

# Modèle Atmosphérique Régional

## MAR-3



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## User Guide

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[www.mar.cnrs.fr](http://www.mar.cnrs.fr)

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# 1 Introduction

MAR is an atmosphere model designed for meteorological and climatic research. It is used for a wide range of applications, from km-scale process studies to continental-scale multi-decadal simulations. It can be run for ideal test cases (e.g., 1-dimensional studies, simple gravity-wave configuration) or for realistic applications (constrained by reanalyses, operational forecasts, or global climate models). MAR was created in the mid-1990s by Hubert Gallée, and most developments since then have been undertaken at IGE (former LGGE)/CNRS/UGA, Grenoble, France, and at the Liège University, Belgium. MAR is now open to the international community, and this website is designed to facilitate its implementation and use on various platforms and for a large range of applications.

MAR is well known for its fine representation of physical processes in polar regions. It is one of the few models able to simulate realistic surface mass balance, air-snow interactions, and atmospheric circulation over ice sheets, including katabatic winds. MAR has also led to significant advances in the understanding of the surface mass balance of mid-latitude and tropical glaciers. It has also provided climate simulations over Europe and Africa. For more details on the MAR working groups, their publications, or to download the code, see <http://www.mar.cnrs.fr>.

This User Guide aims to help new MAR users to set up regional configurations and run simulations but it is not intended to describe the details of the model numerics and physics. This document also provides guidance on the installation and use of NESTOR, that is, MAR's pre-processing software.

To download MAR and NESTOR, see the Download section on <http://www.mar.cnrs.fr>. To subscribe to the MAR mailing list (mostly to receive information on workshops and new versions), send an email containing "subscribe mar\_community" in the subject to [sympa@services.cnrs.fr](mailto:sympa@services.cnrs.fr). To see and use the MAR Forum (for any question on MAR or NESTOR), see the Forum page on <http://www.mar.cnrs.fr>, and subscribe to the Forum to post questions or receive emails about new posts. Additionally, alternative 'unofficial' documentation can be found at <https://gitlab.com/atedstone/MARv3.7/wikis/>.

## 2 Domains versus simulations

A domain (e.g. GRa, GRb...) is the spatial area and grid over which MAR is run. The domain itself is created by NESTOR, and NESTOR is also used to put the global forcings (e.g. ERA-Interim) onto the domain grid. The first two letters of the domain are determined by the world region that you are simulating (see Section ??).

A simulation (e.g. a01, b01) is named after the domain label (e.g. a) plus a numerical code. Simulations inherit all domain characteristics from their parent domain but have their own MAR code.

### 3 System requirements

MAR can in theory be installed on any Linux-like system, including clusters and supercomputers. Some platforms are pre-defined in the pre-processing and running scripts, e.g. ada (IDRIS), froggy (Grenoble), Climato (Liège), and NASA. If your platform is not pre-defined, you will need to adapt the settings to your system (see below).

Some softwares and libraries are also included in the current model distribution (lib directory) to facilitate installation: Netcdf 4.0.1, Ifortran 12.0.2 and Fsplot. It is recommended to use them although it is possible to use other versions that would be installed on your platform. In addition, installing MAR requires:

- the OpenMP library
- the glibc library

These libraries can be loaded if pre-defined in a module environment (e.g. `module load openmp`), installed through the linux package manager (`apt-get`) or equivalent (e.g. homebrew for Apple OSX).

MAR outputs are written in NetCDF format, so any software dealing with this format may be used, e.g., Ferret, Python, Matlab. See this webpage to know more on how to deal with NetCDF files: [https://nicojourdain.github.io/students\\_dir/students\\_netcdf](https://nicojourdain.github.io/students_dir/students_netcdf)

All the command lines below are given with the example of "vi" as a text editor, but you can of course use emacs, gedit, or any other text editor instead.

## 4 Setting up a new domain (MAR and NESTOR)

In the following, it is assumed that you have downloaded MAR into the \$HOMdir directory (which may be any directory, not necessarily your home directory):

```
export HOMdir="home/bob"
ls -al ${HOMdir}/MAR
```

This should give the following tree:

$$\begin{array}{l} \$HOMdir/MAR/ \left\{ \begin{array}{ll} \text{bin/} & \text{Scripts used to execute MAR and NESTOR} \\ \text{src/} & \text{Model sources} \\ \text{usr/} & \text{User-specific files} \\ \text{lib/} & \text{Useful libraries} \end{array} \right. \end{array}$$

Note that all the export commands here and after have to be re-executed if you the session is interrupted.

First of all, adapt the INI.ctr file:

```
cd ${WORK_MAR}/MAR/bin
vi INI.ctr
```

You will need to choose the typical regional environment in which you plan to work:

```
#=====
#                               TECHNICAL INFORMATIONS
#
# Domain information
#
WLDreg=GR                      # world region (e.g. GR, AN, EU, BE, WA...) [a2]
```

The typical region will be used to enable or disable a few lines in the fortran code prior to compilation. For example, lines starting with #GR will be uncommented in the example above. Possible options are:

$$\text{Regions} \left\{ \begin{array}{ll} \text{AN/} & \text{ANtarctique} \\ \text{GR/} & \text{GRoeland} \\ \text{EU/} & \text{EUrope} \\ \text{BE/} & \text{BElgique} \\ \text{AF/} & \text{AFrique de l'ouest} \end{array} \right.$$

For typical mid-latitude applications, choose Europe.

You also need to set a few variables depending on your working platform:

```
#=====
# CLUSTER

# -----CLIMATO-----
HOMdir=/climato_tmp1/$USER ; cluster=linux
QSUB="qsub"
# -----

## -----FROGGY-----
# HOMdir=/home/$USER ; cluster=froggy
# QSUB="ssh froggy oarsub -S"
## -----
#
```

Note the \$WRKdir will be automatically taken as \$HOMdir/MAR/run if not predefined in the CLUSTER section of INI.ctr.

And adapt the paths of useful directories:

```
#=====
# SIMDIR

MARsim=$HOMdir/MAR

[ ${#MARdir} -gt 0 ] && [ -d $MARdir ] && MARsim=$MARdir

SIMdir=$MARsim/sim           # SIMDdir    directory path (MAR simulations)
MARsrc=$MARsim/src           # MARdir    directory path (MAR model)
MARbin=$MARsim/bin           # scripts   directory path (INI NST CODE MAR)
WRKtmp=$MARsim/tmp           # temporary directory path
WRKmsg=$MARsim/msg           # work      directory path (batched messages)

#=====
# STOCK

stock=139.165.29.17           # address of the mass storage system*
ustock=fettweis

sftp=y                        # y or n

STKmar=/climato_tmp1/fettweis/MAR/out  # MAR      directory path on stock
STKsrf=/climato_tmp1/fettweis/MAR/in    # DATA    directory path on stock (FAO,SST...)
STKlsc=$STKsrf/ECMWF              # LSC files directory path on stock
```

Note that if they don't exist yet, you may need to create the STKmar, STKsrf and STKlsc directories, e.g.:

```
mkdir $HOMdir/MAR/in
mkdir $HOMdir/MAR/out
mkdir $HOMdir/MAR/run    ## only if WRKdir was not defined
                        ## in the CLUSTER section of INI.ctr
```

If you set job\_pbs to 'n' then \$HOMdir/MAR/bin/MAR needs to be adapted:

```
$ (linux) if [ $job_pbs = "y" ] ; then
    BCH " cd $WRKmsg ; $QSUB $RUNdir/$bchN.cmd"
```

```

else
    BCH " ( ./\$RUNdir/\$bchN.cmd &> \$RUNdir/\$bchN.cmd.log ) &"
fi ;;

```

to

```

$ (linux) if [ \$job_pbs = "y" ] ; then
    BCH " cd \$WRKmsg ; $QSUB \$RUNdir/\$bchN.cmd"
else
    BCH " ( \$RUNdir/\$bchN.cmd &> \$RUNdir/\$bchN.cmd.log ) &"
fi ;;

```

Once INI.ctr adapted, you can proceed to the installation. Adapt the first few lines on \$HOMdir/MAR/bin/INSTALL, then:

```
./INSTALL
```

Choose the third option and reply "yes", then put your password.

Then you need to initiate the environment of your domain. For example, for domain "a" in Greenland:

```

export CONFIG=a
export WLDreg=GR
export DOM=${WLDreg}${CONFIG}
./INI $DOM
ls -al $HOMdir/MAR/$DOM # to check that the new directory has been created

```

where CONFIG is a letter in [a-z], and WLDreg corresponds to what you previously set in INI.ctr.

## 5 Running NESTOR

First, edit \$HOMdir/MAR/bin/NST.ctr to choose the nesting parameters (see comments therein). Then, compile NESTOR for the corresponding parameters:

```

cd $HOMdir/MAR/sim/$DOM/input/NESTOR
./Compile.exe

```

Note that if you want to visualize your domain through a netcdf file, you need to choose n08=T in NST.ctr.

Note to froggy users: Because of the absence of the "m" library (-lm), you need to recompile fsplit without the -static option:

```
cd $HOMdir/MAR/lib/fsplit
vi Makefile  ## remove the -static option
make
```

If your simulation is short, e.g. covering January 2001, prepare NESTOR as follows:

```
NST $DOM 2000 01
```

If your simulation is longer, e.g. covering 2000-2002, you can do as follows:

```
for YEAR in $(seq 2000 2002); do
for MONTH in 01 02 03 04 05 06 07 08 09 10 11 12; do
NST $DOM $YEAR $MONTH
done
done
```

This will prepare the .cmd script that will launch NESTOR for your domain. Edit it to add "exit" just before section 6 ("NESTOR launch") in order to create the NESTOR directory :

```
cd $HOMdir/MAR/sim/$DOM/input/NESTOR/run
ls -al
vi NST_$DOM.00.01.01-31.cmd  # or any other date
```

In the .cmd file, add "exit" just before section 6 ("NESTOR launch") in order to create the NESTOR directory, then execute it:

```
./NST_$DOM.00.01.01-31.cmd
```

Then, go to the working directory (scratch or whatever has been defined previously), check that LSCfil.dat and NSTing.ctr correspond to your settings (they should have been modified automatically), and set your parameters in MARgrd.ctr and src/NSTdim.inc:

```
export WRKdir="$HOMdir/MAR/run" ## if not defined in the CLUSTER section
                                ## of $HOMdir/MAR/bin/INI.ctr (adapt otherwise)
cd $WRKdir/NST_$DOM.00.01.01-31
vi LSCfil.dat
vi NSTing.ctr
vi MARgrd.ctr    ## to adapt
vi src/NSTdim.inc ## to adapt
```

Here is an example of MARgrd.ctr file (for the Amundsen Sea sector Antarctica):

```
PARAMETERS FOR MAR GRID CREATION
=====

-----
0                               | Map type (0=polar,1=stereo,2=lambert)
```



```

-----|-----
-112      | MAR domain center longitude
55         | MAR domain center longitude (grid point = imez)
-75        | MAR domain center latitude
46         | MAR domain center latitude (grid point = jmez)
-----|-----
25.0       | MAR mesh size (km)
-----|-----
-20.       | x-Direction (2D runs only ; 0=North, clockwise)
-----|-----
0.01       | Pressure at top (kPa)
-----|-----
2.         | zzmin= STD NEW (0=>OK) Vertical discretisation
1.8        | aavu=  STD NEW (0=>OK) "
1.13       | bbvu=  STD NEW (0=>OK) "
1000       | ccvu=  STD NEW (0=>OK) "
-----|-----
T          | Fine resolution of the Surface Layer
-----|-----
271.2      | Sea ST - parameter only used for vertical grid
-----|-----
0.0075     | Filter selectivity FISlo* (0.->sets to default)
-----|-----

```

NB: If you do want to remove topography filtering, you can comment the **stop** in `src/NESTOR.f`:

```

      print *, "Are you sure to not filter the topo"
.    //" at the boundaries ???" ; stop

```

In `src/NSTdim.inc`, you need to specify the domain dimensions:

```

!-NST domain dimensions
! -----

INTEGER mx,my,mz,mzabso,mw,nvx,ns1,nsno,nbdom

PARAMETER (mx   = 110)  ! X-grid
PARAMETER (my   = 92)   ! Y-grid
PARAMETER (mz   = 24)   ! Z-grid
PARAMETER (mzabso= 4)   ! Z-grid

PARAMETER (nvx  = 3)    ! Sub-division of grid cell (SVAT)
PARAMETER (mw   = nvx)  ! Sub-division of grid cell (Deardorff)

PARAMETER (ns1   = 7)   ! Soil layers           (SVAT)
PARAMETER (nsno  = 30)  ! Snow layers           (Snow model)
PARAMETER (nbdom = 2)   ! Number of continents  ("GLOveg.f")

```

You may also select a sub-region to make NESTOR faster, or take the full reanalysis as in this example:

```

!      A sub-region of the external large-scale domain is defined in order to
!      reduced the CPU cost and the memory requirement for the interpolation.

!-1. SIZE of the SUB-REGION (in grid points)

PARAMETER (isLMz = 0)

```

```

PARAMETER (ni = 360)
PARAMETER (nj = 181)
PARAMETER (njv= nj-isLMz)
PARAMETER (nk = 60)

!      Warning:
!      For LMDz, you may use the scalar grid size, nj= size(lat_s)
!      but in that case, you must set   isLMz=1 (njv = nj-1)
!      For all other models, please set isLMz=0 (njv = nj  )

!-2. BEGINNING INDEX of the SUB-REGION

PARAMETER (bi = 1)
PARAMETER (bj = 1)

```

Once this has been done, you can compile and execute NESTOR to create the domain:

```

./Compile.exe
./NESTOR.exe

```

Keep in mind that you need to re-compile NESTOR each time you change the domain dimensions. You can visualize the NESTOR output file NST\*.nc to check that the domain matches your expectations (only created if n08=T in \$HOMdir/MAR/bin/NST.ctr).

Once you are glad about the newly generated domain, you need to copy the files you modified to the input directory that will be used by NESTOR to prepare MAR's boundary conditions::

```

cp -r $WRKdir/NST_$DOM.00.01.01-31/MARgrd.ctr $HOMdir/MAR/sim/$DOM/input/NESTOR/.
cp -r $WRKdir/NST_$DOM.00.01.01-31/NESTOR.exe $HOMdir/MAR/sim/$DOM/input/NESTOR/.
cp -r $WRKdir/NST_$DOM.00.01.01-31/src/NSTdim.inc $HOMdir/MAR/sim/$DOM/input/NESTOR/.

```

Now, to launch NESTOR in order to create all the boundary conditions that will later on be used by MAR, you need to do the following:

```

cd $HOMdir/MAR/sim/$DOM/input/NESTOR/run  ## adapt if another choice was made
vi NST_$DOM.00.01.01-31.cmd  ## remove the "exit" that was added earlier
./NST_$DOM.00.01.01-31.cmd  ## alternatively use qsub or equivalent

```

You can follow the progress of NESTOR by checking NESTOR.log in \$WRKdir.

## 6 Compiling and running MAR

To compile MAR, you first need to edit CODE.ctr to choose among multiple options for MAR (e.g. choice of turbulence closure, activation of blowing snow, etc). If your platform is not defined in the COMPILE file, you will need to indicate everything in the `Compilers set` section.

```
cd $HOMdir/MAR/bin
vi CODE.ctr # make your choices
vi COMPILE # adapt if needed
```

Then, compile MAR (after checking that \$CONFIG is still defined):

```
echo $CONFIG ## In [a-z], see previous export if needs to be redefined
export CASE=01 ## Simulation ID : 2-digit number in [00-99]
CODE ${CONFIG}${CASE} ## For Froggy users : Compile in batch ? n
(because does not work under Ciment)
```

Then, adapt MAR.ctr, then execute the MAR command to prepare the script that will be used to run the MAR simulation:

```
vi MAR.ctr ## adapt if needed
MAR ${CONFIG}${CASE} 2000 01 a
```

where 2000 and 01 are the year and month respectively, and "a" can be replaced by any of these options:

- "a" for 15-day runs (which will be referred to as "a", "b")
- "c" for 10-day runs (which will be referred to as "c", "d", "e")
- "o" for 1-month run

Now you should be ready to launch the MAR simulation, for example, with qsub:

```
qsub $HOMdir/MAR/sim/$DOM/run/a01/MAR_$DOM.2000.01.01-15.cmd
```

To follow the progress of your simulation, it is recommended to look at the MAR.log file in \$WRKdir and at the .e files in \$HOMdir/MAR/msg. Importantly, a file ".OK" is created in \$WRKdir if the run is successful.

## 7 How to run multiple years

To run NESTOR or MAR for multiple years, there are already scripts for that. All these scripts are in the bin repository (HOMdir/MAR/bin).

### 7.1 For NESTOR

For NESTOR, you will need to use the NST\_yr script to create all NESTOR simulation launch scripts. Then you have just to type:

```
NST_yr ${DOM} Year1 Year2
```

This will create all the NESTOR simulation launch scripts, month by month, for the entire Year1-Year2 period.

Once it's done, change your domain and then run your simulations using the following script (This example is intended for users of the Cement machine), adapt it according to the machine you are working on:

```
for file in NST_${DOM}.XX.*.*.cmd; do
qsub -S --project regional-climate $HOME/MAR/sim/${DOM}/input/NESTOR/run/$file
done
```

## 7.2 For MAR

To create the MAR launch scripts, you can use the `MAR_yr` script. To do this, simply type this command after compiling the MAR:

```
MAR_yr ${CONFIG}${CASE} Year1 Year2 o
```

Once this step has been taken, you just have to run your MAR simulations with the following command:

```
sub_MAR_yr ${CONFIG}${CASE} Year1 Year2
```

## 7.3 Running MAR in chunks

When running long (i.e decades) simulations, break it up into chunks of sometimes down to 2-3 years, depending on the stability of the SMB, melt and runoff to the spin-up length of the run. Create a new, identical simulation with a different name in order for MAR not to overwrite its own outputs for the overlapping periods. Example: Running MAR from 1979-2017, breaking it up into 19 chunks of 3 years with one year overlap:

1. 1979-1982 (simulation: y20)
2. 1981-1984 (simulation: y21) ...

All these new but unchanged simulations link for example to 'MAR\_y01.exe' but have a different name. In order to automate this process this is what we can do. First we create the folders for the simulations:

While being in `/MAR/out/GRy` run to create folder y20-y38 (save as bash script):

```
#!/bin/bash
n=20;
max=38;
while [ "$n" -le "$max" ]; do
    mkdir "y\${n}"
    n=$((n + 1));
done
```

After creating the folders we can automatically create MAR\_yXX.exe files in the corresponding folders, all linking to an existing .exe (in this example linking to 'MAR\_y01.exe'). From /MAR/out/GRy run:

```
#!/bin/bash
n=20;
max=38;

while [ "$n" -le "$max" ]; do
    cp -r y01/* "y\$n"
    cd "y\$n/code"
    rm MAR_y01.exe
    ln -s ../../y01/code/MAR_y01.exe "MAR_y\$n.exe"
    cd ../../
    n=`expr "$n" + 1`;
done
```

After that we can run MAR from /MAR/bin with:

- MAR y20 1979 09 a -> qsub .cmd file and change MAR.ctr for following run
- MAR y21 1981 09 a -> qsub .cmd file and change MAR.ctr for following run
- Continue as desired

Spin-up times: these are generally minimal/non-existent if starting simulations with initialised snowpack included. Thus, it is acceptable to - for example - just run MAR for a single year and not discard any of the early data.

However, this would not be the case if the global forcings at the domain boundaries are out of equilibrium with the climate conditions that the spun-up snowpacks were created with - e.g. if one were to force the boundaries with temperature a degree higher than the model run that the snowpacks were made with.

## 8 Tips and tricks for running MAR

### 8.1 Restart a simulation from the beginning

Let's say that you killed a foreground MAR process by CTRL-C. You can't just re-run the cmd file, MAR will crash. Instead, do as follows:

```
$ rm -rf ~/MAR/sim/<domain>/run/<simulation>
$ rm -rf ~/MAR/sim/<domain>/ctrl/<simulation>
$ cd ~/MAR/bin
$ MAR <simulation> <year> <month> <chunk>
$ ./MAR...cmd
```

## 8.2 Provide input dat files per-domain

Rather than each simulation grabbing its dat files etc from usr and bin, you can add these files to `/MAR/sim/<dom>/input/datMAR/` (note that you will have to create datMAR).

## 8.3 Troubleshooting

If MAR crashes, a tarball of all the files used for the run is generated and saved to `STKsrf/MARout/user/$dom/crash/`.

You can use the error tarball to run MAR by hand:

```
$ cd ~/MAR/out/GR\${DOM}/crash      (you may need to mkdir)
$ tar xzf MAR_GR\${DOM}.xxxxxx.CRASH.tar.gz
$ cd MAR_GR\${DOM}.xxxxxx.CRASH
$ rm -f MAR.log MARphy.out
$ export OMP_NUM_THREADS=4
$ ulimit -s unlimited
$ ./MAR_\${DOM}xx.exe
```

Messages generated by MAR are saved to `'/MAR/msg/'`.

## 8.4 Interpolating fine Greenland topography onto NESTOR grid

This requires some additional scripts from Xavier Fettweis. In summary, the procedure is as follows:

- Save the basic variables from NESTOR (last section) to a netCDF file.
- Use these basic variables as input to the script `'topo_mask'`, which will interpolate the detailed topography and output it to a new netCDF file.
- Copy over the detailed topography netCDF file back into the `$WRKdir` version of NESTOR, and re-run NESTOR there to include the detailed topography in the domain.
- Add these changes into the `'home'` version of MAR/NESTOR.

The full procedure is as follows.

Staying in ferret, we need to create a new NetCDF file, with four variables:

```
$ save/file=mydom.nc lon,lat,sh,sol,svt,sfr
```

This gives the grid for the program that will then interpolate the topography onto the MAR grid.

Exit ferret. Copy this netCDF file to 'topo\_mask' and go to this location.

Open 'interpol.inc' and go to the 'Configuration for interpolation onto the NESTOR grid' section. Make the following edits:

```
- XXkm = name of the netcdf file, minus .nc; make sure to update character
dimensions to match length of provided filename
- filen = output file
- mx and my = the dimensions as in NSTdim
- range = resolution, say 5 km
- imez and jmez = the MAR grid centres as in MARgrd.ctr
```

Now compile and run the index and interpolation programs:

```
$ ifort index.f90 libUN.f -lnetcdf_ifort
$ ./a.out
$ ifort interpol.f90 libUN.f -lnetcdf_ifort
$ ./a.out
```

A new file named as specified in 'filen' in 'interpol.inc' is generated. Open this file in ferret to check that it looks sensible.

```
$ ferret
$ use <filen>
$ shade ICE,lon,lat ; go land_detail
$ shade SRF,lon,lat ; go land_detail
$ exit
```

Now go to '\$WRKdir/NST\*\*/input/TOPO' and copy the new NetCDF file in 'topo\_mask\_for\_MAR' to this location.

Open '\$WRKdir/MARrun/NST\_\*/srcUSRgrd.f' for editing. Go to the "Topography for ETOPO" section and insert the name of the new NetCDF file in the relevant locations (three times in total, with relative path e.g. 'input/TOPO/myout.cdf'). Remove 'no\_' from 'ETOPOg' and 'GLOveg'. Also change 'subnam GLOvegcc' to 'GLOveg'.

Go up one directory (i.e. to '\$WRKdir/MARrun/NST\_\*\*') level and run:

```
$ Compile.exe
$ NESTOR.exe
```

Now go to ' /MAR/sim/GRb/input/NESTOR/input/TOPO' and copy the netcdf file into this location from the ' /topo\_mask\_for\_MAR' folder.

Next go to ' /MAR/sim/GRb/input/NESTOR' and delete the 'src/' folder and 'MAR-grd.ctr', then replace these with the equivalent folder and file from '\$WRKdir'. Compile NESTOR again.

```
\$ Compile.exe
```

Go to /MAR/bin and run:

```
\$ NST GRb 2005 09
```

(substitute values as appropriate), and run the resulting command file that is generated. Run the complete file, do not add an 'exit' command in the file.