Working notes for creating CCSM3 T31 LGM run

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Thanks to help from Bette Otto-Bliesner, Esther Brady, Bruce Briegleb, Cecilia Bitz

This document and all files I edited for this run can be downloaded from my website or obtained by emailing me. They are also available on NCAR mass storage at
`/EISENMAN/working-notes/T31-LGM.tar.gz`
All files are in a directory called T31-LGM/, and paths to files in the directory are mentioned in this document.

1 Introduction

These are notes I put together while setting up a low resolution CCSM3 simulation with last glacial maximum (LGM) forcing, which was presented in Eisenman et al. (2009). This experiment is based closely on a previous high resolution LGM experiment (Otto-Bliesner et al., 2006a), as well as a previous low resolution run with 1780 forcing (Otto-Bliesner et al., 2006b). The high resolution run uses T42 atmosphere/land and gx1v3 ocean/ice; the low resolution runs use T31 atmosphere/land and gx3v5 ocean/ice. At times in these notes (e.g., the title) I simply use T31 or T42 to refer to the resolution, whether discussing just the ocean or the whole coupled run.

Compared to 1780 (the paleoclimate control run), the LGM has different sea level (simulated here by changing the coastline but leaving the bathymetry otherwise largely unaltered), ice sheets (affecting the land topography and surface type), greenhouse gases, and insolation. Section 2 describes the process of taking the topography/bathymetry and land surface type datasets from the ICE-5G reconstruction (Peltier, 2004) and creating the necessary data files for the model. Note that I used some files already created for the T42 LGM run. Section 3 describes setting up the run and making the necessary changes in the namelists.

A document I have found very helpful in this work is "Procedures for Generating Input files for CCSM2", written by Esther Brady, Steve Yeager, Christine Shields, Sam Levis, and Bette Otto-Bliesner. I've copied the file to T31-LGM/doc/SetupCCSM3.pdf.

1.1 Computers

Although it would be nice to do this all on one computer if it had the necessary FORTRAN libraries, the makefiles were configured correctly, etc, I ended up using 5 computers for this work: bluesky (AIX), tempest (IRIX64), neva (SunOS), poorman (Linux), and my laptop (XP; I used it for Matlab). I try to indicate in the notes below which computer I used for various jobs. I worked primarily on bluesky and copied files to other computers as necessary, ran jobs, and then copied the output files back to bluesky.

2 Creating input data for model

2.1 ATM

Need to create LGM surface BC (topography). This is contained in the ...cam2.i...nc init file. I used the T31 1780 run (b30.105) atm init file from year 100, changing the topography to be PD plus the difference between LGM and PD in the Peltier ICE-5G reconstructions. This was all done with the fortran program definesurf, in `T31-LGM/atm-definesurf/`. The program is described in the README file, and my use of it is documented in definesurf.readme. The final product was the file `b30.105.cam2.i.0100-01-01.LGM_c050523.nc`

Unfortunately, definesurf doesn't change the variable LANDM_COSLAT. I changed this with the ncl program in `T31-LGM/atm-definesurf/landmcoslat/`, described in the .readme file, and created the new file `b30.105.cam2.i.0100-01-01.LGM_c050615.nc`

Note that while I am working primarily on bluesky, definesurf was run on tempest and fix_landmcoslat was run on neva, as explained in the .readme files.

2.2 LND

I used the data already prepared for b30.104, since the land accepts high resolution surface-type datasets and interpolates them to T31 at the start of the run. The files are described in section 3.

2.3 OCN

2.3.1 Bathymetry

Needed to create ocean bathymetry files:

KMT (bin) file contains depth(lat,lon) measured in number of boxes. KMT=0 over land, so this contains the coast.

Region mask (bin) file contains basin(lat,lon), where the basin is an integer corresponding to which ocean it is. Negative integers indicate marginal seas.

Region ids (text) file contains the names of each numbered basin and the location and area over which each marginal sea imposes it's salinity balance.

The first two files are created by first zeroing all shallow water and making a few corrections based on region mask ("method 1") to approximate LGM ocean starting with PD ocean. This is calculated using `T31-LGM/ocn-kmt/makekmtgx3v5.f`. Next, the file is visually compared in matlab with the Peltier ICE-5G reconstruction, and ocean points are manually selected to be changed to land ("method 2"). The matlab routine, `T31-LGM/ocn-kmt/matlab/KMT_gx3v5_compare.m`, creates a text file identifying the grid boxes selected. This is read by the Fortran program makekmtgx3v5.f, and final versions of the kmt and region mask files are created. This entire procedure is described in `T31-LGM/ocn-kmt/makekmtgx3v5.readme`.

Next, I examined the locations in the ocean for the marginal sea balances and slightly adjusted the ocean target for the Caspian sea in `gx3v5_region_ids`; I also re-numbered some of the regions because of dried up seas. I saved this altered file as `gx3v5_region_ids_LGM`.

2.3.2 Initial condition

I also needed to create T-S initial condition based on the climatology of b30.104 at a fairly late (i.e., spun up) time in the run. Hence, I needed to interpolate from a gx1v3 (netcdf) hist file to gx3v5 (bin) init file. I did this with `T31-LGM/ocn-ic/lev2grid.csh`, which requires the program regrid (compiled to work on tempest) as well as Matlab with the netcdf toolbox (I used my laptop). My usage of the program is described in `T31-LGM/ocn-ic/lev2grid.readme`. The final product was the file `LGM_jan_ic_gx3v5_Y0290-0299.ieeed`.

2.4 ICE

This module just takes the KMT file made for the ocean.

This run, like b30.104, will start from the default sea ice initial condition.

2.5 CPL

Need to create 4 mapping files:

```
map_T31_to_gx3LGM_aave_da.nc
map_T31_to_gx3LGM_bilin_da.nc
map_gx3LGM_to_T31_aave_da.nc
map_r5_to_LGMgx3.nc
```

The last one, which maps from the runoff grid to the ocean grid, takes the longest to make. This appears to be mostly because of smoothing - 1 runoff point needs to map to many ocean points.

Procedure:

(1) Create mapping files between T31 atm and gx3v5 LGM ocean: Use `T31-LGM/cpl-mapping/mk_remap.csh`; this script, and my usage of it, are documented in `T31-LGM/cpl-mapping/mk_remap.readme`.

(2) Correct mapping errors (related to singularities at poles). Uses the idl routine `T31-LGM/cpl-mapping/correct_map_errors.run`; my usage is documented in `T31-LGM/cpl-mapping/correct_map_errors.readme`. This is done only for aave (i.e., conservative) mappings. The maps I'd created had no errors since 90.0 north was changed to 89.9999 in T31_040122.nc.

(3) Create initial map from runoff grid to gx3v5 LGM ocean: 0.5x0.5 runoff grid to gx3v5 LGM ocean grid mapping is created with `T31-LGM/cpl-mapping/mk_runoff_remap.csh`; usage is explained in `T31-LGM/cpl-mapping/mk_runoff_remap.readme`.

(4) Smooth runoff map (this is most computationally expensive step): Need to (a) correct, (b) smooth, and (c) check map. The smoothing is to avoid making sea surface salinity get too perturbed in a single box. This is all done in one fell swoop in a FORTRAN program compiled on bluesky and then submitted to the cluster; a full description is at `T31-LGM/cpl-mapping/map_runoff/main.F90.full.readme`.

3 Creating a new experiment and modifying namelists

The relevant scripts from the new experiment are copied in
`T31-LGM/scripts/T31.LGM.test/`

3.1 creating default low resolution CCSM run

On bluesky

```
cd /fis/cgd/cseg/csm/collections/ccsm3_0_rel04/scripts
./create_newcase -case $HOME/scripts/T31.LGM.test -res T31_gx3v5 -mach bluesky
cd $HOME/scripts/T31.LGM.test
```

Edit `env_conf` to change the case string to T31 LGM test run

```
./configure -mach bluesky
```

3.2 Copying over relevant data files

I copied the files created in section 2 to the SourceMods directory of the new experiment, following the convention used in b30.104 (even though these aren't really modifications to the source code). All the file copying is documented in `SourceMods/readme`.

3.3 Namelist modifications

Note that by default data files are often copied to the run directory (/ptmp/user/expt) using the script ccsm_getinput, but apparently the script ccsm_cpdata should be used instead for user-specified data files. I ended up modifying the ccsm_cpdata script to avoid errors when the model was built twice - see note in section 33.4 below.

These modifications were made based on using diff (or ediff) with previous experiments. I got the previous run scripts from the following locations:

```
# b30.004=T42_PD; 100.02=T42_1780; 104[w]=T42_LGM; 031=T31_PD; 105=T31_1780;
set cgd=/fis/cgd/cseg/csm/runs/ccsm3_0
set zav=/home/bluesky/zav/ccsm_runs
cp -r $zav/b30.104 $zav/b30.104w $cgd/b30.105 .
# note that /fis/cgd/ccr/paleo/ccsm_runs should have same scripts as in zav
```

3.3.1 ATM

For LGM, need to change topography (note that the atmosphere has pressure levels near the surface and height levels higher up; PHIS specifies surface geopotential; SGH specifies orography standard deviation, used for gravity waves) and surface pressure (PS; note that the land surface during the LGM is at a higher elevation on average compared the sea level because of the ice sheets, but the pressure should be the same since the atmosphere has the same mass; this subtle point is addressed in b30.104, and hence also here, because it is required by PMIP). Also need to change ozone and aerosols from default PD values to 1780 values, and change CO_2, CH_4, N_2O to LGM values.

`Buildnml_Prestage/cam.buildnml_prestage.csh`: Give location of 1780 aerosol and ozone data as in b30.105. Change initial condition (datinit), which includes topography, to LGM file generated in Section 2. I took the fincl1 and fincl2 fields - extra variables to include in primary and secondary history files - from b30.104w. Mentioned ozncyc (true to assume 1 year ozone data rather than longer dataset) and scenario_carbon_scale take their default value; presumably unnecessary but following b30.104/b30.104w/b30.105. Set solar constant as in b30.104/b30.104w/b30.105, and used greenhouse forcings as in b30.104.

3.3.2 LND

`Buildnml_Prestage/clm.buildnml_prestage.csh`: Indicated datasets built based on Peltier ICE-5G for b30.104 for glacier, raw inland water, and plant functional type distributions. Set fsurdat=" so that it will be generated during first run, after which I will copy it from execute directory to SourceMods/src.clm/surface-data.096x048.LGM.nc and specify it in fsurdat.

`SourceMods/src.clm/mksrfdatMod.F90`: This file corrects default to put wetlands on glaciers since they weren't specified otherwise (b30.104). Also makes new coast area nearest neighbor type rather than wetland (b30.104w).

Note that I used present day (default) runoff rather than create a file based on the new topography. b30.104/b30.104w did the same - didn't seem worth the headache. Also note that in b30.105 (b30.031 hybrid), finidat is specified. This is initialization data for prognostic land model variables, used by hybrid runs but not b30.104 or me.

3.3.3 OCN

`Buildnml_Prestage/pop.buildnml_prestage.csh`: Set initial condition T-S distribution file, LGM topography/coastline, and mask file (tells whether it's a marginal sea, as well as name of basin for diagnostics).

3.3.4 ICE

`Buildnml_Prestage/csim.buildnml_prestage.csh`: Include indication of LGM topography/coastline file as in b30.104. Note that by default lower ice albedos, specified here, are used for T31 runs compared with T42 (for better fit with PD observations).

3.3.5 CPL

Buildnml_Prestage/cpl.buildnml_prestage.csh: Change orbital forcing to orb_year = -19050 and indicate new mapping files.

3.4 Building and submitting run

On bluesky, having made all the modifications described above, try to build the model.

```
./T31.LGM.test.bluesky.build
```

Note that when a run is started (if CONTINUE_RUN is FALSE), the model is automatically built. I replaced a handful of lines in the namelist prestage scripts that had ccsm_getinput with ccsm_cpdata (allows you to specify exactly where data file is rather than searching for it), as described above and in the readme files. While ccsm_getinput will not copy a file if it already exists in the target directory, ccsm_cpdata will. This causes errors due to read-only file permissions when the model is re-built at the start of a run. I could have just skipped the build step, so the model would only be built once, but instead I copied ccsm_cpdata to a local folder and edited it not to overwrite files that already exist (to avoid any other errors). See Buildnml_Prestage/Tools/.

In env_run, set length of time for run (STOP_OPTION, STOP_N) and number of times to resubmit run (RESUBMIT), and submit run to cluster.

```
llsubmit T31.LGM.test.bluesky.run
```

4 Debugging

Thanks to further help from Brian Kauffman, Esther Brady, Cecilia Bitz,
Bruce Briegleb, Bette Otto-Bliesner

The experiment initially had few bugs, which were fixed as follows:

(1) Model crashed with LGM CAM datinit file (topography): This was apparently because CAM runs close to instability with the default 30min time step. I reduced the time step to 10min.

(2) Model crashed with LGM POP T-S initial condition: This was because the TS ic binary file was written in the native machine format, which was apparently different on the machine I used to create the file from on the machine where the script was originally run. I changed lev2grid.csh to explicitly specify the binary format (ieee-be) in the Matlab script it creates.

(3) Model crashed with LGM KMT/regmask/mappings: This was because, in all my copying of files between computers, I accidentally built the coupler mapping files with the penultimate iteration of the KMT file, which differed from the final KMT file at several grid points. So the model saw one ocean coastline in the KMT/regmask files, and a second one in the coupler maps. This led the coupler to mapvalues of 1e30 (missing value) from the ocean (outside the ocean region) to the atmosphere.

To address bug (3), I ran the model with several source code modifications, asking it to print a coupler history file (NetCDF) earlier in the initialization and to include several more fields in the file. There was an issue that a run can spend about 4-25 hours in the queue before running, which was resolved by using a partial node and allowing sharing in the 32-node cluster (this probably made the model run a lot slower, but jobs spent almost no time waiting in the queue). I wrote a shell script to create new cases of this type, as I was running a lot of debug experiments. I also ran the model with horizontally uniform T-S i.c. (based on a Levitus T-S profile); with no sea ice initially; and outputting history files every time step. These modifications are copied in
`T31-LGM/debug/T31.LGM.debug_mods/`

I used several Matlab scripts to examine the setup files. These are in
`T31-LGM/debug/`

References

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