**GEOG 310 Exercise Five (F2022)**

**ENERGY BUDGET MODELS**

**15 points**

**Part I. ZERO Climate Model**

*FIRST READ THE ZERO MODEL GUIDE, ACQUAINT YOURSELF WITH THE PROGRAM, AND THEN DO THE PROBLEMS ON THE LAST TWO PAGES.*

**ZERO COMPUTER CLIMATE MODEL GUIDE**

You will be working with a simple zero-dimensional computer model of the atmosphere. It combines the effects of all atmospheric parameters to produce one result, Global Average Temperature (GAT).

When the program is first started the following will appear on the screen (possibly after a few odd network messages that can be ignored):

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* Global Energy Balance Climate Model Copyright © James E. Burt, 1984

The temperature is 0.0 degrees Celsius,

and all parameters are at their standard values.

Enter: 0-run 1-new temp 2-new parms 3-time step 4-exit > \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* Your response here should be : 0 (be sure to hit the enter/return key) This will initialize the program to the current reference value of global average temperature (15.38 degrees Celsius).

The printout will be:

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* dT/dt s clr s cld ir clr ir cld total total steps

year temp deg/yr w/sq m w/sq m w/sq m w/sq m cloud albedo taken

.0 .00 3.714 123.3 93.4 88.6 102.3 .540 .363 0

10.0 14.29 .300 132.3 103.9 108.6 125.4 .540 .306 7

20.0 15.31 .019 132.9 104.6 110.2 127.2 .540 .301 4

30.0 15.38 .001 132.9 104.6 110.3 127.3 .540 .301 3

40.0 15.38 .000 132.9 104.7 110.3 127.3 .540 .301 2

50.0 15.38 .000 132.9 104.7 110.3 127.3 .540 .301 1

Enter: 0-run 1-new temp 2-new parms 3-time step 4-exit > \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

**ZERO PRINTOUT EXPLANATION**

The ZERO program gives you additional information besides GAT, and also allows you to change 13 variables. The following is a brief explanation of the options and their meaning.

When the program prints:

“Enter: 0-run 1-new temp 2-new parms 3-time step 4-exit >”

This is the main menu.

0 will run the program the specified number of time steps (default is 5 steps of 10 years) and

show the changes in GAT and other variables at each step.

1 allows you to change the current temperature to any value (not particularly useful for simple

applications).

2 prints out the current and standard values of the parameters that you can change in the

program, and allows you to change them.

3 lets you change to a different time step.

4 exits the program when you are finished.

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

The main output of the program shows the following:

1 2 3 4 5 6 7 8 9 10

dT/dt s clr s cld ir clr ir cld total total steps

year temp deg/yr w/sq m w/sq m w/sq m w/sq m cloud albedo taken

.0 15.38 .237 132.9 104.7 109.5 126.4 .540 .301 0

10.0 16.18 .015 133.4 105.2 110.7 127.9 .540 .298 5

20.0 16.23 .001 133.5 105.3 110.8 127.9 .540 .298 3

30.0 16.24 .000 133.5 105.3 110.8 127.9 .540 .298 2

40.0 16.24 .000 133.5 105.3 110.8 127.9 .540 .298 1

50.0 16.24 .000 133.5 105.3 110.8 127.9 .540 .298 1

1. Year shows the results at each specified time step

2. temp shows Global average temperature (GAT)

3. dT/dt shows relatively how fast GAT is changing in degrees/year

4. s clr is the insolation (shortwave) energy absorbed from clear skies

5. s cld is the insolation (shortwave) energy absorbed from cloudy skies

6. ir clr is the longwave (earth) energy going out from clear skies

7. ir cld is the longwave (earth) energy going out from cloudy skies

8. total cloud is the fraction of the earth covered by clouds

9. total albedo is the fraction of solar energy reflected from the earth

10. steps taken shows how "hard" the computer worked to do the calculations

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**ZERO PRINTOUT EXPLANATION (CONTINUED)**

The parameters you can change are as follows:

1 solar parameter (w/sq m)--the total insolation

2 CO2 concentration (ppm)--carbon dioxide concentration

3 cloud fraction--fraction of earth covered by clouds

4 cloud albedo--fraction of insolation reflected by clouds, for example due to different cloud

types or thickness (ice or water)

5 clear albedo--fraction of insolation reflected from the surface of the earth under clear skies

(due to different land surfaces)

6 t-albedo feedback (per deg)--a loop that allows you to cause changes in GAT to change the

albedo (for example a warmer earth should lose some ice cover)

7 cloud emission factor--how much longwave energy is produced by clouds (depends on type

and altitude)

8 above-cloud ir absorbtivity--how much longwave energy produced by clouds is absorbed in

the air above the clouds (depends on how much moisture is there)

9 clear emission factor--how much longwave energy is produced by land surfaces below clear

skies (depends on surface)

10 clear sky ir absorption--how much longwave energy produced under clear skies is absorbed

in the air (depends on gases, moisture, etc.)

11 equiv. mixed ocean depth (m)--the depth of ocean that interacts with the climate system

(variable is very slow to respond and doesn't work well)

12 CO2 ir effect--how much changes in carbon dioxide change longwave trapping (standard

value is "1", which you can decrease or increase, if you think some other factor is

compensating)

13 t-cloud feedback (per deg)--a loop that a allows you to cause changes in GAT to change the

fraction of cloud cover (for example a warmer earth should produce more clouds)

NOTE: Try changing all of these parameters and see how you can “mess up” global climate, or pick some effect you are interested in. One test might be to change something like carbon dioxide, and they try to compensate with the others to “fix” GAT back to its original value.

**GEOG 310 Exercise Five**

**Part I. ZERO Climate Model (5 points**)

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Student#:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Problems: NOTE--RESET TO PRESENT STANDARD CONDITIONS BEFORE STARTING EACH PROBLEM!!!!!!!!!!!!!!!!**

1. Change the solar parameter (#1) to 1300 w/sq. m. What is the new GAT? What causes total

albedo to increase? (1 pt.)

2. Human additions of CO2 into the atmosphere may double its concentration to 640 ppm in the

next century. Set variable #2 to reflect this value. What is the new GAT? What causes

total albedo to decrease? (1 pt.)

3. Human additions of dust into the atmosphere and deforestation will increase albedo. Set the

clear albedo (#5) to .20. What is the new GAT? (½ pt.)

4. Set the solar parameter (#1) to 1300 w/sq. m. What level of CO2 would offset this decrease

and keep GAT at its present (15.38°C) value? (½ pt.)

5. Set the clear albedo (#5) to .20. What level of CO2 would offset this increase and keep GAT

at its present (15.38°C) value? (½ pt.)

6. A future climate scenario may have doubled CO2, increased cloud cover (due to warm

temps.), but higher cloud types, and higher land surface albedo (due to deforestation). Set #2 to 640 ppm, #3 to .60, #4 to .40, and #5 to .17 to reflect this scenario in the model.

What is the new GAT? (½ pt.)

7. Compare the effects of changes in solar radiation, CO2 concentration, and clear albedo on the

model. Rank them according to the sensitivity of GAT to changes in each (absolute

change in GAT per unit percentage change of the variable). Note: a larger absolute

change in GAT means greater sensitivity. (½ pt.)

8. Compare and contrast the advantages and disadvantages of using a simple zero-dimensional

model such as the ZERO model. (½ pt.)

**GEOG 310 Exercise Five**

**Part II. NORTH AND EBMODEL 1-D ENERGY BUDGET MODELS (10 points**)

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Student#:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Your goal in this exercise will be to explore the differences in global climate associated with various carbon dioxide concentrations. You will examine levels during the Pleistocene (.018%), in 1800 (.028%), today (.035%), and projected for 2050 (.053%).

**Part I. NORTH MODEL**

The North model is relatively self-explanatory. Take advantage of “Help” when it is offered.

1. Select CD (Carbon dioxide concentration) as your experimental variable. Use each of the following relative levels for a different experiment (be sure to reset to present climate (PC) after each): Pleistocene (.5), 1800 (.8), today (1)--present climate, 2050 (1.5).

2. For each of the four cases fill in the table (on next page) and report the values of the response variables: TM (mean temperature), temperatures at 0°, 25°, 50°, and 75° latitude (use LV option), SL (snow cover latitude), AP (planetary albedo), and the latitudinal variation variable TG (equator to pole thermal gradient, a proxy of mid-latitude circulation strength).

**Part II. EBMODEL**

The EBMODEL is a much more sophisticated EBM, although slightly 2-D, and therefore very simplistic compared to the state of the art GCMs. Please read the accompanying documentation on the program BEFORE attempting to run it. The program can produce SEASONAL runs which include the variations of the seasonal cycle, but **we will be using the ANNUAL MODE in this exercise**, which averages the months at each latitude (there is also a GLOBAL mode, which work similarly to the ZERO model). Be sure to look at the very nice graphs and tables.

1. Do four separate ANNUAL MODE runs corresponding to the times used in the NORTH model. *Set albedo feedback to -0.111 for ALL of the scenarios below*.

a. today: run with current values (default, except for albedo feedback)

b. Pleistocene: set time to -10,010 AD (-12,000 BP) and CO2 to 175 ppm

c. 1800: set time to 1800 and CO2 to 280 ppm

d. 2050: set time to 2050 and CO2 to 525 ppm

2. For each of the four runs record the Global Average Temperature, and the Northward Heat Transport value (a proxy for mid-latitude circulation strength) at 50̊N (select “Tables” then “E”, and then “14”).

**Part III. Interpreting the models**

3. Using the information from the model runs and your knowledge of causes of global circulation (and other data provided by the model if relevant, such as SEASONAL RUNS), speculate in three short paragraphs (on the back of this page) how the mid-lat. circulation and its features (Rossby waves, Jet Stream) were different than today during the Pleistocene and in 1800, and also how they might be in 2050.

Model Output Table

\*--------------------------------------North Model--------------------------------------\*----EBModel---\*

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| time  (CO2  level) | TM | AP | SL | TG | 0° | 25° | 50° | 75° | GAT | North-ward Heat Trans.  @ 50°N |
| -12000  Pleisto-cene  (.5 or 175ppm) |  | .33 |  |  |  |  |  |  |  |  |
| 1800  .8 or 280ppm) |  |  |  | -30.7°C |  |  |  |  |  |  |
| today  (1 or default) |  |  |  |  |  |  |  |  | 14.64°C |  |
| 2050  (1.5 or 525ppm) |  |  |  |  |  |  |  | -6.4°C |  |  |