Atmospheric Convection

2023-02-15

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Homework

Homework Exercises:

- *Forecast*, Ch. 5, Ex. 1–2

Notes on Homework:

- These two exercises use two different models. In both models, you adjust parameters to achieve radiative balance (where the heat going out equals the heat coming in), but you adjust different parameters in each model, and each model has a different way for you to tell whether the earth is at radiative equilibrium.

  - The RRTM full-spectrum model is a radiative-convective model that considers the impact of lapse rate on the radiative balance. You can adjust the amount of sunlight hitting the earth, the albedo, the surface temperature, the lapse rate, and other parameters including the amount of cloud cover at different altitudes. The model then divides the atmosphere into many layers and at each layer, it calculates the amount of heat going up and down in the form of shortwave radiation (sunlight) and longwave radiation emitted by the earth and the atmosphere. The model also reports about the balance of heat going up and down at the top of the atmosphere.

    Your goal is to adjust parameters until the model reports that "If the earth has these properties . . . then it loses as much energy as it gains."

    You can also move your mouse over the yellow and purple arrows, which represent shortwave and long-wave radiation, respectively, and the computer will show you the amount of heat flowing up or down (in watts per square meter) for that kind of radiation.

  - The MODTRAN model ignores shortwave light and only considers longwave (infrared) light emitted by the earth's surface and atmosphere. When you start it up, you pick a locality (for this exercise, use "Tropical Atmosphere" just as you did for the exercises in Chapter 4) and the model will initialize to conditions of radiative balance at that locality (for the tropical atmosphere, this is 298.52 W/m^2). You can then adjust

all sorts of parameters (the concentrations of different gases, the conditions of clouds or rain, and the temperature of the ground), and the model will calculate the new upward longwave heat flux at the altitude you specify. You want to make a note of the upward IR heat flux for the default conditions before you start changing things, and then when you change parameters, such as the amount of CO_2 in the atmosphere, you can adjust the ground temperature until the upward IR heat flux returns to its initial value.

- For Exercise 1, use the RRTM full-spectrum model, at https://climatemodels.jgilligan.org/rrtm/ or http://climatemodels.uchicago.edu/rrtm/. For this model, you set the lapse rate, CO_2 concentration, etc., and the model automatically calculates the imbalance between I_{in} and I_{out}. You can then adjust the surface temperature until the model reports, "... then it loses as much energy as it gains."

  I recommend trying lapse rates of 2, 4, 6, 8, and 10 K/km. After you change the lapse rate, I recommend setting the temperature to a round multiple of 10 near 270 or 280 K, and adjusting up or down in steps of 10 K until you change from gaining to losing heat or vice versa, and then change in steps of 5 K, then in steps of 1 K, and finally in steps of 0.5, 0.1, and 0.05 as necessary until RRTM reports energy balance.

  Make a table showing the temperature for each lapse rate, and also make a graph of temperature versus lapse rate.

- **There's a typo in exercise 2(a):** The Stefan-Boltzmann constant should be $\sigma = 5.67 \times 10^{-8} \text{W/m}^2\text{K}^4$ (10^{-8}, not 10^8)

- For exercise 2, use the MODTRAN model. Choose "Tropical Atmosphere" for Location and keep the altitude at its default value of 70 km. How would you calculate the skin altitude from this model?

- When exercise 2(d) asks you to add cirrus clouds, use the "NOAA Cirrus model."