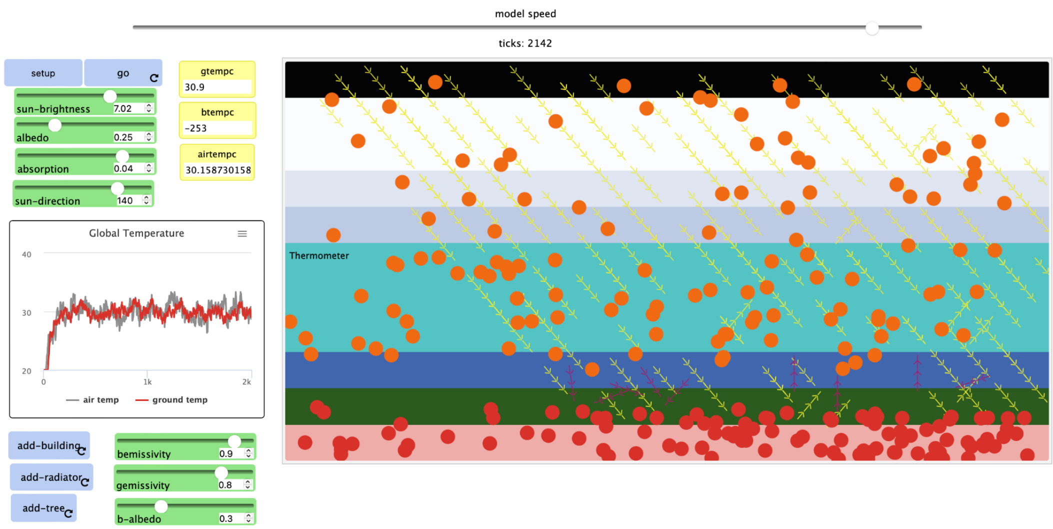
Rishabh Anand • A0220603Y

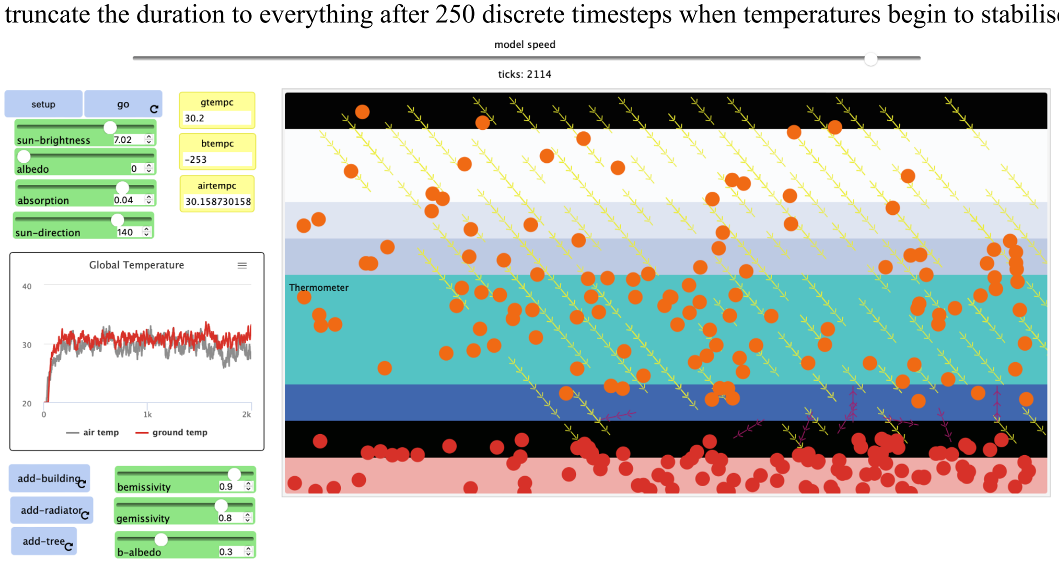
Part 1

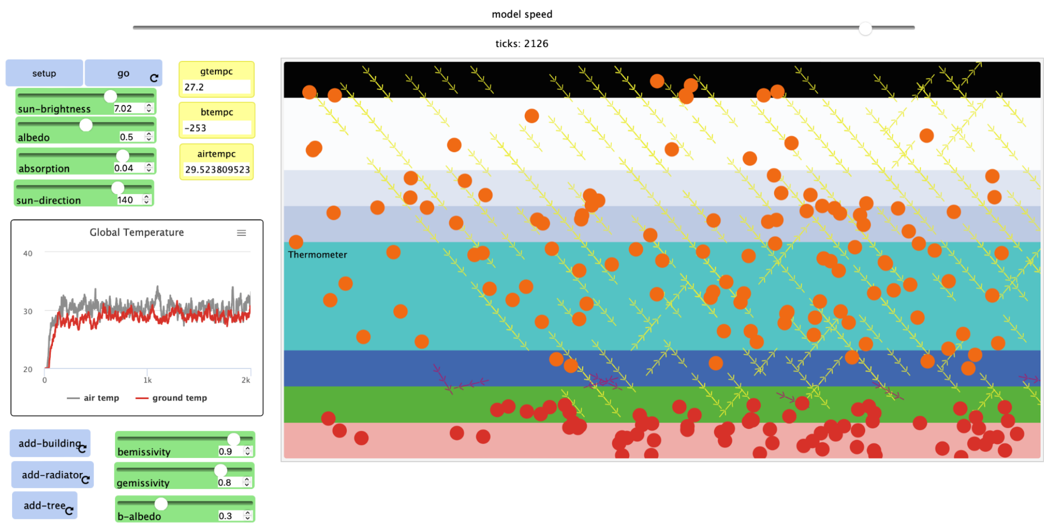
A. Without any environmental factors and keep all else constant, at albedo=0.25, there is an initial increase in air and ground temperature before it starts to stabilise. To compute the average temperatures, I truncate the temperature values, by inspection, to a window after 250 discrete timesteps. I run the simulation for ~2K discrete timesteps.

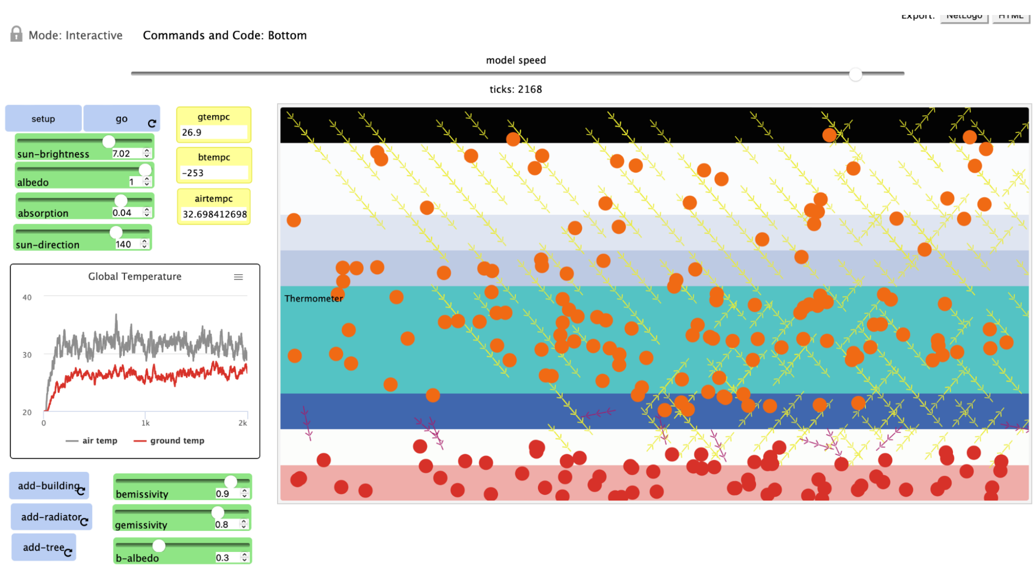
Albedo	**Air Temperature (ºC) (mean | stddev)**		**Ground Temperature (ºC) (mean | stddev)**	
0.25	30.1	1.2	29.9	0.8



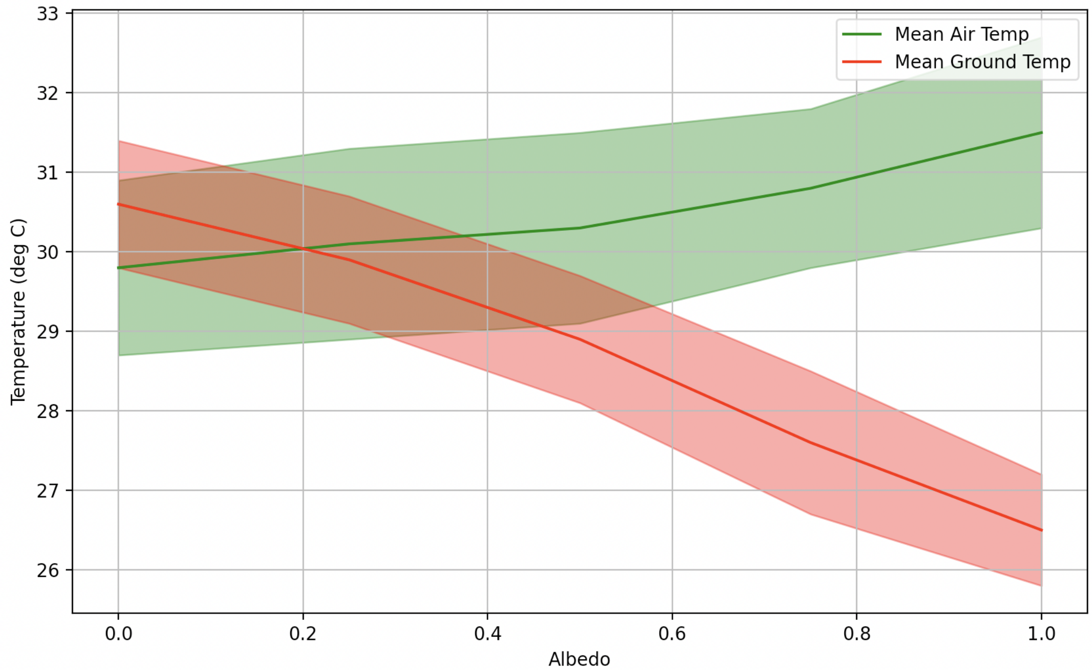
B. I varied the albedo between [0.0, 0.25, 0.5, 0.75, 1.0] at intervals of **0.5**. I then log the air and ground temperatures for ~2K discrete timesteps. Finally, I compute the average air and ground temperatures across these different values of albedo. Here are some selected screenshots for albedo=0.0, 0.5, and 1.0. Similarly, I truncate the duration to everything after 250 discrete timesteps when temperatures begin to stabilise.







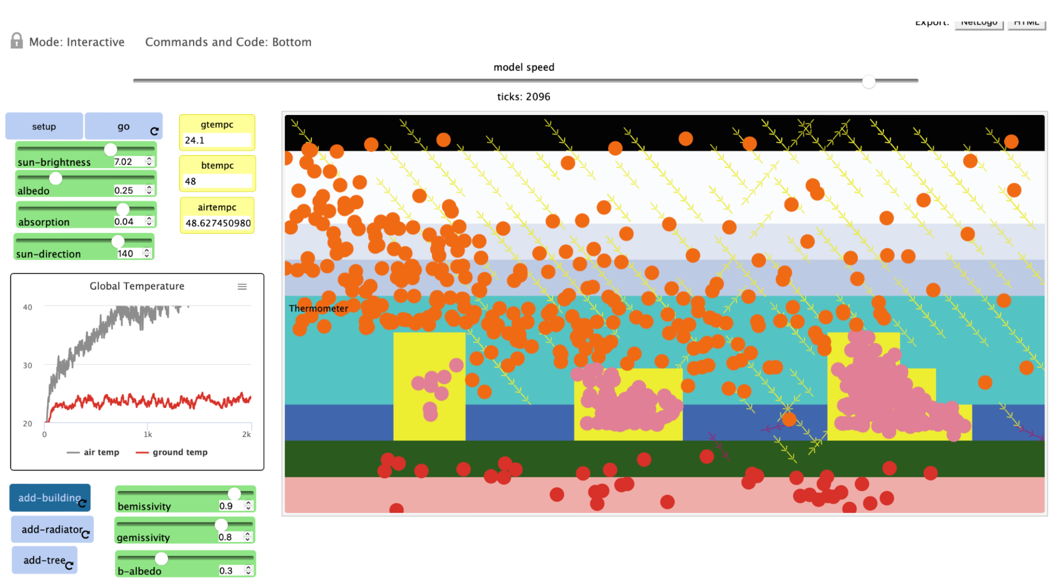
Albedo	Air Temperature (ºC) (mean | stddev)		Ground Temperature (ºC) (mean | stddev)	
0.0	29.8	1.1	30.6	0.8
0.25	30.1	1.2	29.9	0.8
0.5	30.3	1.2	28.9	0.8
0.75	30.8	1.0	27.6	0.9
1.0	31.5	1.2	26.5	0.7



Based on the collected data and plot above, there is an inverse relationship between the albedo and ground temperature. This means when albedo increases, the ground temperature decreases. There is a positive relationship between albedo and air temperature. This means as albedo increases, air temperature increases as well. The red and green bands are the standard deviations for ground and air temperatures respectively.

Part 2

A. Keeping all else constant, 3 buildings (yellow blocks in screenshot below) were added to simulate a city environment compared to the "rural" environment from Part 1. I ran the simulation for ~2K discrete timesteps and collected the air and ground temperature logs. I truncate the computation of the average temperatures to a window beyond 250 timesteps when temperatures begin to stabilise.

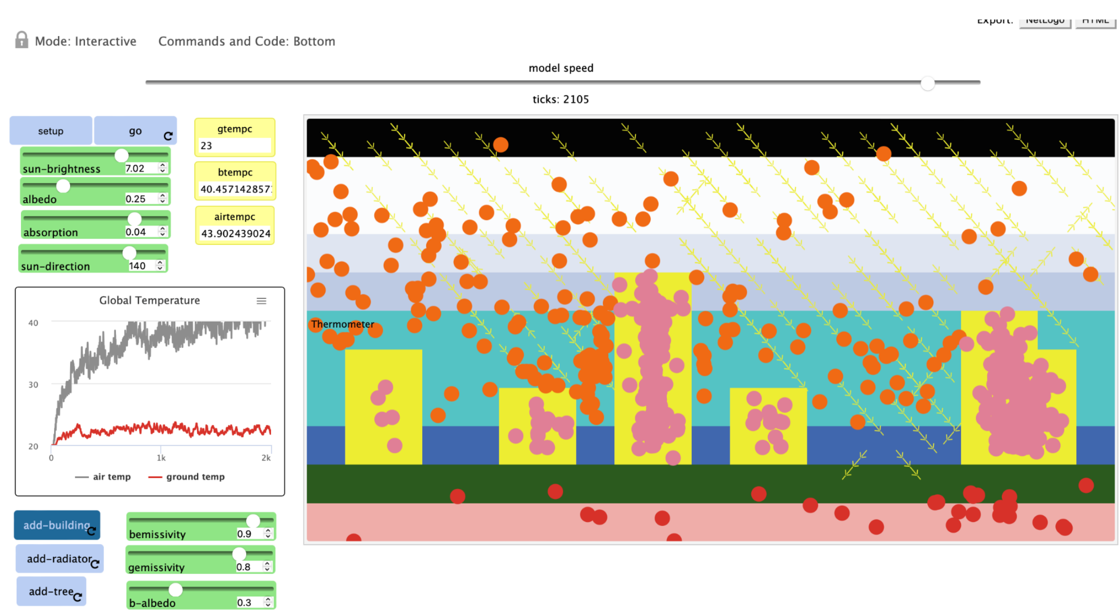


<table>
<tr><th>Albedo</th><th colspan="2">Air Temperature (ºC)
(mean | stddev)</th><th colspan="2">Ground Temperature (ºC)
(mean | stddev)</th></tr>
<tr><td>0.25</td><td>40.7</td><td>4.7</td><td>23.6</td><td>0.6</td></tr>
</table>

Also, notice how the building temperature, **btempc**, is very high at ~48ºC relative to the ground temperature.

Evidently, the presence of buildings causes air temperatures to significantly increase while ground temperatures decrease. Possibly, due to a lowering of the sun's rays falling on the ground, the ground temperature starts to fall. Similarly, due to intense solar reflection (off the tall building surfaces) taking place at higher altitudes, the air temperature increases as there is higher heat concentration in the air.

B. Keeping all else constant, I add 5 expansive buildings that cover the ground (refer to screenshot below). Of course, the air temperature stays at the high temperature and ground temperatures decrease lower than with just 3 buildings, given the possible reasoning in Part 1.

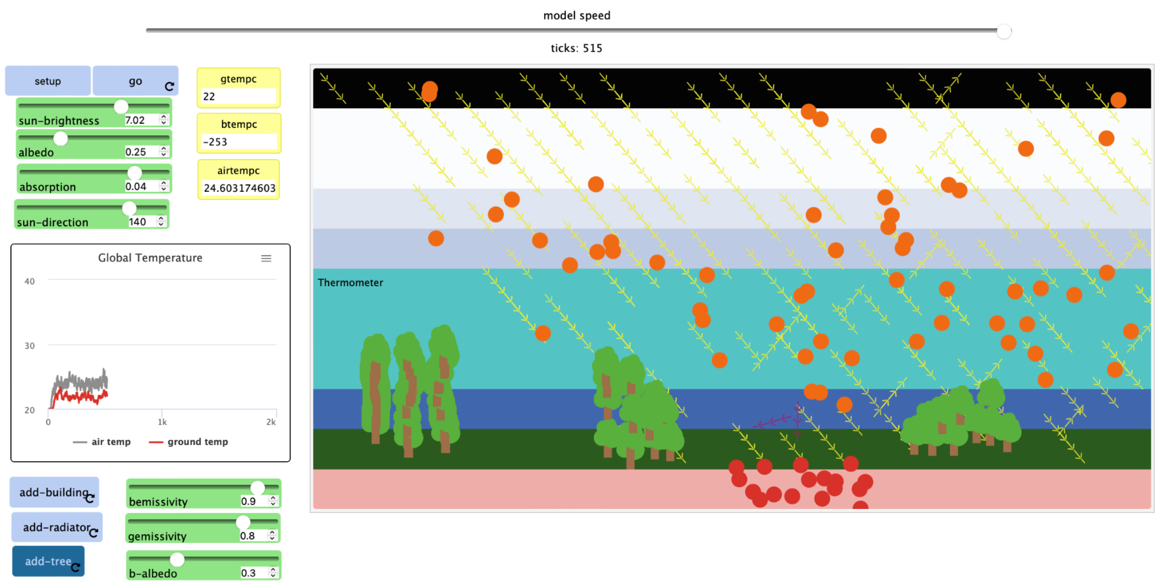


The building temperature, **btempc**, continues to exist at very high temperatures of ~40ºC relative to the ground temperature.

<table>
<tr><th>Albedo</th><th colspan="2">Air Temperature (ºC)
(mean | stddev)</th><th colspan="2">Ground Temperature (ºC)
(mean | stddev)</th></tr>
<tr><td>0.25</td><td>38.2</td><td>2.8</td><td>22.4</td><td>0.5</td></tr>
</table>

Part 3

Keeping all else constant, I now ran this tree simulation for ~500 discrete timesteps given the lag it produces on my device. The trees drawn in the screenshot below represent sparse forests and shrubbery. I truncate the data to everything after 30 discrete timesteps when temperatures start to stabilise.



Albedo	Air Temperature (ºC) (mean | stddev)		Ground Temperature (ºC) (mean | stddev)	
0.25	23.9	0.6	21.8	0.4

Evidently, the air temperature is a lot cooler with trees on the ground compared to the temperature in Part 1 without any trees and shrubbery on the ground. Concurrently, even ground temperatures are lower than in Part 1 with the presence of trees.

Possibly, the trees take in a fraction of the incoming solar rays for photosynthesis. Given the concentration of trees in certain areas of the map, those areas contribute to the global decrease in air (and ground) temperatures. Additionally, [transpirative cooling](#) allows the surrounding air temperature to decrease since cool water vapour is released back into the environment.

Part 4

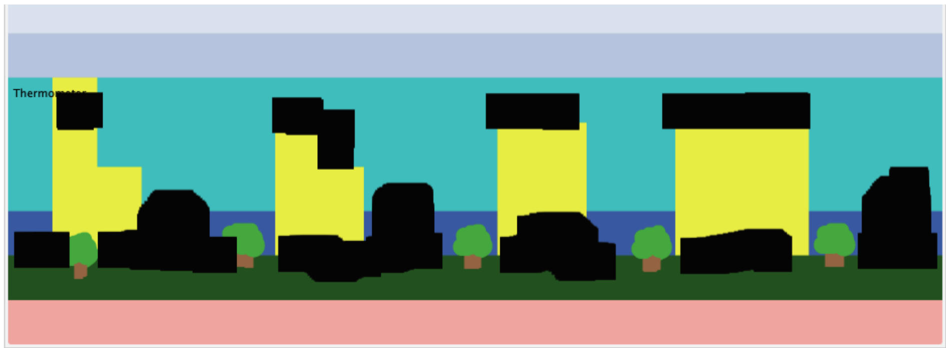
Keeping all else constant, the presence of radiators (black columns), that mimic anthropogenic heating, increase the air temperature (and ground temperature). Compared to Part 1, both temperatures have increased since more heat from the radiators is released into the atmosphere above the surface.

Similarly, I look at the window after 250 timesteps once the temperatures start to stabilise. I record it for ~2000 timesteps.

Albedo	Air Temperature (ºC) (mean | stddev)		Ground Temperature (ºC) (mean | stddev)	
0.25	32.0	1.2	32.3	0.9

Part 5

A. The environment is an urban/metropolitan city. I document my design choices like so:
  - Trees are sparse but still present
  - Many tall buildings representing skyscrapers. There are occasional buildings with shrubbery on the surface of the buildings (eg: Park Royal Hotel, Pickering Street, Singapore) .
  - Radiators on the ground simulating vehicular exhaust and traffic. Building rooftops also have a radiator to mimic fumes and heat through chimneys.



Keeping all things constant, the air temperature increases significantly compared to temperatures in Part 1. This could be due to the hot air from the surface rising towards the atmosphere. However, what is counterintuitive is the lower, almost constant ground temperatures despite the presence of many radiators (simulating vehicular exhaust and dust). I look at the window beyond 250 timesteps when temperatures stabilise on their trends.

Albedo	Air Temperature (ºC) (mean | stddev)		Ground Temperature (ºC) (mean | stddev)	
0.25	33.1	3.1	20.5	0.2

B. This model is highly limited in terms of its scope, plausibility, and utility. It might be too simple when modelling complex environments with many interacting components.

   While it may be valid for open-country-like environments where the sun is the primary heat source without many physical features/elements, it is not reliable to model a dense city where there are other major secondary sources of heat like fumes, dust, and exhaust, which should cause ground temperatures to increase compared to Part 1 and Part 5A. This model doesn't account for such aspects which makes it inaccurate.

   Also, it shows most of the sun's rays being reflected back up towards the atmosphere (on average) with very few solar rays hitting the ground after being reflected off the buildings. This may be why the ground temperatures are still very low in Part 5A.