

GLD Skill Booster #5: Climate Change and Loopfield Performance

The GLD Skill Booster Series is a series of documents that guide you through the process of performing a specific task in GLD. This particular Skill Booster focuses on a thought experiment rather than a specific GLD skill. This thought experiment is related to climate change and its influence on geothermal loopfield performance.

More specifically, the purpose of this Skill Builder is to encourage building energy simulation modelers and geothermal designers to being thinking about what will happen to the heating and primarily cooling requirements of buildings and to the loopfield temperatures as day and night outside air temperatures increase in the future.

The fundamental science of climate change is fairly well understood regarding climate change. While many details remain to be worked out and no doubt, surprises remain on the scientific horizon, the basic concept of human-induced climate is accepted by basically all scientifically literate people across the globe. Predicted temperature increases vary depending on predicted greenhouse gas (primary CO²) emissions scenarios.

CO² emissions trends and total atmospheric CO² concentration over the last half century are easily discernible in the famous Keeling Curve:



With a longer longitudinal ice core-based data set, it becomes clear that the last half century of human-induced CO^2 emissions have been quite dramatic on overall CO^2 concentration as can be seen in the next chart.



There is broad agreement among the climate science community that these emissions are driving climate change. In the 2013 IPCC report, the summary states that "it is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century."

The amount of climate change will be dependent on future emissions. Minimum estimates predict an average global temperature increase of 2°C. Higher estimates range as high as 6-8°C, a temperature increase that will likely not be conducive to human civilization as we now know it (which frankly is quite disturbing).

The take home message for geothermal designers is the following: the energy models we create for predicting building heating and cooling loads are based on historical weather data. Historical weather data however are insufficient because future climate and temperature patterns will be different from historical ones. As geothermal designers, we need to assume that the heat rejection needs of our loopfields will be greater than predicted based on our current generation of building energy and loads modeling tools.

Let's see what GLD predicts for hourly loopfield temperatures in June/July under several different scenarios. Note that the scenarios should be considered as conceptual demonstrations only for a 40,000 sq ft office building. The three scenarios are described as follows:

SCENARIO

DESCRIPTION

SCENARIO 1:	Baseline loopfield temperatures in the month of July
SCENARIO 2:	Loopfield temperatures under two week heavy heat wave scenario (similar to a heat wave in summer 2013 in which nighttime temperatures did not drop below 80°F)
SCENARIO 3:	Loopfield temperatures under climate change temperature-based scenario and two week heat wave. Climate change induced increase is 9.8% overall.

Each of these scenarios is then input to Ground Loop Design for simulation and analyzed for the resulting temperature profiles as shown in the following screenshots:

Scenario 1 – Baseline loopfield temperatures in the month of July as Modeled in GLD

Conditions:

Borehole Design Proj	ect #1			- E X					
ngths		Temperatures							
otel Length (ft): orehole Length (ft):	COOLING HEATING 15410.0 15410.0 308.2 308.2	Feak Unit Irlet (°F) Feak Unit Outlet (°	COOLING : 80.3 -): 88.6	HEATING 51.7 46.5	Average Block Los	ds - Borehole Design P B	roject#1	Untitled	
alculations	Results Fluid Soil	U-Tube Pattern	Extra KW Inf	ormation)	Reference Label:				
Calculate				HEATING	IEATING Design Day Loads				
Hourly 💌 🔛	Total Length (ft):		15410.0	15410.0	V.0 Days / week	Time of Day	I leat Gains (kBtu/Hr)	Heat Losses (kBtu/Hr)	
diction Time: 1 ye	Borehole Length	(ft):	308.2	308.2	Transfer	8 a.m Noon	741.5	810.7	
C Fixed Temperatu	Ground Temperat	ure Change (°F):	N/A	N/A	Calculate Hours	4 p.m 8 p.m.	711.2	531.5	
Fixed Length	Peak Unit Iniet (* Peak Unit ()utlet (F): (*+):	80.3 88.6	51.7	Monthly Loads	8 p.m 8 a.m.	102.9	72.9	
BO.3 9F 51.7	op Total Unit Capacit	Total Unit Capacity (k3tu/Hr);		810.7	Annual Equ	uivalent Full-Load Hours: 633 457			
prehole Length: 308	Peak Load (kBLu/	Peak Load (kBLu/Hr):		810.7	Heat Pump Specificat	ions at Design Temperature and Flow Rate —			
- 1	Heat Rump EER/C	Heat Rump EER/COP		43.Z	🖂 Custom Pump	Pump Name NS		5048	
Lise External File	Seasonal Heat Pur	mp EER/COP:	20.3	4.8	Select	Capacity ((Blu/Hr)	Cooling	Heating	
orehole Number: 50	Avg. Annual Powe	(KUVII):	2.30774	7.70574	Details	Power (kW)	46.82	52.07	
Rows Across: 10	System Fow Rate	(gpm):	189.0	202.7	Cear	EER/COP	17.9	4.6	
Separation: 20.0	ft *Update	System: *Off *Cooling	*Hc	ating		Flow Rate (qpm) Partial Load Factor	189.0 0.90	202.7	
	*Reset	*Peaks	0 ~~	0 %	Tlow Rate	Urit Inlet (°F):	80.3	51.7	
	*Summary							-	
					<u> </u>				

Scenario 1 Results Graph:



Scenario 2 – Loopfield temperatures under two week heavy heat wave scenario (similar to a heat wave in summer 2013 in which nighttime temperatures did not drop below 80°F) as Modeled in GLD

Conditions:

Temperatures Peak Unit Inle: (%): Peak Unit Outlet (%) U-Tube Pattern ft): Tre Change (*F): c)-	COOLING 84.6 93.6 Extra kW In COOLING 15410.0 50 308.2 N/A	HEATING 51.7 46.5 formation HEATING 15410.0 50 308.2 N/A	Average Block Load	ds - Borehole Design Pr	n Day Load Heat Gairs (HBtu/Hr)	Untitled.	
Peak Unit Inle: (°F): Peak Unit Outlet (°F) U-Tube Pattern ft): ure Change (°F):	COOLING 84.6 93.6 Extra kW Jn COOLING 15410.0 50 308.2 N/A	HEATING 51.7 46.5 iformation HEATING 15410.0 50 308.2 N/A	Reference Label: Design Day Loads 7.0 Days / Week Hourly Data Transfer	ds - Borehole Design Pr Design Time of Day 8 a.m Noon	n Day Load Heat Gains (HBtu/Hr)	Untitled Untitled S Heat Losses (kEtu/Hr)	
U-Tube Pattern ft): are Change (°F):	Extra kW In COOLING 15410.0 50 308.2 N/A	formation HEATING 15410.0 50 308.2 N/A	Reference Label: Design Day Loads 7.0 Days / Week Hourly Data Transfer	Design Time of Day 8 a.m Noon	Heat Gains (kBtu/Hr)	s Heat Losses (kEtu/Hr)	
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ft): ure Change (°F);	50 308.2 N/A	50 308.2 N/A	Transfer	8 a.m Noon	(KDUU/HI)	(KEW/HI)	
ure Change (°F):	N/A	N/A			755.0	810.7	
	04 6	F1 7	Calculate Hours	Noon - 4 p.m. 4 p.m 8 p.m.	755.0	438.1	
°F):	93.6	46.5	Monthy Loads Annual Equi	valent Hull-Load Hours:	678	457	
Total Unit Capacity (kBtu/Hr): Peak Load (kBtu/Hr):		.0 810.7 .0 810.7	Heat Pump Specifications at Design Temperature and Flow Rate				
OP:	45.2	43.2 5.5	Custom Pump	Pump Name	N5048 Cooling Heatin		
r (kWh):	19.9 2.57E+4	4.8 2.28E+4	Select	Capacity (kBtu/Hr) Power (kW)	815.4 49.05	810.7	
(gprr): System: *Uff	188.8	202.7	Clear	EER/COP Flow Rate (gpm)	16.6 188.8	4.6	
*Peaks	°% ⊢	eating 0%	=low Rate 3.0 gpm/ton	Parial Load Facto [.] Unt Irlet (약):	84.6	51.7	
	*Cooling	*Cooling **	*Cooling *Heating *Peaks J	*Cooling *Heating *Peaks / 0 % / 0 %	*Cooling *Jeating *Peaks J 0 % J 0 % Second Partial Load Factor Flow Rate (Jinit) Partial Load Factor Flow Rate J	*Cooling *Heating Partial Load Factor 0.93	

Scenario 2 Results Graph:



Scenario 3 – Loopfield temperatures under climate change temperaturebased scenario and two week heat wave. Climate change induced increase is 9.8% overall as Modeled in GLD

Conditions:

cnoths			Temperatures						
CO Fotal Length (ft): 15 Borehole Length (ft): 30	OLING 5410.0 08.2	HEATING 15410.0 308.2	Peak Unit Inlet (약) Peak Unit Outlet (%	COOLING : 87.2 -): 96.9	HEATING 51.6 46.6	Average Block Load	ls - Borehole Design P	roject #1	Untitled
Calculations Calculate Hourly Calculate Hourly Calculate Hourly Calculate Hourly Calculate Hourly Calculate Calculate Hourly Calculate	Results Tota Bore Grou Peal Peal Heat Seat Avg Syst	Fluid Soil Fluid Soil Fluid Soil Fluid Length (ft): thole Length (ft) thole Length (ft) (Unit Inlet (°F) (Unit Outlet (° al Unit Capacity c Load (kBtu/Hr C Dermand (kW) Fluid Power em Flow Rate (tional Hybrid Sy "Update "Reset *Summary	U-Tube Pattern t): re Change (°F): : F): (kBtu/Hr):): : P: p EER/COP: (kWh): gpm): stem: *Off *Cooling *Peaks	Extra kW Inf COOLING 15410.0 50 308.2 N/A 87.2 96.9 829.0 820.0 820.0 820.0 820.0 800.0 800.0 800.0 800.0 800.00	ormation HEATING 15410.0 50 308.2 N/A 51.6 810.7	Reference Label: Design Day Loads 7.0 Days / Week Hourly Data Transfer Calculate Hours Monthly Loads Annual Equi Heat Pump Specificable Custom Pump Select Details Clear Flow Rate 3.0 gpm/ton	Design Time of Day 8 a.m Noon Noon - 4 p.m. 9 p.m 8 p.m. 8 p.m 8 a.m. valent Full-Load Hours: ons at Design Temperatu Pump Name Capacity (#Stu/Hr) Power (KV) EER/COP Flow Rate (gpm) Partial Load Factor Unit Inlet (†):	n Day Load Heat Gains (k8bu/Hr) 829.0 829.0 2.5 678 ure and Flow 829.0 51.98 15.9 207.2 1.00 87.2	s Heat Losser (kBtu/Hr) \$10.7 438.1 531.5 72.9 457 Rate 048 Heating 835.7 53.70 4.6 202.7 0.97 51.6 8

Scenario 3 Results Graph:



The graph below directly compares the average fluid temperatures (average of entering and exiting temperatures) of the three scenarios.



It becomes clear that in scenarios 2 and 3 the average fluid temperatures are 10° to 15°F warmer, respectively, than those in scenario 1. Over the short term with this particular design, the temperature increase results in reduced performance. Over the longer term, one can imagine increased challenges for the loopfield. The take home message is that as the climate warms on average, cooling loads will increase, heating loads will decrease and sustained heat waves will become more common. Designing loopfields for the historical climate rather than the future climate is a risk-fraught endeavor, an endeavor that will negatively impact loopfield performance in many instances.