# Factors Affecting Average Global Temperature

**Purpose:** The purpose of this electronic lab is to investigate three of the many factors that affect Earth’s average global temperature; the greenhouse effect, cloud cover, and albedo.

**Background information** (You will need some of this info to answer the Qs)**:**

Earth’s atmosphere is made of mostly nitrogen N₂ and oxygen O₂ gases, but also contains small amounts of many other gases. These other gases include carbon dioxide CO₂, water vapor H₂O, and methane CH₄. Gases that absorb and reemit infrared light are greenhouse gases. Gases that do not interact with infrared light are not greenhouse gases. The **greenhouse effect** makes temperatures favourable for life on Earth but makes other planets, like Venus, uninhabitable.

**Albedo**is the fraction of light that a surface reflects. A surface that reflects 100% of light has an albedo of 1, while a surface that absorbs 100% of light has an albedo of zero.

**Instructions:** For each part, follow the instructions to set up each scenario in the simulation and answer the corresponding questions.

## Part 1: Greenhouse Gases

Go to

[https://phet.colorado.edu/sims/html/molecules-and-light/latest/moleculesand-light\_all.html](https://phet.colorado.edu/sims/html/molecules-and-light/latest/molecules-and-light_all.html)

In this simulation, you will observe how different wavelengths of the electromagnetic spectrum (just the two in the table below) interact with different molecules of gas. Try passing photons of light (press the green button) of infrared and visible light through molecules of each of the gases listed in the table below. Describe the interaction (behaviour) for each in table one below.

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| Gas | Behaviour in Visible light | Behaviour in Infrared light |
| Carbon dioxide |  |  |
| Nitrogen |  |  |
| Oxygen |  |  |
| Methane |  |  |
| Water Vapour |  |  |
| Nitrogen dioxide |  |  |
| Ozone |  |  |

1. What characteristic makes a greenhouse gas different from other gases?

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1. Based on your observations, which gases in the table above are greenhouse gases.

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The remaining parts of the lab, you will use the simulations at the link below. For Part 2, click the Layer model

## [https://phet.colorado.edu/sims/html/greenhouse-effect/latest/greenhouse-effect\_all.html](https://phet.colorado.edu/sims/html/greenhouse-effect/latest/greenhouse-effect_all.html%20)

## Part 2: Modelling the Greenhouse Effect with Absorbing Layers

In the Layer Model module,

1. set the albedo (reflectivity of a surface) to 0.3 to approximate Earth’s current average albedo.
2. Click on *Flux Meter.* Drag the flux meter to just above the surface of the earth.
3. Click on *Start Sunlight*, and let the sim run until the surface temperature stabilizes.

The **Earth absorbs the sunlight** photons (yellow) and then, **radiates infrared** photons (red). The *Flux meter* measures the two things – the amount of sunlight being absorbed by the earth (↓) and reflected (↑); and the amount of infra red being absorbed by the earth (↓) and reflected (↑).

Using the arrows on the *Flux Meter*, record the amount (there are no units) of both incoming and outgoing sunlight radiation; and infrared radiation in the table below (in the first row). Then, calculate the totals.

Add one absorbing layer (this represents one greenhouse present in the atmosphere), and keep the flux meter just above the surface of the earth. Let the simulation run until the surface temperature stabilizes and again record the data in table two below.

1. What effect does the absorbing layer have on the sunlight photons (yellow)? Look closely at the simulation!

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1. What effect does the absorbing layer have on the infrared photons (red)? Again, pay close attention to the sim.

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Add another layer and record the data. Finally, add a third layer and record the data.

Table 2: Date on atmospheric absorption of radiation

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| **# of Layers** | **Sunlight In** | **Infrared In** | **Total In** | **Sunlight Out** | **Infrared Out** | **Total Out** | **Surface Temp (0C)** |
| 0 |  |  |  |  |  |  |  |
| 1 |  |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |  |

1. As you added absorbing layers which each represented a greenhouse gas, describe the change in the amount of (i) sunlight radiation being absorbed at the earth’s surface; and (ii) infrared radiation being absorbed at the earth’s surface. (A simple unchanged, increase, decrease will do)

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| 1. sunlight radiation being absorbed at the earth’s surface: |  |  |
| 1. infrared radiation being absorbed at the earth’s surface: |  |  |

1. How did the surface temperature change as you added absorbing layers? Explain why this happens.

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## Part 3: The Greenhouse Effect on Earth

## Go back to the simulations link ([https://phet.colorado.edu/sims/html/greenhouse-effect/latest/greenhouse-effect\_all.html](https://phet.colorado.edu/sims/html/greenhouse-effect/latest/greenhouse-effect_all.html%20)) and click on the Photons module.

## Set the greenhouse gas concentration to none and

## uncheck *Cloud (bottom right)*.

## *Start Sunli*ght and let the simulation run until the surface temperature stabilizes.

1. With no greenhouse gases or clouds in the atmosphere, what is the temperature at the surface of Earth?

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Slowly move the greenhouse gas concentration slider upward and stop at the middle.

1. Observe the behaviour of the infrared photons. Explain what is happening.

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1. When the slider is in the middle, what is the surface temperature? How does this compare to the temperature when there are no greenhouse gases present.

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1. An increase in greenhouse gas concentration leads to a(n) (**increase** or **decrease**) in surface temperature.

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Reset the photon simulation by:

* Under *Greenhouse Gas Concentration*, click on the calendar. Set the conditions to *Ice Age*.
* Record the greenhouse gas concentrations in the table below.
* Run the simulation until the temperature stabilizes. Record the surface temperature in the table below.
* Complete the table (Table3) below by running the simulation for the remaining time periods.

Table 3: Data on Earth conditions at different time periods.

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| Time Period | Greenhouse Gas Concentrations | | | Temperature (0C) |
| CO₂ (ppm) | CH₄ (ppb) | N₂0 (ppb) |
| Ice Age |  |  |  |  |
| 1750 |  |  |  |  |
| 1950 |  |  |  |  |
| 2020 |  |  |  |  |

1. Notice the different units for CO2 gas and CH4 and N2O (ppm versus ppb). Describe the different meaning of ppm and ppb; and explain what this means in term of the amounts of each gas in the atmosphere.

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1. From the Ice Age to 2020, how much did the global average temperature increase? Based on the table above, what was/were the contributing factors to this temperature increase?

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## Part 4: Effect of Clouds on Temperature

Reset the photons simulation from calendar to greenhouse gas concentration.

* Start with the greenhouse gas concentration at zero.
* check *Cloud* to simulate the presence of clouds.
* *Start Sunlight*. Allow the surface temperature to stabilize.

Observe the simulation carefully, looking at how several of the sunlight photons and infra-red photons are moving.

1. Describe how the sunlight photons are interacting with the cloud?

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1. How are the infrared photons interacting with the cloud?

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1. Did the surface temperature increase, decrease or stay the same? (compare to the temperature in Part 3 Question 1)

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For the following questions, use the internet to research.

1. What effect can clouds have on surface temperature **on a local scale** during the day?

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1. What effect can clouds have on surface temperature **on a local scale** during the night?

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1. What is the net effect of cloud cover on Earth's global temperature today?

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## Part 5: Albedo

**Albedo**is the fraction of light that a surface reflects. A surface that reflects 100% of light has an albedo of 1, while a surface that absorbs 100% of light has an albedo of zero. Keep in mind that a perfect absorber is also a zero reflector.

## Go back to the simulations link ([https://phet.colorado.edu/sims/html/greenhouse-effect/latest/greenhouse-effect\_all.html](https://phet.colorado.edu/sims/html/greenhouse-effect/latest/greenhouse-effect_all.html%20)) and click on the Layer Model module.

* Set the surface albedo to zero.
* Click on *Flux Meter.* Drag the flux meter to just above the surface.
* Click on *Start Sunlight*, and let the sim run until the temperature stabilizes.

The Earth **absorbs** the **sunlight** **photons** (yellow) entirely (as albedo, or reflectivity is set to zero – none of the sunlight photons are reflected, all are absorbed) and then, this absorbed energy is **reradiated** from the surface of the earth as **infrared photons** (red).

1. Compare and contrast the *Energy Flux* sunlight and infrared arrows. Relate your observation to the fact that you set the albedo to zero (see opening paragraph).

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1. What is the surface temperature in this scenario?

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Reset the simulation by:

* Set the albedo to 0.3 (30%), which is the current average albedo of Earth’s surface.
* Click on *Start Sunlight* and let the sim run until the temperature stabilizes.

1. Observe the *Energy Flux* sunlight and infrared arrows. Explain why they look the way they do at o.3 albedo.

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1. What is the temperature and why is it colder than the temperature with zero albedo?

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While the sim is running, slowly increase the albedo of Earth’s surface.

1. Observe the *Energy Flux* arrows for sunlight and infrared radiation. What happens to the temperature? Explain why.

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**Closing Questions:** Do you think Earth’s albedo was more or less during the Ice Age than it is now? Would this affect global temperature? Explain.

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