User Manual for NetCDF version Energy Balance Model

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I. How to untar the code

After untarring the code, it should list as follows:
/EBM
- /input
- /output
- /postprocess
- /preprocess (Test data stored here)
- /src
- ReadMe.txt
- /run_ebm_with_plot.sh
- /UserManual.pdf (this file)

II. How to change NetCDF path in the code

1. Change NetCDF include and lib to your own directory.
The code has been fully tested in Ubuntu12.04, CentOS6.5, and MacOSX using intel fortran and gfortran compilers. Readers are on your own to compile in other platforms and other fortran compilers.
2. Readers need to compile netcdf using your own fortran compiler. For example, if you use ifort and compile netcdf3.6.3 into directory /usr/local/netcdf, then modify two files, namely, /EBM/src/Makefile and /EBM/preprocess/preprocess.sh. Detailed instructions have been given in these two files.

III. How to preprocess data inputs

We take the Last Glacial Maximum (LGM) as an example. Geography, orbits and CO_2 level are required to input into the code.

1. Geography

See " A brief tutorial a) geography" part in the paper for instructions. The LGM geography data has been prepared for the demo in /EBM/preprocess/The_World.dat.

2. Orbits

Explicitly set Initial_Year=-21000 in the main code (/EBM/src/EBM.f90 line 205)

3. CO_2 level

Explicitly set CO2ppm=185.0 in the main code ((/EBM/src/EBM.f90 line 204)
These have completed the preparation for data inputs for the LGM EBM simulation.

4. Preprocess geography and albedo

We here use Mengel et al. (1988) scheme for albedo by /EBM/preprocess/extract.f90 to obtain annual albedo file, i.e., albedo.dat from The_World.dat. The purpose of /EBM/preprocess/prepare_geography.f90 is to turn The_World.dat into geography.nc. Similarly /EBM/preprocess/prepare_geography.f90 is to turn albedo.dat into albedo.nc. There is a C-shell script named /EBM/preprocess/preprocess.sh to do these transformations in a batch mode and move the two NetCDF files of albedo.nc and geography.nc into /EBM/input.

IV. How to compile and run the code

See compiling options in /EBM/src/Makefile and then run ***make*** to compile the code. The Makefile is an example to compile the EBM using intel fortran compiler. Readers need to change to your own fortran compiler. After successfully compiling the code, an executive file named ***EBM*** should be added into the same directory. /EBM/src/ebm.sh is a C-shell script for compiling and running the EBM in a batch mode.

V. How to postprocess the data outputs

Readers need to install FERRET (http://ferret.pmel.noaa.gov/Ferret) first to plot figure as instructed here.

The final output consists of three files in /EBM/output, i.e., Briefing.out, monthly-output.nc, and timesteps-output.nc. Briefing.out records the EBM running log and several essential parameters defining the specific EBM case. monthly-output.nc is monthly average surface temperature and timesteps-output.nc is surface temperature for the 48 time steps.

After successfully running the EBM, further analysis or plots are required to synthesize the simulation. Here we plot the summer average temperature in the Northern Hemisphere (NH) at the LGM. /EBM/postprocess/summer.jnl is a FERRET (http://ferret.pmel.noaa.gov/Ferret) script to process the monthly average temperature into summer average temperature in the NH, namely, NH_summer.nc. Figure_demo.jnl is the FERRET script to plot the summer temperature in the NH as a pdf, i.e., demo.pdf, while temp_palette.spk is an FERRET palette for this plot. Actually postprocess.sh has integrated all the postprocess steps into a batch mode.

VI. One-click-for-all demo

Readers need to install FERRET (http://ferret.pmel.noaa.gov/Ferret) first for this demo.

We attach a C-shell script in /EBM/run_ebm_with_plot.sh to combine all preprocessing, running the EBM itself, and postprocessing steps into a batch mode.

If readers follow this manual step by step, then run the command ./run_ebm_with_plot.sh, your terminal should display the following message:

```
----------------------------------------
 Preprocess begins:
 SUCCESS in writing geography to geography.nc!
 SUCCESS in writing albedo to albedo.nc!
 Preprocess DONE!
 ----------------------------------------

ifort EBM.f90 grid.f90 app.f90 geography_input.f90 albedo_input.f90 A_value.f90
orbital_params.f90  monthly_output.f90 timesteps_output.f90 -o EBM -
I/home/kelin/ifortnetcdf363/include -L/home/kelin/ifortnetcdf363/lib -lnetcdf
 SUCCESSLY reading geography from [../input/geography.nc] into simulation!
 SUCCESSLY reading albedo from [../input/albedo.nc] into simulation!


************************************************************
*****                                                  *****
*****          2D EBM PALEOCLIMATE MODEL               *****
*****                                                  *****
*****          -------- netCDF version --------         *****
*****                                                  *****
*****                  Kelin Zhuang                    *****
*****                Dickinson College                 *****
*****                                                  *****
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*****                       &                          *****
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*****                      2015                        *****
*****                                                  *****
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 Start Energy Balance Model simulation:

 Year   Global Temperature
   1    4.48116
   2    5.59012
   3    6.57062
   4    7.38245
   5    7.99177
   6    8.43713
   7    8.75981
```

```
 8    8.99296
 9    9.16138
10    9.28312
11    9.37121
12    9.43502
13    9.48129
14    9.51488
15    9.53928
16    9.55702
17    9.56993
18    9.57933
19    9.58618
20    9.59117
21    9.59481
22    9.59747
23    9.59941
24    9.60083
25    9.60186
26    9.60261
27    9.60317
28    9.60357
29    9.60386
30    9.60408
31    9.60424
32    9.60435
33    9.60443
34    9.60450
35    9.60454
36    9.60458
37    9.60460
38    9.60462

EQUILIBRIUM REACHED AFTER  38 YEARS. GLOBAL TEMP=  9.6046

 Elapsed time:      0.38 minutes
 Monthly temperature results stored successfully in ../output/monthly-output.nc!
 48 time steps temperature results stored successfully in
 ../output/timesteps-output.nc!
 *** NOTE: Axis coordinates are decreasing-ordered. Reversing ordering for axis
latitude
 LISTing to file NH_summer.nc
 *** NOTE: Axis coordinates are decreasing-ordered. Reversing ordering for axis
latitude
```

It is of note that 1) the output values will differ slightly under different CPUs and platforms due to their respective precisions. This is normal! 2) There are two NOTEs in the display because the NetCDF output is coded in a decreasing order. FERRET can reverse the order in an increasing order. This is normal as well!

In a nutshell, we attach the following data files for readers' comparison:
/EBM/preprocess/The_World.dat, albedo.dat
/input/geography.nc, albedo.nc
/output/Briefing.out, monthly-output.nc, timesteps-output.nc
/postprocess/demo.pdf, NH_summer.nc.

VII. Concerning Figures 4, 5 & 6 in the paper

We attach the geographies of 9ka and 12kaBP in /EBM/preprocess/The_World9.dat and The_World12.dat. When readers run these two cases, please rename them to The_World.dat for each run. CO_2 levels and Initial_Year setup have been added in /EBM/src/EBM.f90 as comments (Lines 204-209). Readers are encouraged to plot the similar figures using your own favorite plotting software.