# Solar Update/Orbit Update

There are a number of solar/orbital updates that have historically been used in HadCM3. These have evolved to the very latest version which is **solar\_orbit\_real1950\_ver03.mod**.

## Earlier orbit updates

For a long time, the best way to change the orbit was to add an update such as orbit\_6k. This changed the orbital parameters by changing the relevant code in the model. This was very simple but required a different executable and different orbital parameter file for each orbit.

Then, in FAMOUS, Robin Smith (Reading) backported code from HadGEM2 to allow the orbit to change based on namelist inputs. The strength of this approach is that we need only one executable. The weakness is that a hand\_edit needs to be added too.

The original updates is: $UMDIR/../famous/mods/source/orbital\_parameters-6.1.mod (/mnt/storage/private/bridge/um/PUM64/famous/mods/source/orbital\_parameters-6.1.mod on bc4)

I installed it into the HadCM3 code and made a number of small changes. Most of these were based around the fact that paleo orbital time periods are relative to 1950 and not a normal calendar. For instance, 21k yr BP is in fact 21000 years before 1950, and hence is -19050 BC. I often forgot this and specified -21000 for an LGM run.

Also, if you are running with variable orbit, then the modset uses the date from the model dump files. This can be problematic since negative years need the long\_filenames update and are not handled well within netcdf files. A simulation starting at the LGM would have a year of -19050 and output file ….0000019050c1-, changing to c1+ at model time 0 (AC/BC). The way around this is to shift the time origin. Hence many of the modset variants are adaptations to these issues.

1. orbital\_parameters-6.1\_1950.mod: Sets the preind orbit year to be 1950, with an offset of 50000. i.e. pre-ind orbit = dump year 50000.
2. orbital\_parameters-6.1\_50k.mod: Sets the preind orbit year to be offset of 50000. i.e. preind orbit= dump year +51950.
3. orbital\_parameters-6.1\_real1950.mod: Sets the preind year to be 1950 i.e. preind orbit= dump year 0.
4. orbital\_parameters-6.1\_real1950o.mod: As real1950.mod but outputs solarorbit.dat file recording value.
5. orbital\_params-6.1\_real1950\_100k.mod: As (1) but offset of 100000
6. orbital\_params-6.1\_real1950\_100ko.mod: As (5) but output
7. orbital\_params-6.1\_real1950\_99k.mod: As (1) but offset of 99000

There are also some similar files with original at the end of the name. There are no science differences, but the files were modified to avoid lots of warning messages from nupdate.

## Earlier Solar Updates

The situation with solar constant changes is a bit more simple. There are a range of modsets that simply change the solar constant (normal value in standard HadCM3 is 1365.0 Wm-2). The update names are sometimes called by their solar value, but naming may also be related to geological time period. Again, the standard update required different executables for different constants.

## Orbital Bug

Michel Crucifix discovered an important bug in the orbital code. This bug impacted on all versions of the model and was independent of any of the updates above. Simply, the equation to calculate insolation (S(t)) was wrong. The original equation was: S(t) = So ( (1+e2/2)\*(1+ecosv)/(1-e2))2 This was incorrect. The correct equation should be: S(t) = So ( (1+ecosv)/(1-e2))2

The bug made relatively small difference to any particular time period but could have a big impact on the spectrum of variability.

New versions of all the earlier orbital update files were created. They are identical to previous except are called \_v2 at the end. (i.e. orbital\_params-6.1\_real1950\_100k.mod becomes orbital\_params-6.1\_real1950\_100k\_v2.mod). The old versions should only be used if backward compatibility is required.

## Merged Solar/Orbit Update

These different updates were merged into a single modset, solar\_orbit\_real1950.mod. A further version was created that allowed variable solar constant (solar\_orbit\_real1950\_ver02.mod). The latest version **(as of Dec 2023)** of this file is called **solar\_orbit\_real1950\_ver03.mod** and includes the orbital bug fix.

The update allows you to have variable or fixed orbit and variable or fixed solar within one executable. The inputs to the modset are added within the “Script Inserts and Modifications” of the umui. These are then converted into a namelist contained in CNTLATM with the relevant umui\_jobs folder. The hand\_edit script solar\_orbit\_update converts the umui input into the CNTLATM file

|  |  |  |  |
| --- | --- | --- | --- |
| **Description** | **Variable in umui** | **Variable in namelist** | **Default** |
| Solar constant | SOLAR | SC | 1361.0 |
| Solar percent change. This will change the solar constant based on the % change (i.e. -1.0 reduces the solar constant by 1%)1 | SOLAR\_PERCENT\_CHANGE | SC is modified and input into NAMELIST | Null |
| Solar percent. Modified the solar constant as an absolute  (i.e. 99.0 reduced the solar constant to 0.99 of original)1 | SOLAR\_PERCENT | SC is modified and input into NAMELIST | Null |
| Solar Age. Changes the solar constant based on the age of the simulation, using the formula of Gough et al. Units is Ma.1 | SOLAR\_AGE | SC is modified and input into NAMELIST | Null |
| Solar Variability File: Allows the solar constant to vary every year. | SOLAR\_FILE | L\_SOLAR\_VAR\_FILE=.TRUE.  SOLAR\_VAR\_FILE=$SOLAR\_FILE | Null |
| Solar spectral changes: When doing last millennium simulations, changes in the solar constant AND solar spectrum included | L\_SOLAR\_SPEC | L\_SOLAR\_SPEC | .FALSE. |
| Time of orbit (i.e. 21ka orbit should be 21000). Only valid if orbit is not changing in run. | YEAR\_ORBIT | SEC\_VAR\_YEAR  (-ve of YEAR\_ORBIT) | 0 |
| Acceleration factor  Only valid if orbit is changing.  (i.e. orbit changes faster than real year) | SEC\_VAR\_FACTOR | SEC\_VAR\_FACTOR | 1.0 |
| Orbit changing during run | L\_SEC\_VAR | L\_SEC\_VAR | .FALSE. |
| Alternative orbital parameters store in file. | ORB\_FILE | Several variables | Null but the Laskar solutions is in INSOLN.LA2004.BTL.ASC2 |
| Precise orbital parameters | ORB\_GAMMA  ORB\_E  ORB\_TAU0  ORB\_SINOBL | GAMMA\_IN  E\_IN  TAU0\_IN  SINOBL\_IN | If not specified, standard 1950 values. |
| Alternative for orbital values | ORB\_ARRAY | ORB\_ARRAY | Null  List of the 4 orbital parameters separated by , with no blanks. |
| Output parameters to file solarorbit.dat | NOUTPUT\_ORB | NOUTPUT\_ORB | 1 (output every year) |
| Real orbit year reference time | ORB\_REAL\_YEAR | ORB\_REAL\_YEAR | 1950 |
| Offset year (to prevent negative years) | ORB\_OFFSET\_YEAR | ORB\_OFFSET\_YEAR | 100000.0  Only relevant if L\_SEC\_VAR=.TRUE. |

1 – Only one of these variables should be defined.

2 – The file should be specified as the local file location (i.e. /home/swsvalde/um\_updates/INSOLN.LA2004.BTL.ASC)

## WARNING

If writing a script to do multiple runs with different orbits or solar using the files created in umui\_jobs, then you must change the variables in CNTLATM, and not in SCRIPT (which is where the “Script Inserts and Modifications” variables are stored). Alternatively, change the SCRIPT variables and then manually invoke the hand edit (i.e. hand\_edit\_name expt\_name).

## ISSUES

1. The code uses orbital parameters from Berger 1978. This probably is not the best source of orbits, although it is commonly used in MIPS so I am being “picky” in this criticism. Andre Berger in a long series of papers solved the orbital equations through a semi-analytical asymptotic expansion of the governing equations. This has the benefit that he had a set of equations for the orbital parameters (which are implemented in the modset) but they are approximations for all time periods. So even the modern orbit is an approximation. Laskar and others use a numerical solution, initialised from the best modern observations so is more accurate. Also note that Berger (1978) is only valid for the last 1 million year so you do need to use Laskar for other periods.
2. A more difficult issue, which is largely ignored although was considered in the first PMIP, is that there is an impact of the 360 day year. If you do a simulation where you change orbit (e.g. mid-Holocene), then the resulting radiative forcing change at the top of the atmosphere is not the same as if you have 365 day year. In PMIP1, the experimental protocol demanded that we match the correct change in radiative forcing (in HadCM3, done by tuning the vernal equinox timing). We applied the same idea for the original BBC runs (though it emerged there was a small bug in these). Subsequently, we ignore this problem.