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Due: Friday, 28 March, 2003; 14:00

Introduction

This project is based on the simple energy balance model depicted in Fig. 1, the code of which is contained in *energy.m* and *energyinsert.m*. Both are written in Matlab® ; for those of you unfamiliar with Matlab®, a brief *tutorial* explains the basics.

The model is a hybrid of the energy balance model used to explore the ice-albedo feedback and the physics behind a Snowball Earth, a radiative model, and the coupled energy transport model used in Assignment IV. The model consists of an ocean of 2000m depth, and an atmosphere of realistic mass but that assumes it is concentrated in a thin (2 m thick) sheet with the density and heat capacity of water, hovering at some arbitrary height above the ocean. The ocean radiates as a blackbody, while the atmosphere is "grey", that is, of finite absorptivity and emissivity, ε (epsilon).

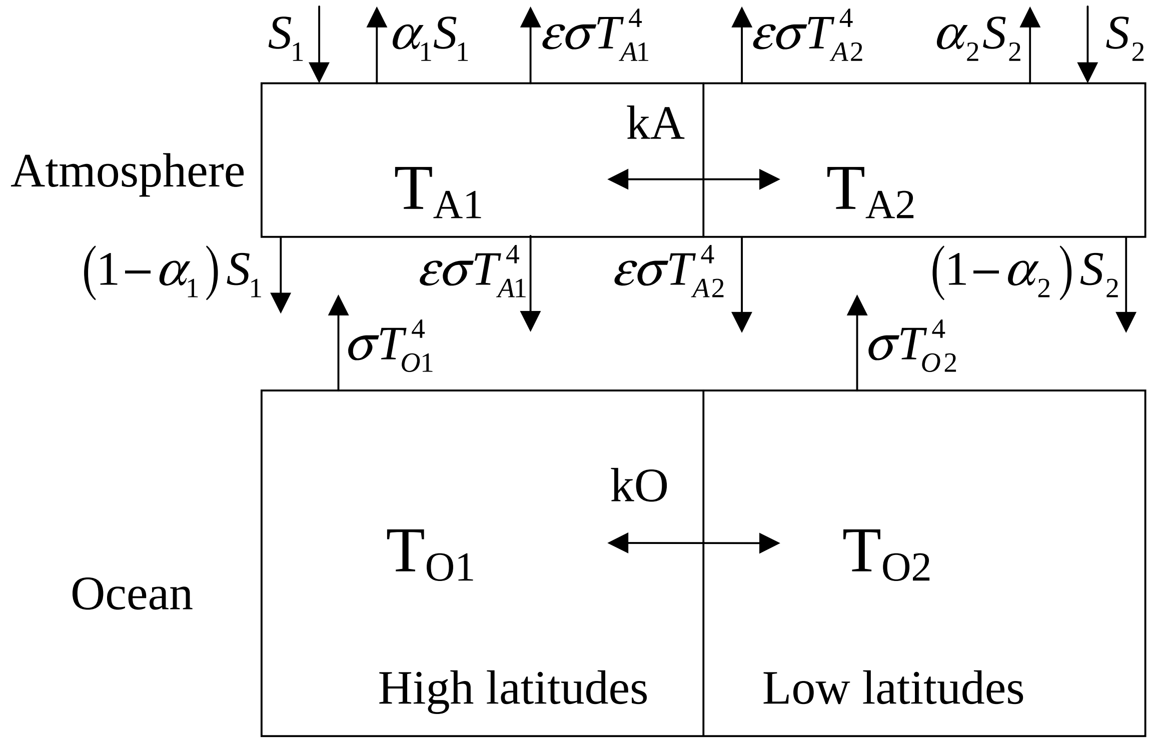

Figure 1. Sketch of the Course Project model.

Notice that in the calculations, all temperatures are in Kelvin.

The atmosphere reflects part of the incoming shortwave radiation with an albedo, α (alpha), that is a function of surface (ocean) temperature. In an extremely crude way, this reflects (!) the effect of increased ice cover. Part of the albedo, alpha_c, arises from cloud cover.

Horizontal energy transports in both ocean and atmosphere are represented as simple linear diffusion with coefficients kO and kA, respectively.

We suggest as the main parameters to be changed:

Incoming solar radiation,	S1 (high lats.), S2 (low lats.)
Atmospheric emissivity,	epsilon
Cloud albedo,	alpha_c
Atmospheric diffusivity,	kA
Oceanic diffusivity,	kO

In addition, these run parameters can be set:

Integration time
Initial temperatures

Many other things can be meaningfully changed around, but entirely at your own risk. If you "munge" (Mashed Until No Good) your code and did not keep a backup, pull down the clean one from the web. Use this model to investigate the tasks outlined below. Many of the questions have open-ended answers; it is up to you to provide the numerical evidence for your conclusions.

Assessment

This Course Project counts for 50% of the course mark. We have given weights to the sub-tasks; notice that we reserve the right go give extra marks for investigations that probe a problem to particular depths. We encourage you to discuss technical aspects of the assignment among yourselves; however, the design, execution, analysis, interpretation, and write-up of your numerical experiments must be entirely your own. A judicious selection of printouts of your numerical results must accompany your write-up to support your conclusions.

Assignments

1. By using the standard set of parameters and, starting from a simulated time of one year or less, run the model over successively longer times to establish which components adjust (come to near-equilibrium) over which timescales. Can you distinguish fast from slow components? Can you find, theoretically, estimates for these adjustment timescales from the model's parameters? Can you formulate conditions that would ensure that model components are in (quasi-) equilibrium? Use examples of the model output to support your statements.

[20%]

2. Establish the strength of the Greenhouse Effect for the standard set of parameters, by varying the atmospheric emissivity, epsilon. What happens if you use extreme values for epsilon? Justify your choices of “extreme values”.

[20%]

3. Investigate the effect of oceanic and atmospheric heat or energy transport on the model’s climate. What is the maximum possible energy transport by the combined, ocean plus atmosphere, system? Can you find a theoretical expression for this maximum transport? Do changes in meridional energy transports affect global mean properties? If so, why?

[20%]

4. By varying either insolation or albedo, can you create a Snowball Earth, that is, find a steady state that has complete ice cover in both high and low latitudes? Can you find a set of parameters that allow both a Snowball Earth and a non-Snowball, depending on your choice of initial conditions?

[20%]

5. Find an interesting question and investigate it with this model.

[20%]