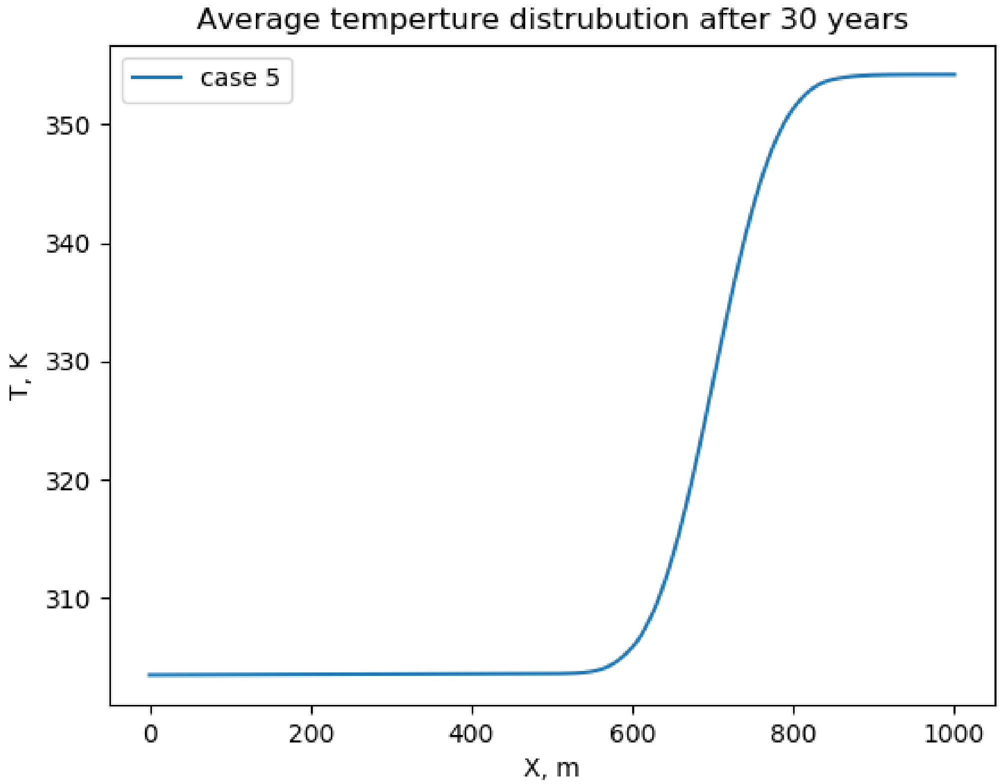


Figure 35: Case 5

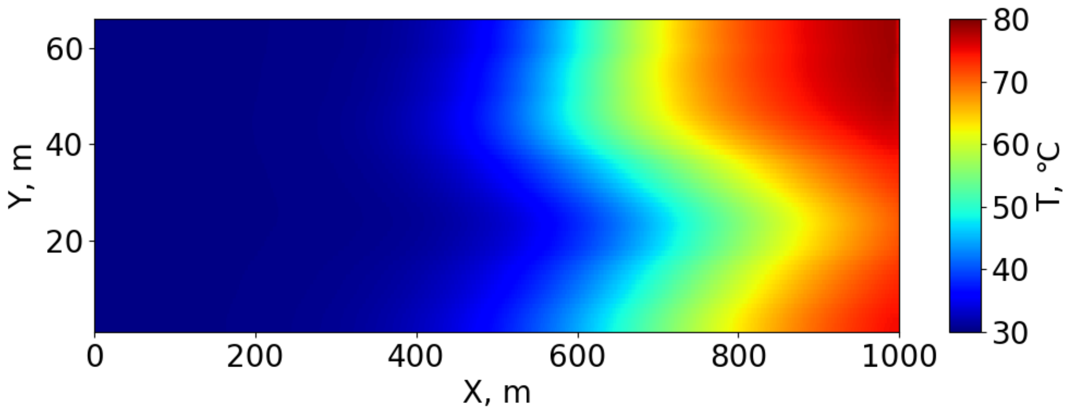


Figure 36: Case 6

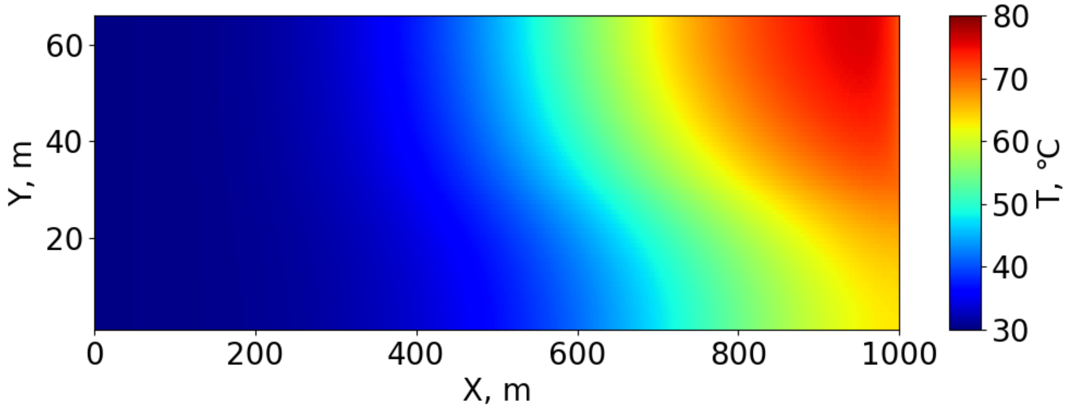


Figure 37: Case 7

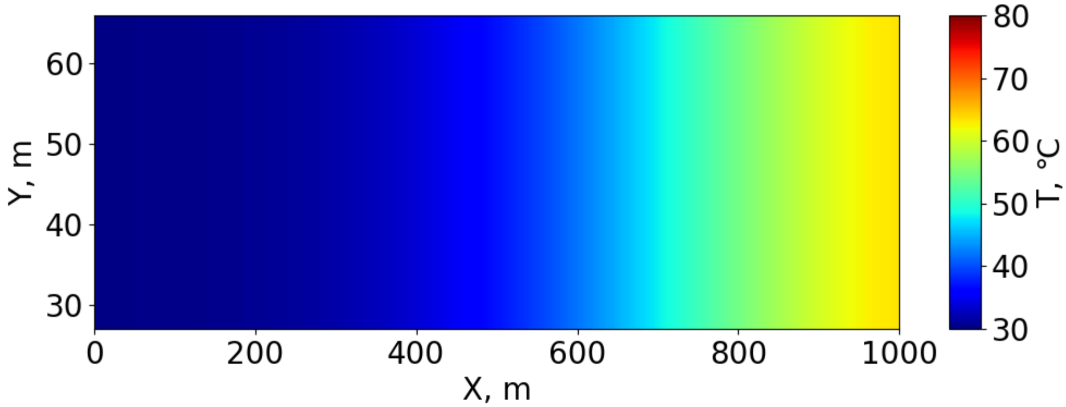


Figure 38: Case 8

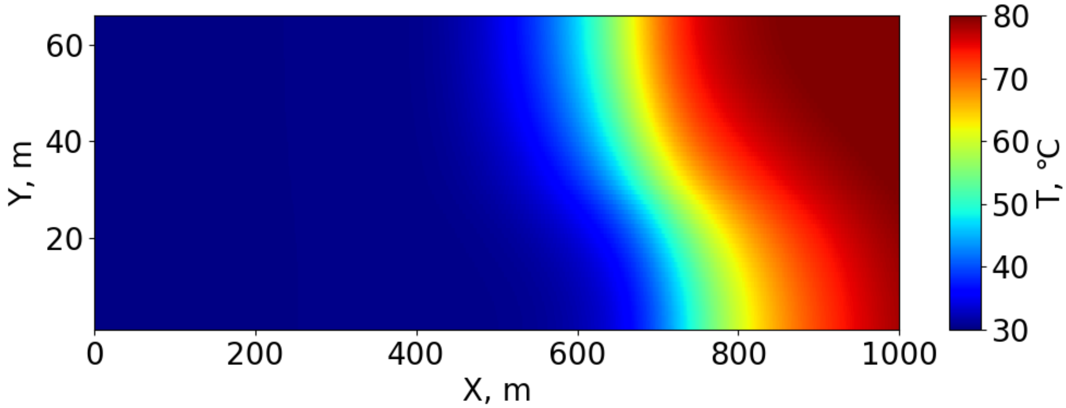


Figure 39: Case 9

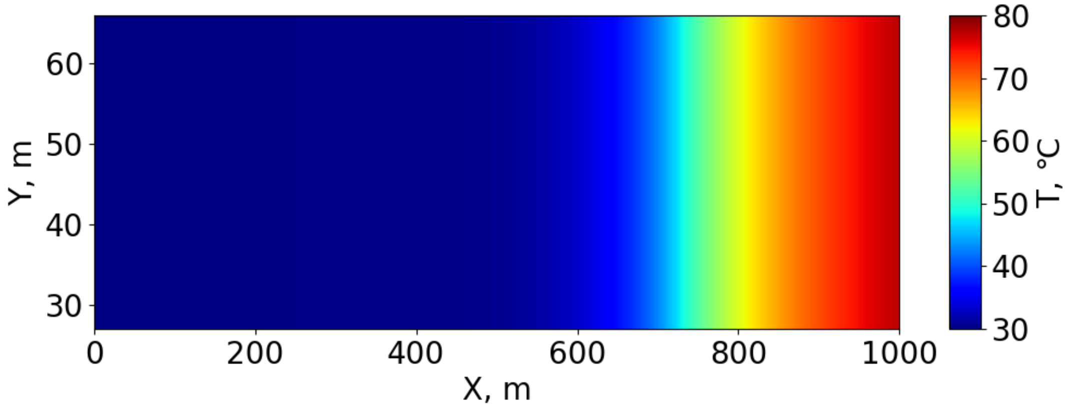


Figure 40: Case 10

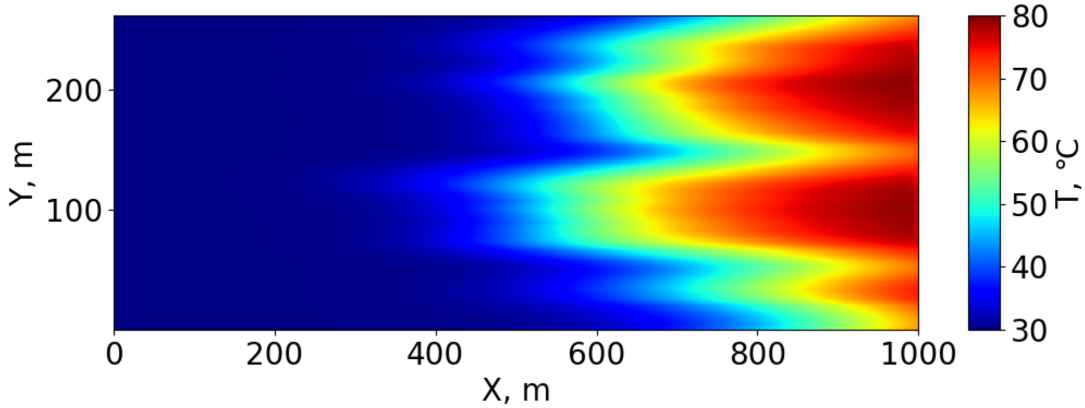


Figure 41: Case 11

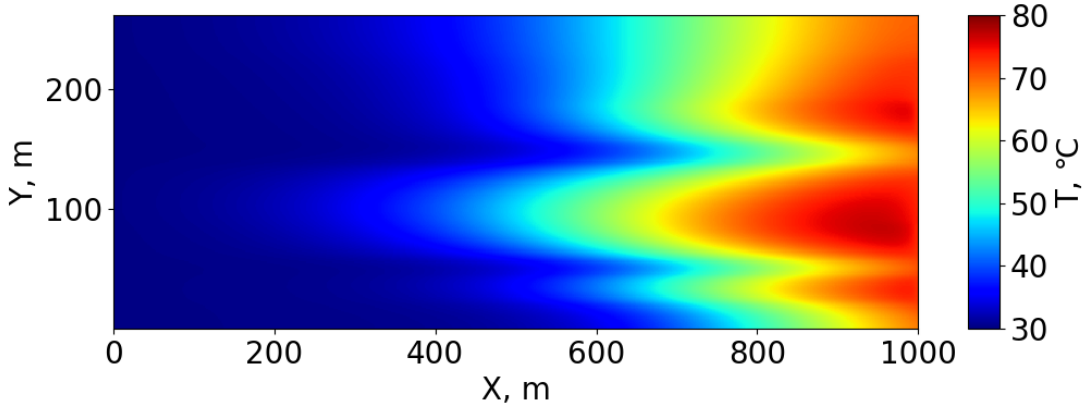


Figure 42: Case 12

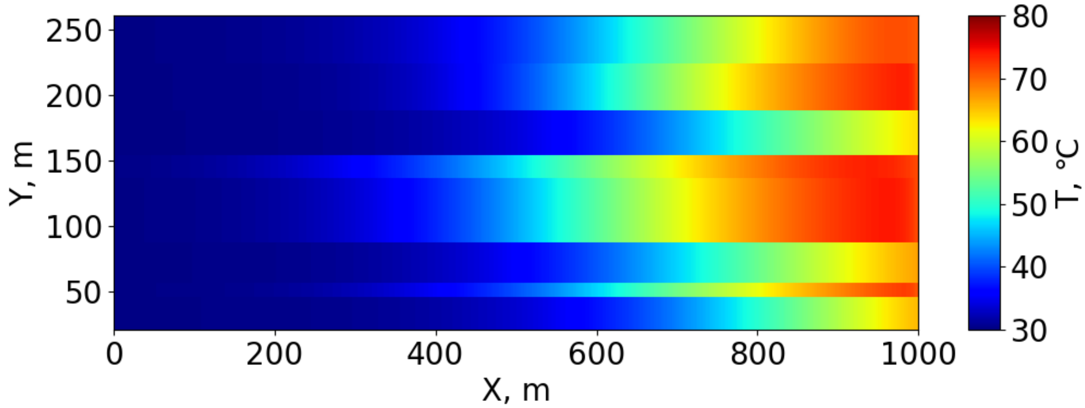


Figure 43: Case 13

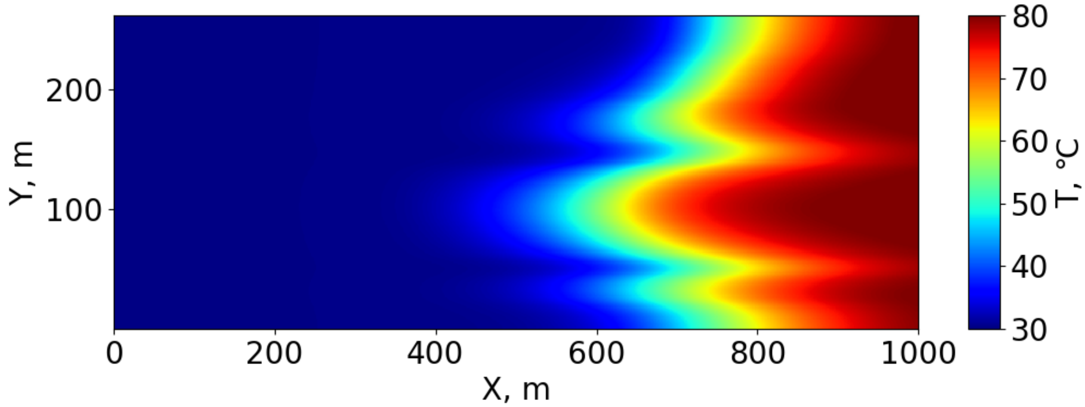


Figure 44: Case 14

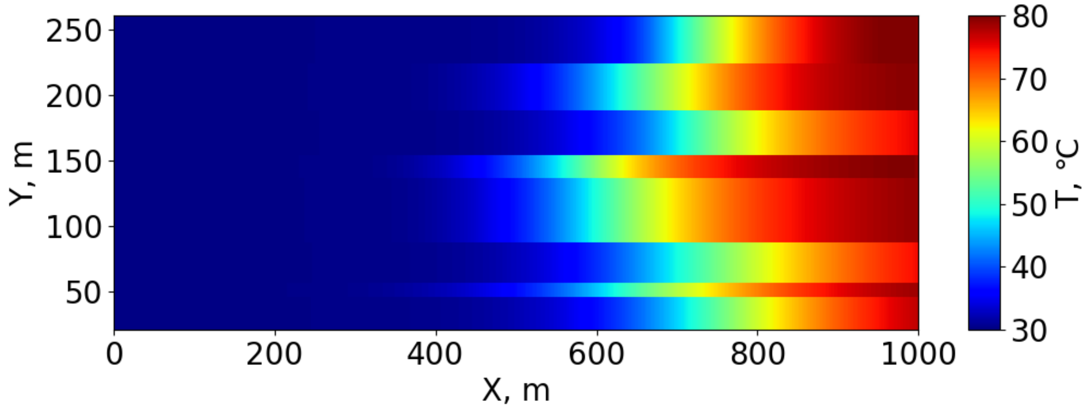


Figure 45: Case 15

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