Long-term Effects of Ground Source Heat Pumps on Underground Temperature

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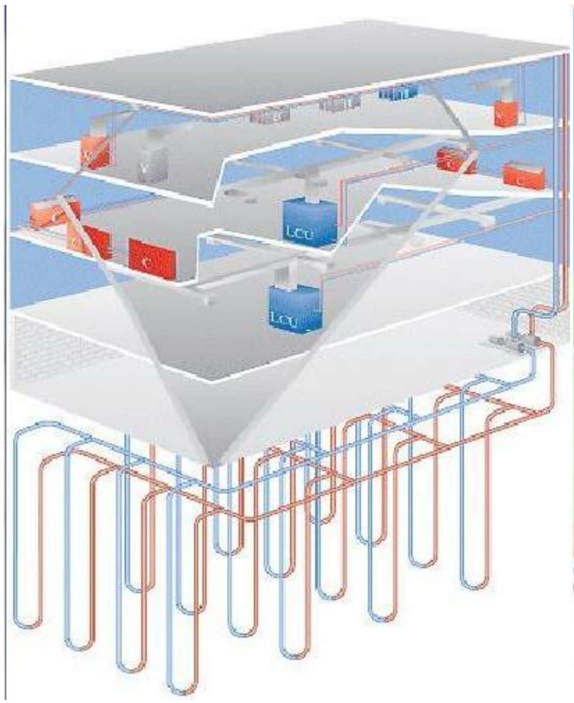
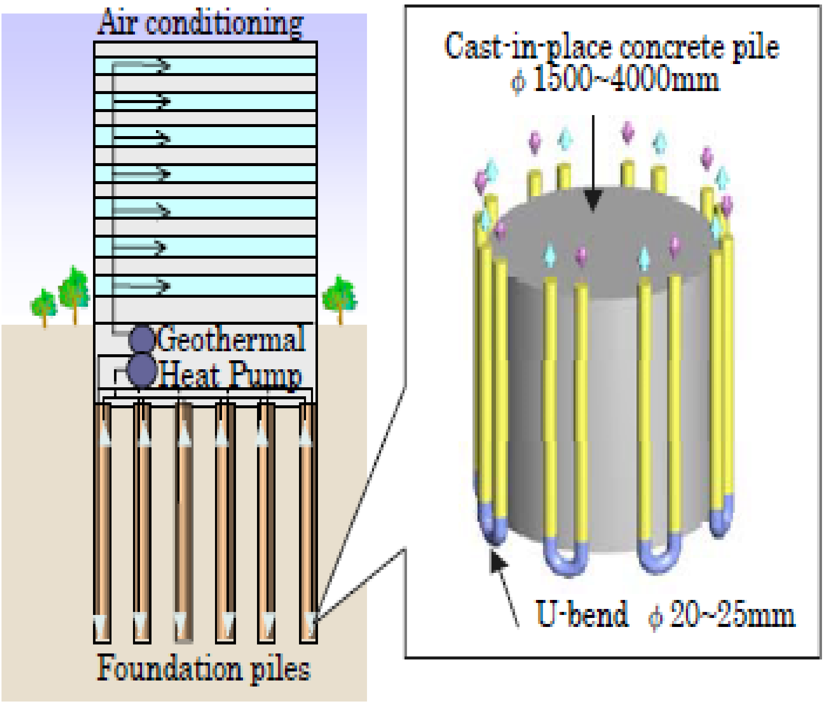
GSHPs





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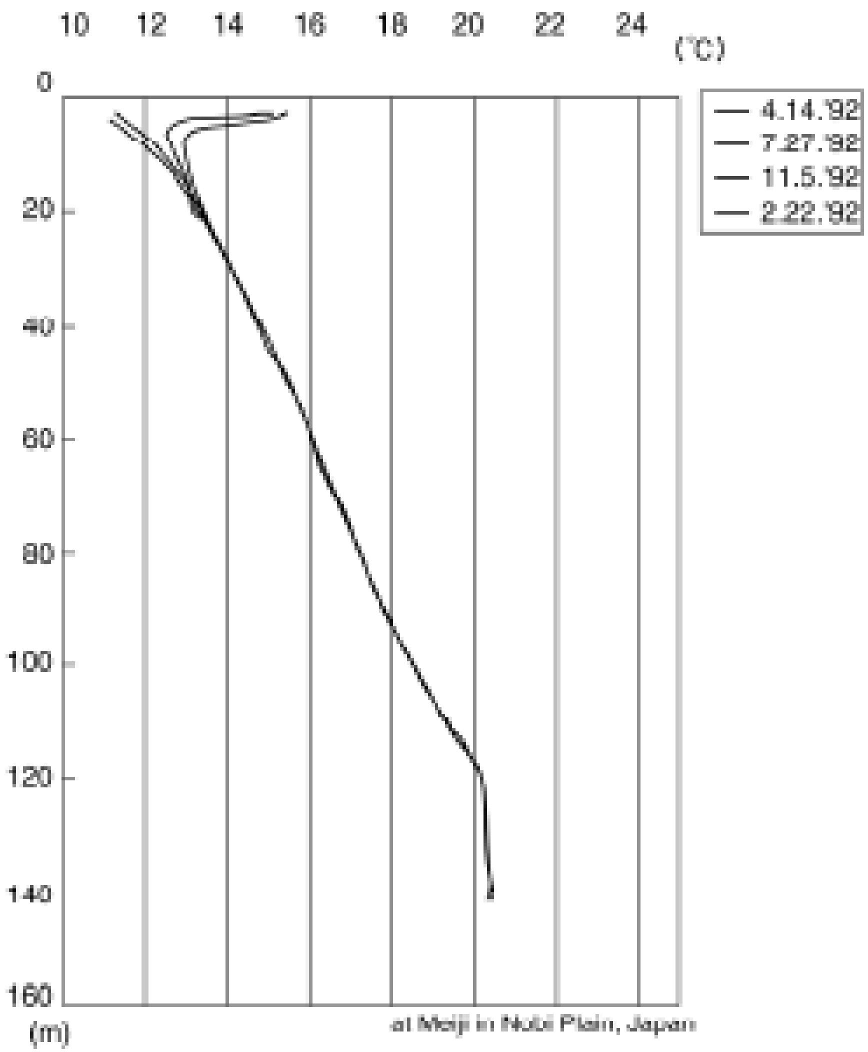
Underground temperature



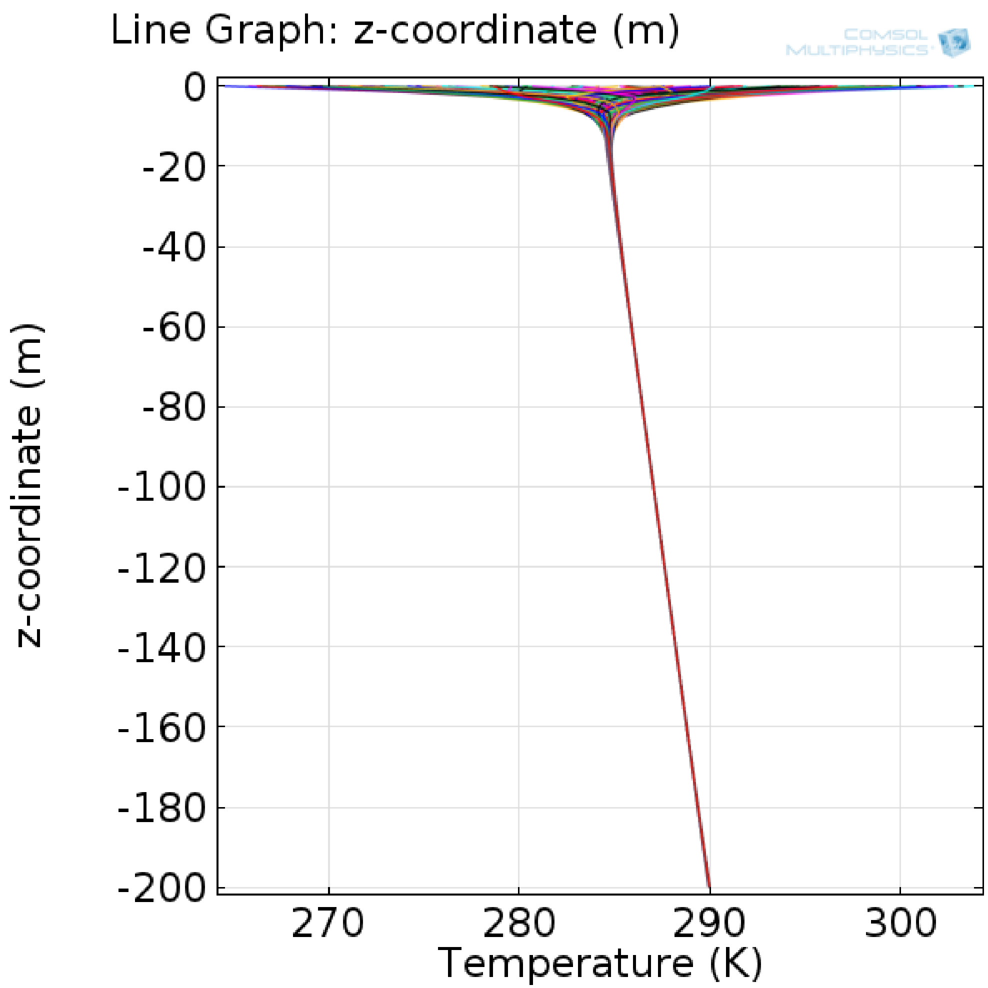
- The upper 5~10 meters of the ground is affected mostly by atmosphere and solar energy.
- The temperature below the depth of 10m often keeps constant through out the year, and there is a gradient between the temperature and the depth.

Long-term simulation

- Material properties and boundary conditions

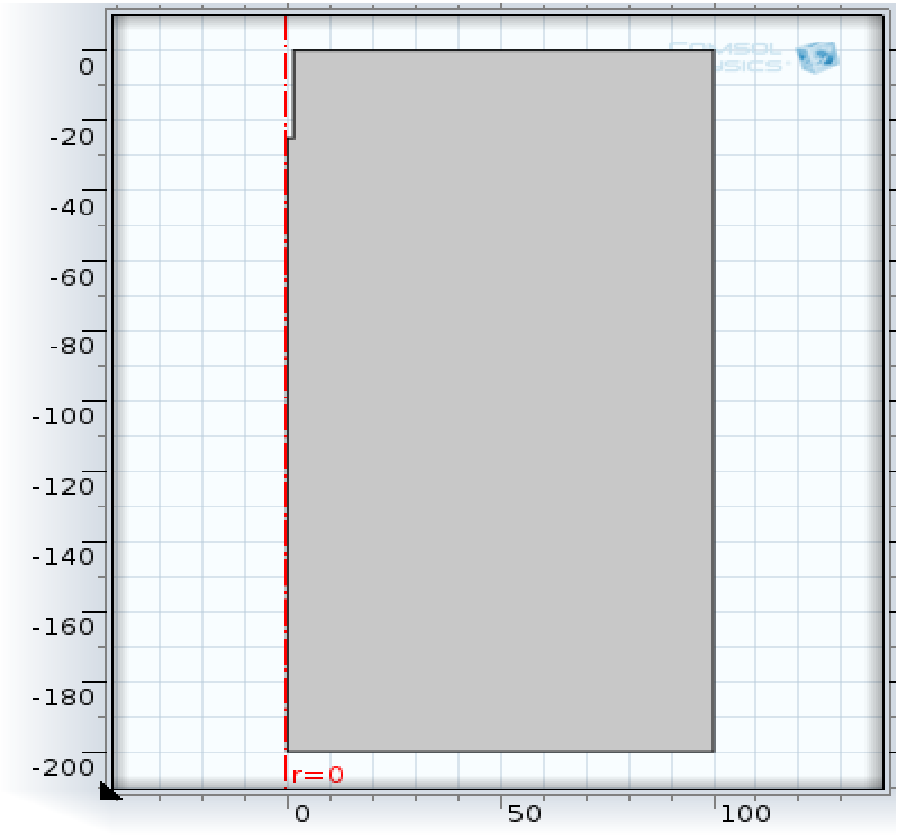
Material	Soil (solid)		Boundary conditions	
Dimensions	R100m*D200m		Upper boundary	Sinusoidal temperature
Soil Density	2000 kg/m^3			Ts=A*sin(2πt/τ)+Ta
Heat Capacity	1480 J/(kg*K)		Lower boundary	Constant heat flux 0.075 W/m^2
Thermal Conductivity	2.35W/(m*K)		Initial temperature	284.15 K
Time duration	200 years		Thermal gradient	0.029 K/m

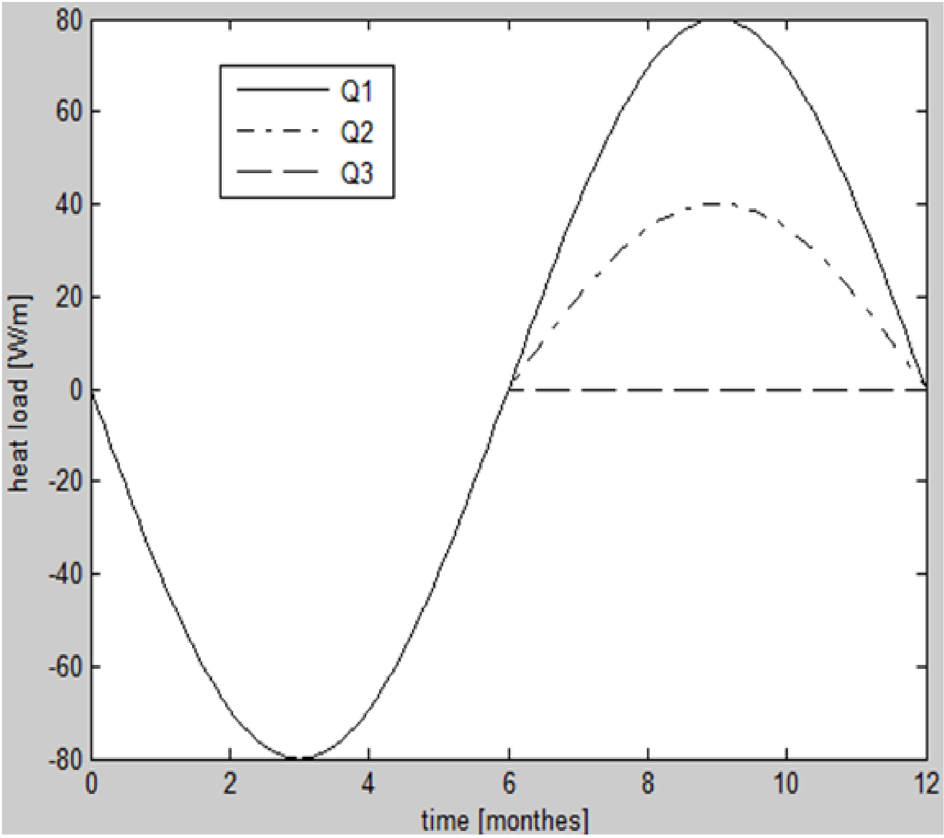
Long-term simulation



Long-term simulation

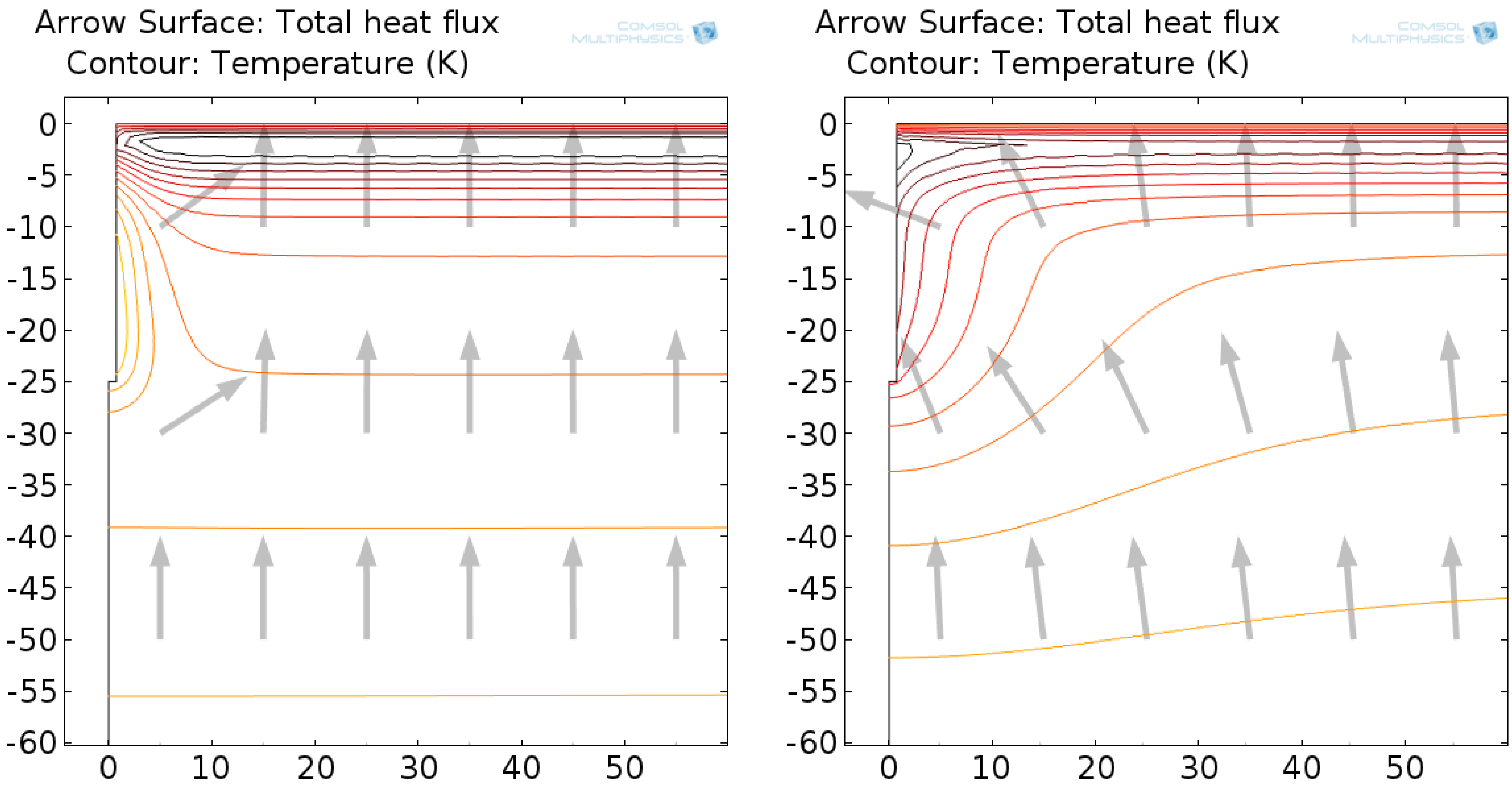
- Computational domain and thermal loads





Long-term simulation

Isothermal lines of ground at the end of the 100th year



Long-term simulation

Underground temperature changes at the selected points at the end of 5th, 10th, 50th, and 100th year under different heat compensations

Distance to pile center (m)		1				11				21			
Temperature Change (℃)		At the end of years											
Depth (m)		5 a	10 a	50 a	100 a	5 a	10 a	50 a	100 a	5 a	10 a	50 a	100 a
No compensation	-10	-1.84	-4.06	-4.12	-4.14	-0.67	-0.85	-0.98	-1.54	-0.25	-0.40	-0.44	-0.46
	-15	-1.71	-4.03	-4.13	-4.17	-0.47	-0.77	-0.79	-1.11	0.01	-0.24	-0.31	-0.36
	-25	-1.03	-2.47	-2.63	-2.70	-0.30	-0.54	-0.61	-0.77	0.03	-0.16	-0.28	-0.35
	-40	-0.10	-0.18	-0.36	-0.42	-0.05	-0.12	-0.27	-0.36	0.00	-0.04	-0.18	-0.24
	-60	0.00	-0.01	-0.16	-0.16	0.00	-0.01	-0.10	-0.14	0.00	0.00	-0.09	-0.13
Half compensation	-10	-0.58	-0.22	-1.47	-0.85	-0.34	-0.25	-0.70	-0.33	-0.13	0.00	-0.48	-0.20
	-15	-0.42	-0.12	-1.42	-0.86	-0.15	-0.10	-0.62	-0.35	0.09	0.20	-0.37	-0.12
	-25	-0.27	-0.18	-0.90	-0.66	-0.09	-0.13	-0.41	-0.34	0.08	0.08	-0.23	-0.15
	-40	-0.04	-0.07	-0.14	-0.18	-0.02	-0.03	-0.11	-0.13	0.01	0.02	-0.06	-0.08
	-60	0.00	0.00	-0.02	-0.04	0.00	0.00	-0.01	-0.04	0.00	0.00	0.00	-0.03
Full compensation	-10	1.46	1.60	1.33	1.62	0.02	-0.22	-0.20	-0.25	0.02	-0.25	-0.22	-0.28
	-15	1.64	1.84	1.47	1.87	0.21	0.04	-0.05	0.01	0.22	0.01	-0.07	-0.02
	-25	0.93	1.11	0.81	1.11	0.12	0.09	-0.05	0.06	0.14	0.08	-0.06	0.04
	-40	0.01	0.05	-0.04	0.06	0.02	0.05	-0.04	0.06	0.03	0.05	-0.04	0.06
	-60	0.00	0.01	-0.01	0.04	0.00	0.01	-0.01	0.04	0.00	0.01	-0.01	0.04

Summary

- Heat compensation to the ground is important for the long-term performance of the GSHP system.
- With full heat compensation, the underground temperature did NOT decrease. The underground temperature decreased if heat extracted from the ground without heat injection.
- When there was no compensation, the underground temperature decreased in the beginning few years, then decreased very slightly.
- The region that temperature changes relates to material properties and thermal loads.
- Porous medium with groundwater movement model and double-piles model are suggested in further research

Questions?

Thanks!