

2 Radiative-Convective Model Practical

2.1 Introduction

In this practical, you will run a very simple Radiative-Convective (RC) model and examine the output. The model is essentially a numerical version of the analytical model we constructed in lecture 8. However, the fact that it is numerical means that it is straightforward to extend it in a variety of ways. For example, we can observe how the equilibrium condition is reached, include the absorption of visible light, and turn on a simple convective scheme.

2.2 Getting started

2.2.1 Logging on and getting the model: What should happen

You need the machine to be running Linux, not Windows. If it is currently running Windows, then re-boot it into Linux.¹ Log in with your user name and password² You will need to download the model code. Do this by typing this URL into your web browser

`http://xweb.geos.ed.ac.uk/~hcp/poc_lab`

... and then right-clicking on the relevant link. Choose “Save Link as” and then select your home directory as the place to save the file. You should end up with a file called `grey_1d.R`. The model

needs to be run from a terminal window: start this using the button  in the bar at the top of the screen.

2.2.2 Logging on and getting the model: The back-up plan

If everything in section 2.2.1 has worked, then ignore this section and go directly to section 2.2.3. These instructions are just here in case you can not log in to the LCFG machines. Log in to one of the PCs using your usual Windows username and password. (You may have to hit the power button to wake the machine up.) The model is run on a Linux machine called fleet. To connect to this, use the Windows menu, choosing the item:

All Programs→School Applications→Science and Engineering→Geosciences→Connect to→Connect to Fleet

You will be asked for your username and password again. (This time, you want your EASE (SMS) password if it is different from your Windows password.) Once you have logged in you will be presented with an xterm window containing a prompt `:-bash-3.00$` at which you can type commands. Obtain a copy of the model by typing:

```
cp ~/hcp/grey_1d/* .
```

Don't miss out the space and the dot at the end of that command.

2.2.3 Getting started with the model

The model is written in a language called R. Start R up by typing `R` at the prompt and pressing return. You will see R's startup message and its prompt `>`. Start up the model itself by typing

```
source("grey_1d.R")
```

at the R prompt.

2.3 How it works

The model divides the atmosphere into many isothermal slabs. You can vary the number of slabs between 1 and 60. The edges of the slabs are at fixed *pressures*, not at fixed *altitudes*. This means that the mass of air in each slab does not change as the temperature changes. The model starts by calculating the downward and upward fluxes. From these it can calculate the heating rate H . With a heating rate for every slab, the temperature at a later time can be calculated from the current temperature:

$$T(t + \delta t) = T(t) + H\delta t$$

¹Do Ctrl-Alt-Del then press the Options button, then the Shutdown button, then choose “Restart” from the list and press the OK button. Watch the machine as it re-starts. When it reaches the gray GRUB boot screen, choose LCFG quickly. If you are not quick, the machine will re-boot into Windows.

²If your EASE password is different from your Windows password then you want the WINDOWS password.

2.4 Running the model

The model control window has a variety of sliders to adjust the model's parameters. You can always set it back to the default configuration with the `default settings` button.

When you press the `Run 1d-RC Model` button, the settings you have dialled in are fed to the model, which runs for a while. When it has finished, a window appears, displaying the results. Having looked at them, you can adjust the sliders and re-run.

2.5 The grey atmosphere

The default settings correspond to the analytical case we looked at in lectures. The atmosphere has a diffusive optical depth of $\chi^* = 3$ and hence a transmissivity of $\tau = 0.05$. The atmosphere is made up of slabs of air which has the same heat capacity as real air.

- Do the upward and downward fluxes look as you expect?
- How well does the surface temperature agree with the analytical answer (which was 321 K)? Does this depend on the number of slabs? How many slabs do you need for a good agreement with the analytical answer?
- Does the answer with one slab agree with the single slab model from lecture 5?
- How long does the model take to reach equilibrium? Which part of the atmosphere reaches equilibrium the fastest?

2.6 Adding the visible radiation

The visible radiation is simple to add because the atmosphere only absorbs it: it does not emit it. The visible flux densities and heating rate do not vary with the temperature of the atmosphere and can be calculated once at the beginning of the run.

Press the “default settings” button to set all the sliders back to their standard positions. Now increase the absorption for incoming sunlight to 0.036 units — this will give a total transmissivity of 0.7.

- How does this affect the surface temperature?
- What happens if the atmosphere is *more* absorbing for the incoming solar radiation than for the long-wave infra-red radiation?

2.7 Adding convection

Like most 1-d RC models, this one does not attempt to model convection properly. We merely note that the real atmosphere does not have lapse rates greater than a given value, and adjust any lapse rate generated by the model to be no greater than this critical value (See appendix for details). You can adjust this with the “Max lapse rate” slider on the model’s control panel.

Set the model back to its default settings, and then increase the infra-red absorption so that the lapse rate becomes larger than the Earth’s typical lapse rate of 6.5 K/km. Note the surface temperature and then set the maximum lapse rate to 6.5 K/km. How much difference does the convection make to the the surface temperature?

2.8 Finishing up

If you want to leave R at any point, type `q()` at the R prompt. Please log off the PCs before you leave.

Appendix A. How it works: the convection scheme

Adjusting the lapse rate is not a completely trivial problem. Suppose the uncorrected profile was the line with dots in figure 1. We could start at the top, and for any pair of levels with too large a lapse rate between them, we could replace the lower level with a temperature giving the chosen maximum lapse rate. That gives the dot-dash line T_1 . But we have not conserved energy: we have made some energy vanish. We could alternatively start at the bottom of the profile and adjust the upper layer of each pair to reduce the lapse rate to the critical value. This gives the dashed line T_2 on figure 1, but involves creating some energy. We therefore take a combination of the two profiles $T = (1 - \alpha)T_1 + \alpha T_2$ where α is chosen to ensure that no energy is created or destroyed. This is the solid line with no dots.

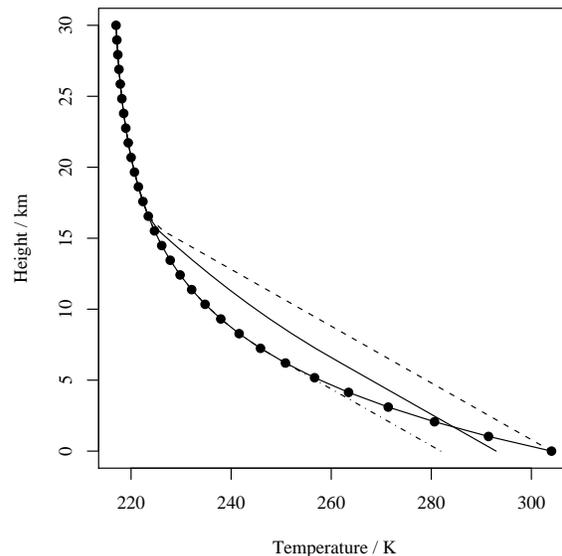


Figure 1: Two ways to fix the lapse rate.