

# **SICOPOLIS V3.0**

## **– Quick Start Manual –**

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# 1 Requirements

- UNIX/LINUX system.
- Fortran 90/95 compiler.
- Optional: GNU Autotools (automake, autoheader, aclocal, autoconf, make).
- SICOPOLIS supports output either in native binary or in NetCDF format (see Sect. 6). For the latter, you need an installation of NetCDF version 3.6.x or later (<http://www.unidata.ucar.edu/software/netcdf/>).
- For the shallow shelf approximation solver, the Library of Iterative Solvers for Linear Systems (Lis) version 1.2.53 is required (<http://www.ssisc.org/lis/dl/lis-1.2.53.tar.gz>). Later versions don't work so far!

# 2 Download

- **Option 1: Using subversion**

The subversion repository of SICOPOLIS is hosted by the GForge system AWIForge of the Alfred Wegener Institute for Polar and Marine Research (AWI) in Bremerhaven, Germany (front page: <http://aforge.awi.de/gf/project/sicopolis/>).

1. Check out from the subversion repository:

```
svn checkout \  
http://aforge.awi.de/svn/sicopolis/tags/version30 sicopolis
```

2. You should then have a new folder “sicopolis” that contains the entire program package.

- **Option 2: Downloading a tarball**

1. Download the gzipped tar archive `sicopolis_v30.tgz` from the SICOPOLIS web page (<http://sicopolis.greveweb.net/>).

2. Unpacking:

```
tar -x -v -z -f sicopolis_v30.tgz
```

3. You should then have a new folder “sicopolis” that contains the entire program package.

### 3 Building with GNU Autotools

This is *optional* (since revision 254). For details see the INSTALL file.

### 4 Files and directories in “sicopolis”

- **runs:**

Shell script (bash) `sico.job` for running a single simulation under UNIX/LINUX.

Shell script (bash) `multi_sico_template.job` for running multiple simulations by repeated calls of `sico.job`.

Shell scripts (bash) `sico.sh` and `multi_sico_template.sh`: Same purpose, but to be used when SICOPOLIS was built with GNU Autotools.

Subdirectory **headers**: specification files `sico_specs_run_name.h` (*run\_name*: name of run).

- File included for run `v30_emtp2sge_expA`  
→ EISMINT Phase 2 Simplified Geometry Experiment A, resolution 25 km,  $t = 0 \dots 200$  ka (Payne et al. 2000).
- File included for run `v30_grl20_ss25ka`  
→ Greenland ice sheet, resolution 20 km, short steady-state run ( $t = 0 \dots 25$  ka) for modern climate conditions (unpublished).
- File included for run `v30_ant40_ss25ka`  
→ Antarctic ice sheet without ice shelves, resolution 40 km, short steady-state run ( $t = 0 \dots 25$  ka) for modern climate conditions (unpublished).
- Files included for runs `v30_grl20_paleo01_init` and `v30_grl20_paleo01`  
→ Greenland ice sheet, resolution 20 km,  $t = -422 \dots -250$  ka for the spin-up run (...\_init),  $t = -250 \dots 0$  ka for the main run [similar to run `hf_pmod2` by Greve (2005)].
- Files included for runs `v30_grl20_wre1000` and `v30_grl10_wre1000`  
→ Greenland ice sheet, resolution 20 / 10 km,  $t = 1990$  CE  $\dots$  2350 CE [similar to run #11 by Greve and Otsu (2007)].
- Files included for runs `v30_ant40_paleo04_init` and `v30_ant40_paleo04`  
→ Antarctic ice sheet without ice shelves, resolution 40 km,

$t = -522 \dots -422$  ka for the spin-up run (...\_init),  $t = -422 \dots 0$  ka for the main run [see Greve (2006) and Greve (2005)].

- File included for run v30\_nhem80\_nt012\_new  
→ northern hemisphere, resolution 80 km,  $t = -250 \dots 0$  ka [similar to run nt012 by Greve et al. (1999)].
- Files included for runs v30\_grl20\_sr\_paleo44\_xxx (xxx = init100a, fixtopo1, fixtopo2, 100a), v30\_grl20\_sr\_future44\_ctl and v30\_grl20\_sr\_future44\_c2  
→ Greenland ice sheet, low-resolution (20 km) versions of the paleoclimatic spin-up ( $t = -250 \dots 0$  ka), experiment CTL ( $t = 0 \dots 500$  a, constant climate control run) and experiment C2 [ $t = 0 \dots 500$  a,  $1.5 \times$  AR4 climate forcing (based on the A1B emission scenario) over the first 94 years, then held steady] carried out for the SeaRISE community effort (Greve and Herzfeld 2013).
- Files included for runs v30\_ant40\_sr\_spinup01\_xxx (xxx = init100a, fix\_250\_125k, fix\_125\_0k, 20a), v30\_ant40\_sr\_future01\_ctl and v30\_ant40\_sr\_future01\_m2  
→ Antarctic ice sheet with ice shelves, low-resolution (40 km) versions of the paleoclimatic spin-up ( $t = -250 \dots 0$  ka), experiment CTL ( $t = 0 \dots 500$  a, constant climate control run) and experiment M2 ( $t = 0 \dots 500$  a, sub-ice-shelf melting increased to 20 m i. eq.  $\text{a}^{-1}$ ) carried out for the SeaRISE community effort (Sato and Greve 2012).

- **src:**

Directory that contains the main program file sicopolis.F90.

- Subdirectory **subroutines/general**: general subroutines, for any modelled domain.
- Subdirectory **subroutines/ant**: subroutines specific for the Antarctic ice sheet.
- Subdirectory **subroutines/emtp2sge**: subroutines specific for the EISMINT Phase 2 Simplified Geometry Experiments.
- Subdirectory **subroutines/grl**: subroutines specific for the Greenland ice sheet.
- Subdirectory **subroutines/nhem**: subroutines specific for the northern hemisphere.
- Accordingly for Austfonna, Scandinavia, Tibet, ISMIP HEINO, and the north and south polar caps of Mars.

- **sico\_in:**

Directory that contains input data files for SICOPOLIS.

- Subdirectory **general**: general input files, for any modelled domain.
- Subdirectory **ant**: input files specific for the Antarctic ice sheet.
- Subdirectory **empt2sge**: input files specific for the EISMINT Phase 2 Simplified Geometry Experiments.
- Subdirectory **grl**: input files specific for the Greenland ice sheet.
- Subdirectory **nhem**: input files specific for the northern hemisphere.
- Accordingly for Austfonna, Scandinavia, Tibet, ISMIP HEINO, and the north and south polar caps of Mars.

- **sico\_in\_\_searise:**

Directory that contains SeaRISE input data files for SICOPOLIS (SeaRISE = Sea-level Response to Ice Sheet Evolution, multi-model community effort, see <http://tinyurl.com/srise-lanl> and <http://tinyurl.com/srise-umt>).

- Subdirectory **general**: general input files, for any modelled domain.
- Subdirectory **ant**: input files specific for the Antarctic ice sheet.
- Subdirectory **grl**: input files specific for the Greenland ice sheet.

- **sico\_out:**

Empty directory into which output files of SICOPOLIS simulations are written.

- **docu:**

Directory that contains some documentation.

- Subdirectory **quick\_start**:  
L<sup>A</sup>T<sub>E</sub>X source for this manual (PDF must be built with make).
- Subdirectory **doxygen**:  
Documentation created by Doxygen.
  - \* `html/index.html` → Source code browser.
  - \* `latex/refman.pdf` (must be built with make) → Reference manual.

- **tools:**

See Sects. 7 and 8.

- **license:**

Directory that contains a copy of the GNU General Public License (version 3).

## 5 How to run a simulation

### Case 1: SICOPOLIS was not built with GNU Autotools

1. In the script `sico.job` (subdirectory `runs/`), search for “greve”, and replace the path names for `RUN_DIR` and `SRC_DIR` with your own ones.

Also, search for “Compiler”, and replace the variables `F90` and `F90FLAGS` according to the syntax of your own Fortran compiler if needed.

2. In the specification files (subdirectory `runs/headers/`), search for “greve”, and replace the path names for `INPATH`, `OUTPATH` and `ANFDATPATH` (unless set to “none”) with your own ones.
3. The default set-up is to run SICOPOLIS with output in NetCDF format. If you want to create output in native binary format instead, set `NETCDF_FLAG` to ‘no’ (rather than ‘yes’) in `sico.job`, and set `NETCDF` to 1 (rather than 2) in all specification files.
4. The rest is quite simple:

- In order to run simulation `v30_grl20_ss25ka`, use the script `sico.job`. The command is

```
(./sico.job v30_grl20_ss25ka) >out_job.dat 2>&1 &
```

(from subdirectory `runs/`, bash required). Accordingly for the other simulations.

- Alternatively, if you prefer to run all simulations consecutively, copy the template script `multi_sico_template.job` to `my_multi_sico.job` and execute it:

```
(./my_multi_sico.job) >out_mjob_000.dat 2>&1 &
```

### Case 2: SICOPOLIS was built with GNU Autotools

- For this case, the script `sico.sh` (subdirectory `runs/`) is the equivalent of `sico.job`. For details see the output of its help option:

```
./sico.sh -h
```

- Running all simulations consecutively: copy the template script `multi_sico_template.sh` to `my_multi_sico.sh`, then customise `my_multi_sico.sh` (see comment in the file) and execute it:

```
(./my_multi_sico.sh) >out_multi_000.dat 2>&1 &
```

## Computing times

The approximate computing times for the simulations, run with the Intel Fortran Compiler for Linux 11.1 (optimisation options `-xHOST -O3 -no-prec-div`) on a  $2 \times 6$ -Core Intel Xeon X5670 (2.93 GHz) PC under openSUSE 12.2 (64 bit), are listed in Table 1.

Run	Model time	Time step <sup>†</sup>	CPU time <sup>‡</sup>
v30_emtp2sge_expA	200 ka	200 a	2.7 min
v30_grl20_ss25ka	25 ka	5 a	11.6 min
v30_ant40_ss25ka	25 ka	10 a	9.6 min
v30_grl20_paleo01_init	172 ka	5 a	1.3 hrs
v30_grl20_paleo01	250 ka	5 a	2.1 hrs
v30_grl20_wre1000	360 a	5 a	10.3 sec
v30_grl10_wre1000*	360 a	1 a	3.2 min
v30_ant40_paleo04_init	100 ka	10 a	0.6 hrs
v30_ant40_paleo04	422 ka	10 a	2.4 hrs
v30_nhem80_nt012_new	250 ka	5 a	2.2 hrs
v30_grl20_sr_paleo44_init100a	100 a	5 a	5.8 sec
v30_grl20_sr_paleo44_fixtopo1	125 ka	5 a	0.8 hrs
v30_grl20_sr_paleo44_fixtopo2	124.9 ka	5 a	0.8 hrs
v30_grl20_sr_paleo44_100a	100 a	5 a	3.5 sec
v30_grl20_sr_future44_ctl	500 a	1 a	1.1 min
v30_grl20_sr_future44_c2	500 a	1 a	1.1 min
v30_ant40_sr_spinup01_init100a	100 a	2 / 10 a <sup>†</sup>	2.1 min <sup>‡</sup>
v30_ant40_sr_spinup01_fix_250_125k	125 ka	2 / 10 a <sup>†</sup>	44.4 hrs <sup>‡</sup>
v30_ant40_sr_spinup01_fix_125_0k	125 ka	2 / 10 a <sup>†</sup>	44.6 hrs <sup>‡</sup>
v30_ant40_sr_spinup01_20a	20 a	1 / 5 a <sup>†</sup>	0.9 min <sup>‡</sup>
v30_ant40_sr_future01_ctl	500 a	1 / 5 a <sup>†</sup>	21.6 min <sup>‡</sup>
v30_ant40_sr_future01_m2	500 a	1 / 5 a <sup>†</sup>	15.7 min <sup>‡</sup>

Table 1: Model times, time steps and computing (CPU) times for the simulations (see main text for details).

<sup>†</sup>: If one value is given, this is the common dynamic (velocity, ice thickness) and thermodynamic (temperature, water content, age) time step. If two values are given (marked by the dagger (<sup>†</sup>) symbol), the first one is the dynamic, the second one the thermodynamic time step.

<sup>‡</sup>: Unmarked times are for a single core, thus approximately equal to the wall clock time. Times marked by the ddagger (<sup>‡</sup>) symbol are across all cores, thus the wall clock time is significantly less.

\*: For this run, see the remark in Sect. 8 under the item “Program resolution\_doubler.F90”.

## 6 Output files

Output files of simulations are written to directory `sico_out`. Four types are produced:

- **run\_name.log:**

ASCII file that lists the main specifications of simulation *run\_name*.

- **run\_name.ser:**

Time-series file (ASCII) that contains global parameters:

- Time,  $t$
- Surface-temperature anomaly,  $D_{Ts}$ , or glacial index,  $glac\_ind$  (forcing)
- Sea level,  $z_{sl}$  (forcing)
- Total ice volume,  $V$
- Grounded ice volume,  $V_g$
- Floating ice volume,  $V_f$
- Total ice area,  $A$
- Grounded ice area,  $A_g$
- Floating ice area,  $A_f$
- Maximum ice thickness,  $H_{max}$
- Maximum ice elevation,  $zs_{max}$
- Volume of the temperate ice,  $V_t$
- Freshwater production due to melting and calving,  $V_{fw}$
- Sea-level equivalent of ice volume,  $V_{sle}$
- Area covered by temperate ice,  $A_t$
- Water drainage due to basal melting,  $V_{bm}$
- Water drainage from the temperate layer,  $V_{tld}$
- Maximum thickness of the temperate layer,  $H_{t,max}$
- Maximum surface velocity,  $vs_{max}$

- **run\_name.core:**

Time-series file (ASCII) that contains for selected locations `xxx`:

- Time,  $t$

- Surface-temperature anomaly, D\_Ts, or glacial index, glac\_ind (forcing)
- Sea level, z\_sl (forcing)
- Thickness, H\_xxx
- Surface velocity, v\_xxx
- Basal temperature, T\_xxx
- Basal frictional heating, Rb\_xxx

For the Greenland ice sheet, these data are written for six locations:

GRIP (xxx=GR), GISP2 (xxx=G2), Dye 3 (xxx=D3), Camp Century (xxx=CC), NorthGRIP (xxx=NG), NEEM (xxx=NE).

For the Antarctic ice sheet, these data are written for six locations:

Vostok (xxx=Vo), Dome A (xxx=DA), Dome C (xxx=DC), Dome F (xxx=DF), Kohlen (xxx=Ko), Byrd (xxx=By).

For the northern hemisphere and the EISMINT Phase 2 Simplified Geometry Experiments, no such data are written.

- **run\_name0001.nc/.erg, run\_name0002.nc/.erg, ...:**

Complete set of fields (topography, velocity, temperature etc., written either in NetCDF (\*.nc) or in native binary (\*.erg) format; see subroutines output\_nc and output1, respectively) for selected time slices defined in specifications file. For example, simulation v30\_grl20\_ss25ka produces three files v30\_grl20\_ss25ka0001.nc, v30\_grl20\_ss25ka0002.nc and v30\_grl20\_ss25ka0003.nc, which correspond to  $t = 0$ , 10 ka and 25 ka, respectively.

## 7 Plotting with SICOGRAPH

The output described in Sect. 6 can be visualised with any plotting tool at the user’s preference. One possibility is to use SICOGRAPH, which is part of the SICOPOLIS package and based on the Generic Mapping Tools GMT (<http://gmt.soest.hawaii.edu/>).

### 7.1 Installation

1. If you do not have an installation of GMT version 4.x yet, download and install the latest version according to the instructions on the GMT web site.
2. Since revision 116, SICOGRAPH is included in the subversion repository of SICOPOLIS. You’ll find it in the directory `sicopolis/tools/sicograph/`.

### 7.2 Customisation

#### Case 1: SICOPOLIS was not built with GNU Autotools

1. In the script `sicograph.job`, search for “greve”, and replace the path name for `RUN_DIR` with your own one.
2. Also, search for “Compiler”, and replace the variables `F90` and `F90FLAGS` according to the syntax of your own Fortran compiler if needed.
3. By default, SICOGRAPH is linked with the NetCDF library. If this is not necessary (native binary rather than NetCDF output produced by SICOPOLIS), set `NETCDF_FLAG` to ‘no’.

#### Case 2: SICOPOLIS was built with GNU Autotools

Nothing to be done.

### 7.3 Producing plots

#### Case 1: SICOPOLIS was not built with GNU Autotools

In order to plot the output of simulation `v30_gr120_ss25ka`, use the script `sicograph.job` interactively:

```
./sicograph.job v30_gr120_ss25ka
```

(bash required; accordingly for the other simulations).

## Case 2: SICOPOLIS was built with GNU Autotools

Use `sicograph.sh` instead. For details see the output of its help option:

```
./sicograph.sh -h
```

In either case, you'll get a menu that allows you to choose the type of plot you wish to produce. For example, try the option

```
(1) Ice-surface topography
```

and enter

```
Number of time-slice file (with leading zeros, 4 digits) > 0003
```

```
Time-slice file contains:
```

```
(0) only 2-d arrays, (1) full set of 2-d and 3-d arrays > 1
```

```
Plot (1) with or (2) without colour bar? > 1
```

```
Plot (1) with or (2) without contour labels? > 1
```

You will find the plot in the subdirectory `gmt_scripts/plots/` as file `v30_grl20_ss25ka0003_zs.eps` (in EPS format). As a second example, try

```
(41) Time series
```

and in the following sub-menu choose

```
(5) Total ice volume
```

This produces the file `v30_grl20_ss25ka_V_tot.eps` in the subdirectory `gmt_scripts/plots/`.

## 7.4 Manipulating plot appearance

For all types of plots, the files in the subdirectory `parameter_files/` control the limits and labels of the  $x$ - and  $y$ -axes. In addition, for the plan-view plots, the files in the subdirectory `gmt_scripts/cpt/` control the colour scales (`*.cpt`) and contour levels (`*.zzz`). If a file is missing, the corresponding parameters are computed automatically.

## 8 Some useful tools

In addition to SICOGRAPH, the directory sicopolis/tools contains some further useful tools.

- Program **make\_searise\_output.F90**:  
Generating SeaRISE output (see <http://tinyurl.com/srise-umt-out>) from the NetCDF time-slice files produced by SICOPOLIS (see Sect. 6).  
If SICOPOLIS was not built with GNU Autotools, to be executed by  

```
./make_searise_output.job run_name
```

  
If SICOPOLIS was built with GNU Autotools, to be executed by the script tools.sh (see the output of its help option: `./tools.sh -h`).
- Program **resolution\_doubler.F90** :  
Doubling the horizontal resolution of a NetCDF time-slice output file produced by SICOPOLIS (see Sect. 6).  
If SICOPOLIS was not built with GNU Autotools, to be executed by  

```
./resolution_doubler.job run_name
```

  
If SICOPOLIS was built with GNU Autotools, to be executed by the script tools.sh (see the output of its help option: `./tools.sh -h`).  
  
For example, run v30\_grl10\_wre1000 (10 km resolution) requires the resolution-doubled final output of run v30\_grl20\_paleo01 (20 km resolution) as initial conditions. So in order to create it, execute the resolution doubler for run v30\_grl20\_paleo01 and enter  

```
Number of time-slice file (with leading zeros, 4 digits) > 0003
```

  
This will convert the original time-slice file v30\_grl20\_paleo010003.nc to the resolution-doubled file v30\_grl20\_paleo01\_dbl.0003.nc that serves as initial conditions for run v30\_grl10\_wre1000.
- Subdirectory **matlab**:  
MATLAB functions for reading SICOPOLIS output files (see Sect. 6).

## References

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