Midterm

Computational Physics (**Phys381**)
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Duration: 2 Hours

[Total: 100 marks including 20 marks for the report]

- The latexed report is worth **20%** of the total mark. Only well documented and neatly presented reports will be worth that much! It is not sufficient to give only numerical results and show plots, you should also discuss your results. Include complete figure captions, introduction and conclusion sections.
- Your report must be in a *two-column format*.
- Your report should include your *Fortran code* and *Gnuplot scripts* in an Appendix using the *verbatim* command.
- You must name your report using your first and last name: *firstnamelastname.pdf*.
- **Procedure for Handing in your exam**:

  1) Set permission to your PDF report as 644. It means: chmod 644 *firstnamelastname.pdf*
  2) cp -a *firstnamelastname.pdf* /home/mkostka/phys381/midterm/
  3) Copy a second time to ensure that your exam copied correctly. If you are prompted as to whether or not you would like to replace the existing file, then you exam has been successfully submitted.

- **You must check with Matt that your report was received and is readable BEFORE you leave the lab.**

Attempt all questions below.

GOOD LUCK.

1 Global Warming?

Governments sponsored long term research programs to measure the amount of CO_2 in the atmosphere. Table 1 in appendix A is an example of measurements of the **CO_2 concentration** (ppm) from 1965 to 1999. For a comparison the current concentration is 0.038%; 380 parts-per-million (ppm). This should be compared to a pre-industrial value of 0.028% = 280 parts-per-million (ppm).

Also shown in Table 1 are measurements of the **Earth's Temperature anomaly** (ΔT) for the same period. The term temperature anomaly means a departure from a reference value or long-term average. A positive anomaly indicates that the observed temperature was warmer than the reference value, while a negative anomaly indicates that the observed temperature was cooler than the reference value. In climate studies the norm is usually the average world temperature recorded between 1951 and 1980.

[Download the corresponding data file from the phys381 course (pjl) website]. Right click on the file link and save it to your **"Midterm"** directory in your machine.

1.1 Gnuplot [40 Marks]

- *[10 Marks]* Using Gnuplot, in a multiplot mode, plot: **(a)** in the top panel the **Temperature Anomaly versus year**; **(b)** in the middle panel the **CO_2 concentration (in ppm) versus year**; **(c)** and in the bottom panel the **Temperature Anomaly versus CO_2 concentration**. Use *linespoints style* when plotting the data.

- *[10 Marks]* The **Temperature Anomaly versus time** data can be best fit by a curve defined as $\Delta T(t) = 0.016 \times t - 31.6$ (here t is the year); the **CO_2 concentration versus year** data can be fit by a curve defined as $ppm(t) = 1.42 \times t - 2473.0$; while the **$\Delta T$ versus CO_2 concentration** data can be fit by a curve defined as $\Delta T(ppm) = 0.012 \times ppm - 4.0$.

  Superimpose on each plot above the corresponding best-fit line and save the output as a color postscript (.eps) file. Add it to your report.

- *[10 Marks]* Analyze and discuss each plot. In particular, can you use the bottom plot to infer that the increase in CO_2 is causing global warming? Can you think of reasons why an increase in temperature could lead to an increase in CO_2 concentration (elaborate on your reasoning). (*HINT: higher temperatures leads to an increase in living organisms*).

- *[10 Marks]* Append your gnuplot script (code) using the *verbatim* command. Your gnuplot script should be clearly written and complete to get full marks (I encourage you to add a few comments).

1.2 Fortran 90/95 [40 Marks]

*You must name your main code as "***studentname.f90***" where "studentname" should be your first and last name attached. Once you code is complete, append it to your report using the verbatim command.*

The temperature of the Earth is affected by the energy received from the Sun, the energy radiated back out to space, the atmosphere as well as volcanic activity. Volcanic eruptions inject dust and aerosols into the stratosphere and quickly mix around the globe. The increase in atmospheric aerosols increases the Earths reflectivity (defined by an albedo factor A). In a very simplistic model (for illustration purposes only) [1], the **Temperature anomaly** is given by the following equation (in Celsius):

$$\Delta T = (-1)^{year} \times \Big(6.0 \times (1 - A)^{1/4} - 5.5\Big)^2 \ , \tag{1}$$

with $0.0 \leq A \leq 0.5$.

Here we ask how the volcanic activity would affect changes on Earth surface temperature (and thus changes on ΔT). In other words, what percent of total global warming can be explained by volcanic activity alone?

- *[10 marks]* Write a Fortran 90 code that loops in time from 1965 to 1999 in steps of 1 year. For each step call the random number generator to get a value for A. The random number generator gives you a number (say, x) between 0 and 1. However, we want a number (here the albedo A) between 0 and 0.5.

  The random number generator is intrinsic to Fortran 90 namely, **random_number()***. Before you proceed read appendix B carefully!*

- *[5 marks]* Use a *Function* to calculate the Temperature anomaly (ΔT) as given in equation (1). It means your code should have a function that takes in A and the *year* as arguments and calculates ΔT. Save your data into a data file and name it *"midterm2013-output.data"*. The first column is the year and the second is ΔT.

- *[10 marks]* Using gnuplot, plot your result (ΔT **versus year**) against the (ΔT **versus year**) data given in Table 1. Use different point style to distinguish between the measured data and your results. Again use *linespoints*.

  Save the output as a color postscript (.eps) file and add to your report. What do you conclude when you compare the data and your model? Some geophysicists predict a

[1] The topic is exceedingly complex, because interactions between the lithospheric, oceanic, atmospheric, and biospheric systems are such that changes in one component may affect each of the other systems. There is also solar variability and volcanic activity that need to be taken into account.

big volcanic eruption in the next 10 years and that this will reverse global warming. What do you say?

- *[15 marks]* Let us assume that on average a tree removes 1000 kg of CO_2 every year which would be equivalent to very roughly 10^{-12} ppm/year:

  (i) *[5 marks]* Add to your code a subroutine (name the subroutine *trees*) that calculates how many trees one would need to plant each year to offset 1% of the increase in CO2 emission (in ppm) from one year to another.

  Loop over the years and save your data into a new file you must call *"Trees-Data.data"*; the first column is the year and the second is the number of trees planted. *Assume that the ppm level in 1964 is the same as in 1965.*

  (ii) *[5 marks]* Plot the total number of trees planted versus the year. Save the output as a color postscript (.eps) file and add to your report. Discuss your results. *Hint: At best 10 billions trees are planted a year worldwide.*

  (iii) *[5 marks]* Which years would require more than 2×10^{10} trees to offset the 1% increase in CO2 emission. *Hint: Add an If command inside your do loop.*

A The Data

See next page.

Table 1: *[Download the corresponding data file from the phys381 course (pjl) website].*

Year	CO2 (ppm) (**p**arts **p**er **m**illion)	Global Temperature Anomaly (^{o}C from 1965 to 1999)
1965	320	-0.16
1966	321	-0.07
1967	322	-0.08
1968	323	-0.10
1969	324	0.03
1970	326	-0.03
1971	326	-0.19
1972	327	-0.04
1973	330	0.09
1974	330	-0.18
1975	331	-0.12
1976	332	-0.22
1977	334	0.06
1978	335	-0.03
1979	337	0.07
1980	339	0.11
1981	340	0.13
1982	341	0.06
1983	343	0.25
1984	344	0.03
1985	346	0.01
1986	347	0.10
1987	349	0.25
1988	351	0.25
1989	353	0.19
1990	354	0.34
1991	355	0.29
1992	356	0.14
1993	357	0.19
1994	359	0.26
1995	361	0.38
1996	363	0.22
1997	364	0.43
1998	367	0.59
1999	369	0.33

B The Random number generator

Here we illustrate the use of the random generator intrinsic to Fortran 90, **random_number(x)**. Since the computer is an entirely deterministic machine, we have to use some sort of algorithm to approximate random numbers. This is the reason why **random_seed()** must be called [but ONLY ONCE] before using **random_number(x)**.

```
!  This code generates 5 random numbers
!
!  Each random number is between 0.0 and 1.0
!
program ouyed
implicit none
integer :: i
real :: x
call random_seed()
do i = 1,5
call random_number(x)
end do
end program ouyed
```