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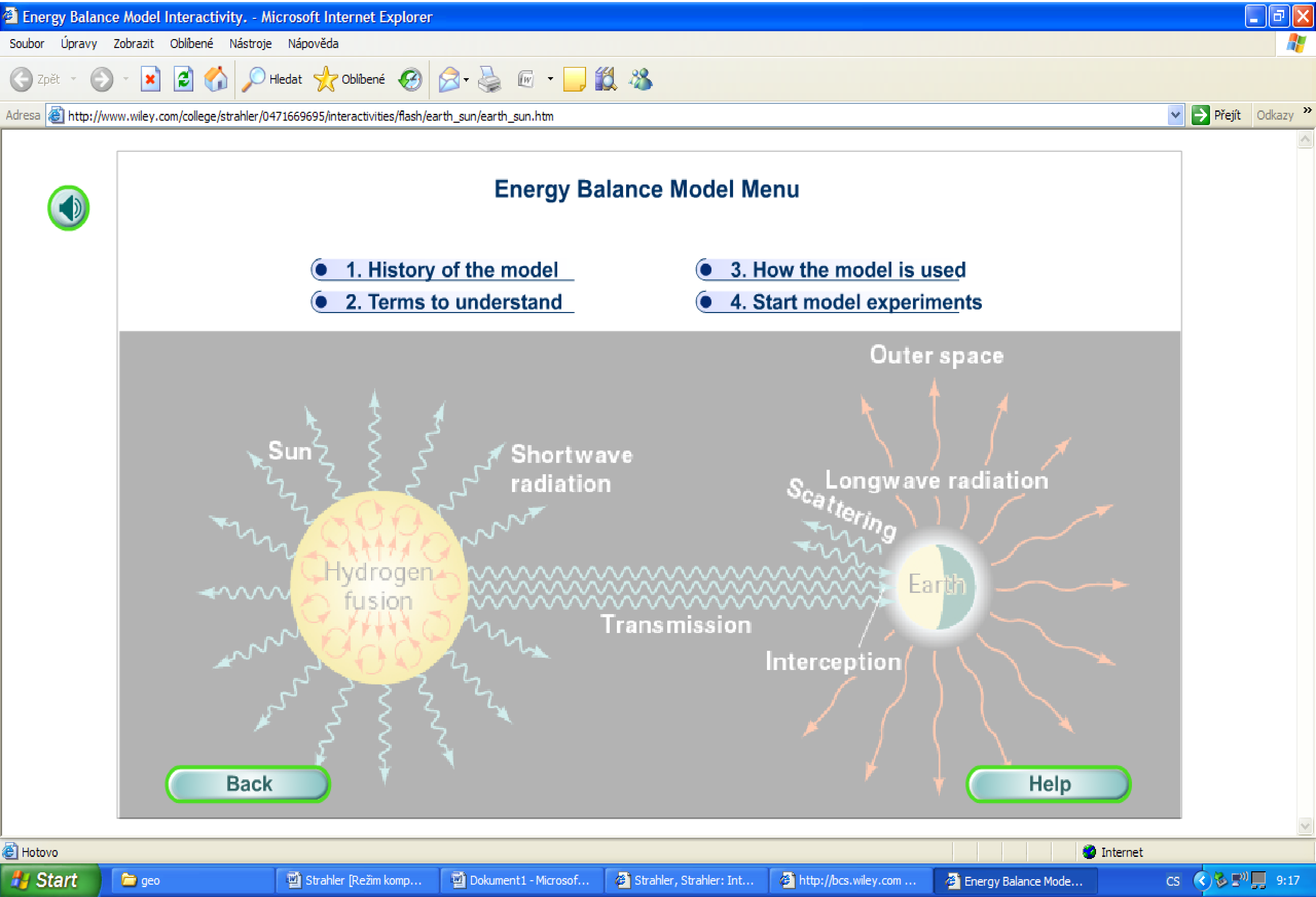
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The History of the Energy Balance Model

The energy balance model was developed separately by two different scientists within just a few months of each other. In 1969, M. I. Budyko a Russian, demonstrated a simple climate model based on the principles of the Earth's energy balance. Around the same time, W. D. Sellers, a US scientist, published a paper outlining his model based on the same principles. These two scientists had not collaborated on their models, and indeed this happened during the Cold War when there was little in the way of communication between the Soviet Union (USSR) and the USA. Their models also depended on the rudimentary and cumbersome computers of the era. Today these models are often referred to as Budyko-Sellers models, and although there are many more complex and realistic models, the energy balance model is a useful tool to teach us about the Earth's climate.

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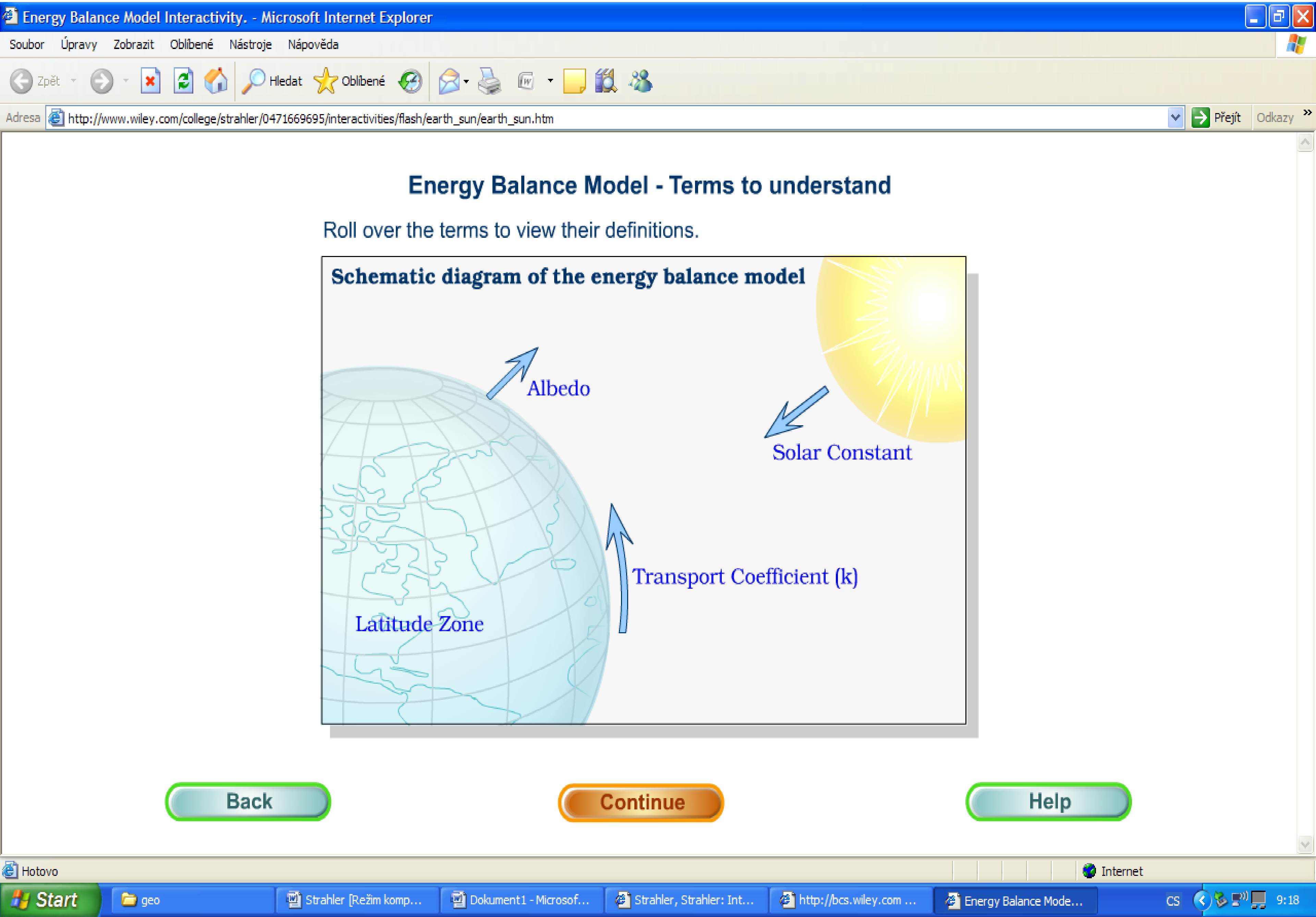
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Energy Balance Model - Terms to understand
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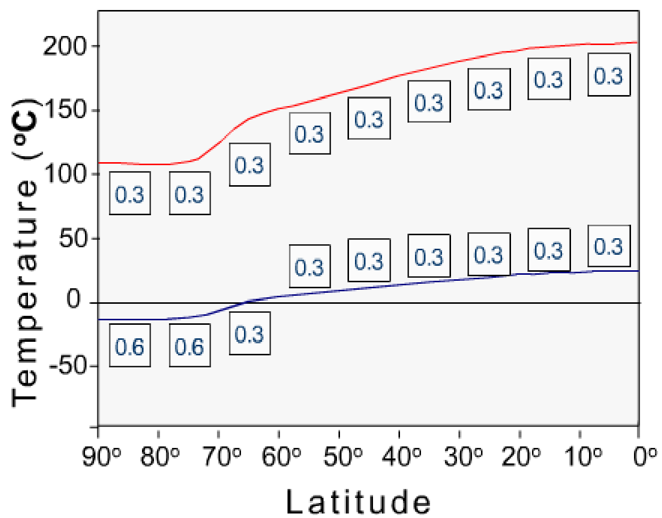
Energy Balance Model - How the model is used

The model generates temperatures and albedos for 9 latitude zones from the equator to the pole. You can choose different simulations to see the effect of changing certain variables. For example, the simulation you can see here shows what happens if we increase the solar constant from today's average on Earth (taken to have a value of 1.0) to 2.58 which is what it would be at the location of the planet Mercury. Each graph also shows the albedos of the surface. 0.6 is the "norm" for the simulation although that can be changed. The "norm" for the land surface is 0.3, although that too can be changed and represents the global average."

When you look at these simulations, ask yourself the following questions:

1. How do temperatures compare to the normal?
2. How do changes at the equator differ from those at the pole?
3. How have the albedos changed?



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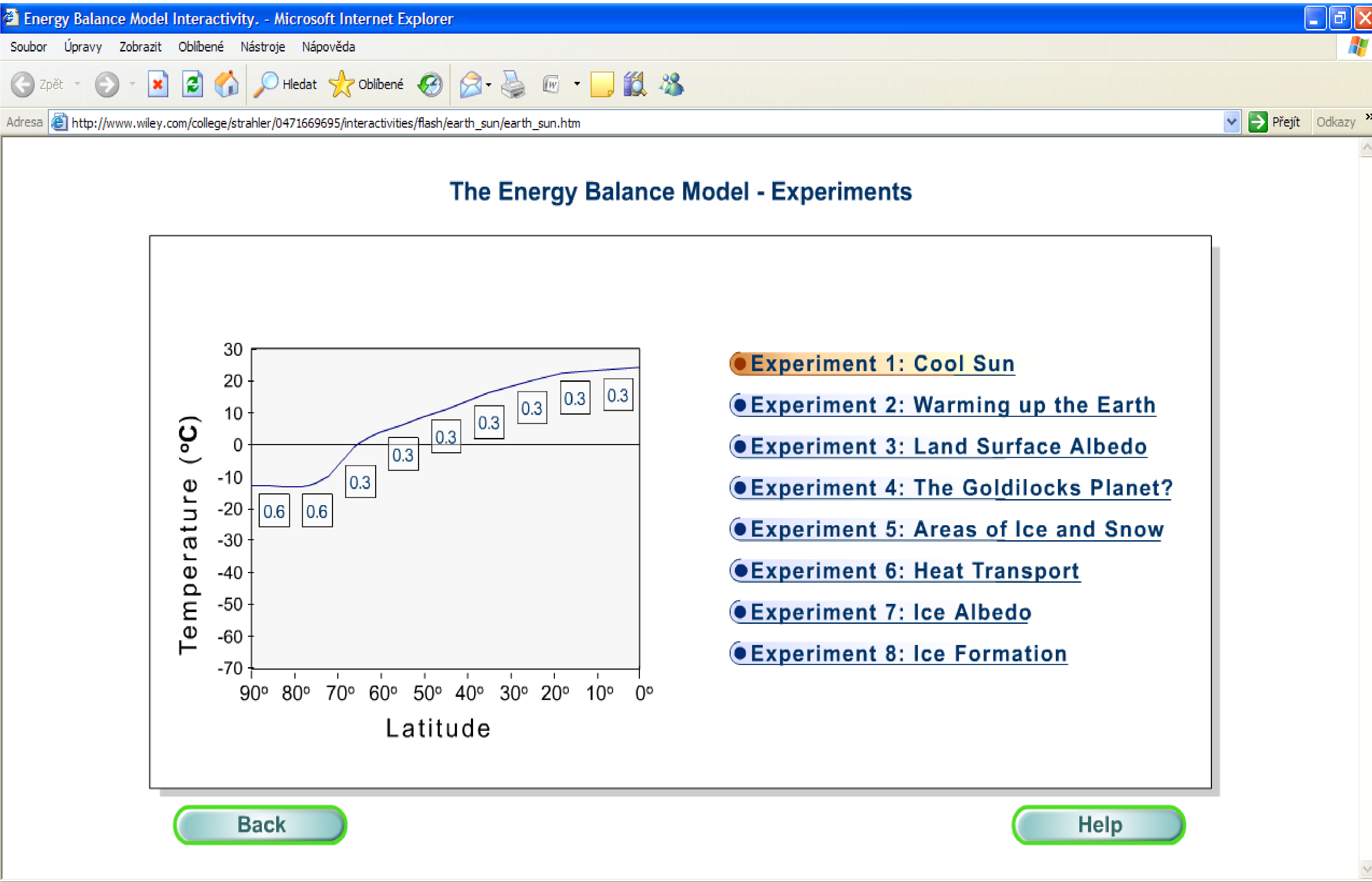
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The Energy Balance Model - Experiments
Temperature (°C)
30 20 10 0 -10 -20 -30 -40 -50 -60 -70
0.6 0.6 0.3 0.3 0.3 0.3 0.3 0.3 0.3
90° 80° 70° 60° 50° 40° 30° 20° 10° 0°
Latitude
Experiment 1: Cool Sun
Experiment 2: Warming up the Earth
Experiment 3: Land Surface Albedo
Experiment 4: The Goldilocks Planet?
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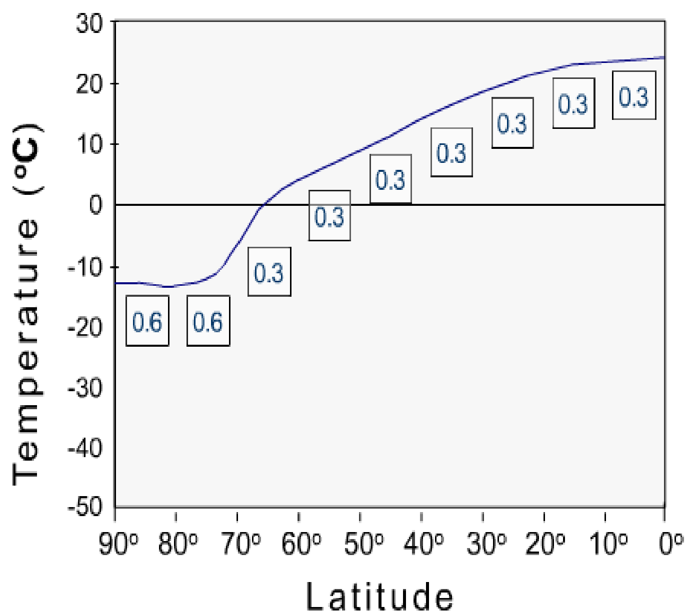
The Energy Balance Model

Experiment 2: Warming up the Earth

Imagine that the Earth was covered in ice from pole to equator. Change the albedos of all of the latitude zones to simulate ice coverage Choose a simulation to see what this may have looked like under these conditions with today's current solar luminosity.



Solar Constant = 1.0

Solar Constant = 1.1

Solar Constant = 1.3

Solar Constant = 1.4

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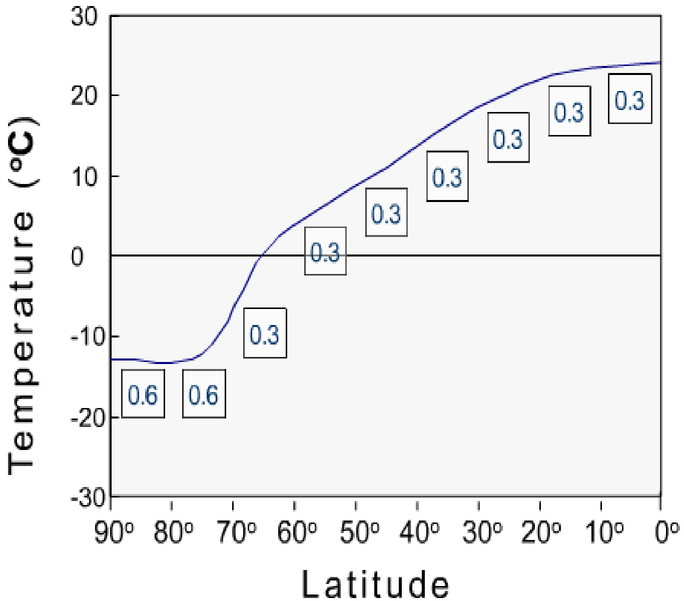
The Energy Balance Model

Experiment 3: Land Surface Albedo

The albedo prescribed for the land surface in this model, where it is not covered by ice and snow is 0.3. Of course, this is an average and worldwide the albedos of different land surfaces vary a great deal. One area of the world where we see albedo change is on the margins of desert regions where, if vegetation is removed, we see a corresponding increase in the albedo. Take a look at these simulations to see what effects changing the albedo can have on our model. Start by increasing the albedo a little, then increase it over a larger area.



Land surface albedo = 0.40 at latitude 20-40 degrees	Land surface albedo = 0.35 at latitude 20-40 degrees
Land surface albedo = 0.40 at latitude 20-30 degrees	Land surface albedo = 0.35 at latitude 20-30 degrees

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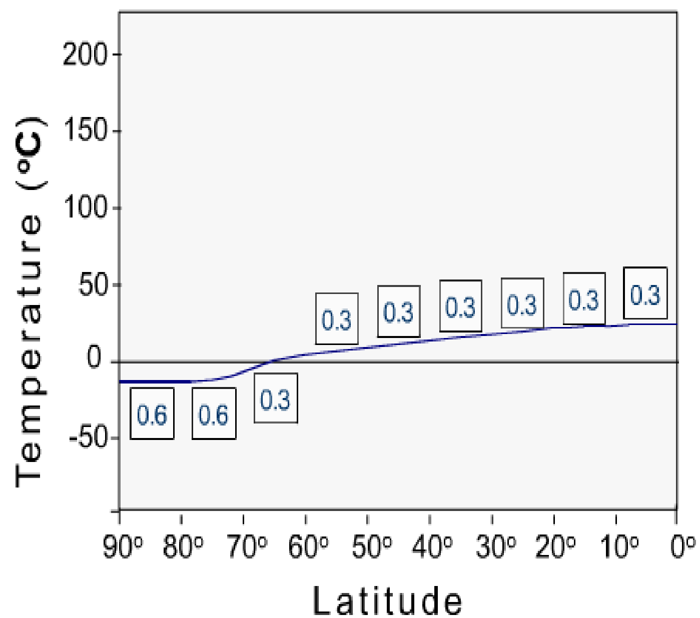
The Energy Balance Model

Experiment 4: The Goldilocks Planet?

One of the questions that arises from looking at changes in the Sun and their impact on the climate concerns the state of other planets in our solar system. Planets that are closer to the Sun receive more radiation than those further away. Click on the "Help" button to see the equivalent solar constants for the different planets in the solar system. View simulations from the the E.B.M. for some other planets to identify why the Earth is sometimes called "The Goldilocks Planet".



Solar Constant at Venus =1.38	Solar Constant at Mars =0.66
Solar Constant at Jupiter =0.19	Solar Constant at Mercury =2.58

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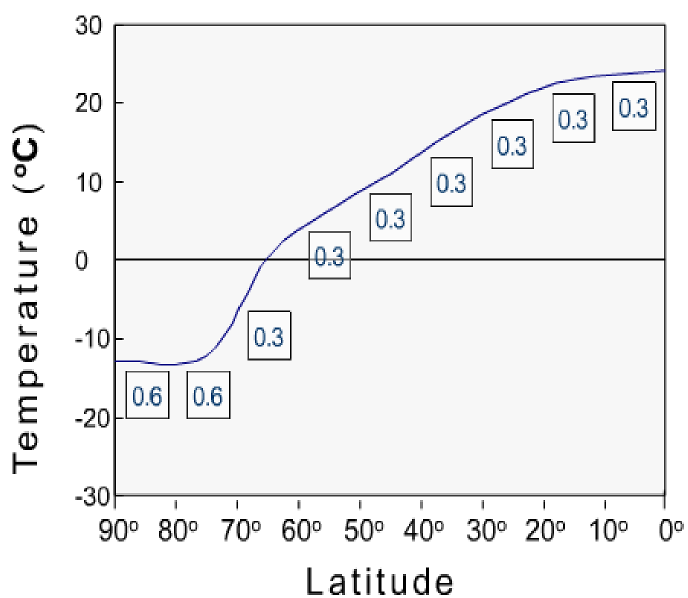
The Energy Balance Model

Experiment 5: Areas of Ice and Snow

As we have seen, ice and snow has a strong influence on the global albedo. The ice albedo feedback, which is a positive feedback, could potentially lead to a global glacier should the area of ice and snow become large enough. Examine simulations showing different areas covered by ice and snow. Consider when the feedback could trigger a global glaciation.



Ice covers from the pole to 60 degrees

Ice covers from the pole to 50 degrees

Ice covers from the pole to 40 degrees

Ice covers from the pole to 30 degrees

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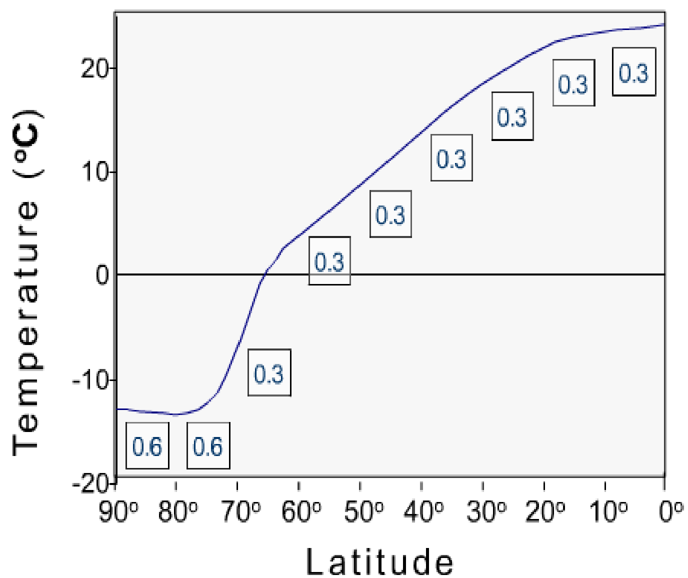
The Energy Balance Model

Experiment 6: Heat Transport

Poleward heat transfer is driven by the imbalances in net radiation between the equator and the pole. By transferring heat polewards, this transfer prevents a much more extreme temperature gradient. The very simple term used to describe this feature is referred to as "k", the transport coefficient. Take a look at some simulations to show what happens if we reduce the heat transport.



Transport Coefficient K= 3.80

Transport Coefficient K= 3.70

Transport Coefficient K= 3.50

Transport Coefficient K= 3.30

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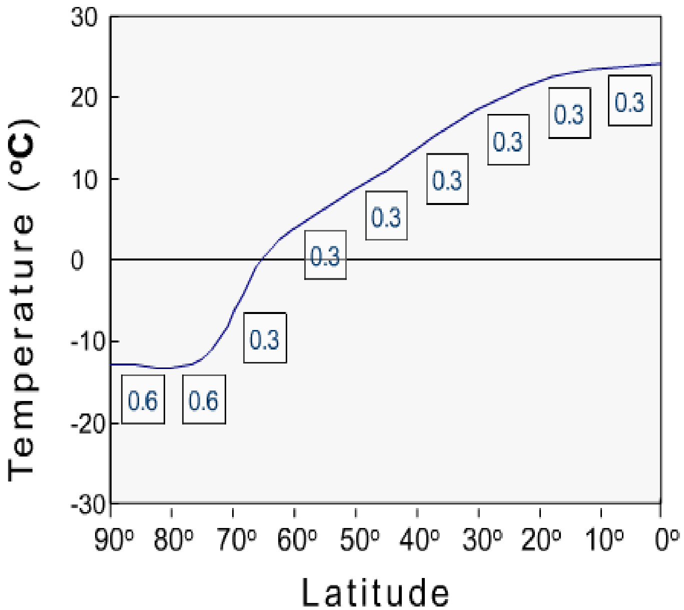
The Energy Balance Model

Experiment 7: Ice Albedo

To this point, we have been running the model assuming that ice and snow covered areas have an albedo of 0.6. Ice and snow generally have a high albedo of anywhere between 40% for old snow to 80% for new, fresh snow. View some simulations here to identify the effect of changing the albedo of ice and snow.



Albedo of the ice = 0.65

Albedo of the ice = 0.7

Albedo of the ice = 0.75

Albedo of the ice = 0.8

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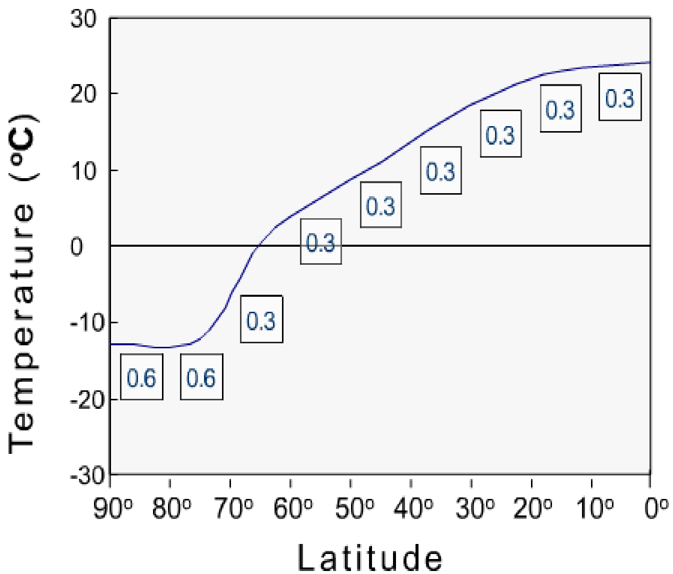
The Energy Balance Model

Experiment 8: Ice Formation

This simple model also simulates how ice forms below a certain temperature. Normally this is set at -10 degrees. In other words, if a latitude band is below -10 degrees it is said to be entirely covered by ice and snow. However, due to this simplicity, slight changes in the threshold temperature do not necessarily create different climates. That is because the initial conditions of the model have no latitude bands with temperatures between -5 and -10 degrees. View some of these simulations to see the effect of changing the threshold temperature.



Ice forms at -5

Ice forms at -1

Ice forms at -15

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