SICOPOLIS V3.1
– 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 newer (http://www.unidata.ucar.edu/software/netcdf/).
- For the shallow shelf approximation solver, a recent version (1.4.13 or newer) of the Library of Iterative Solvers for Linear Systems (Lis) is required (http://www.ssisc.org/lis/).

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 --username anonymous \
       http://aforge.awi.de/svn/sicopolis/tags/version31 sicopolis
     ```

     (username 'anonymous', blank password)
  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_v31.tgz from the SICOPOLIS web page (http://sicopolis.greveweb.net/).
  2. Unpacking:

     ```
     tar -x -v -z -f sicopolis_v31.tgz
     ```

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

3 Building with GNU Autotools

This is *optional*. 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 v31_emtp2sge_expA
    $\longrightarrow$ EISMINT Phase 2 Simplified Geometry Experiment A,
    resolution 25 km, $t = 0 \ldots 200$ ka (Payne et al. 2000).
  - File included for run v31_grl20_ss25ka
    $\longrightarrow$ Greenland ice sheet, resolution 20 km,
    short steady-state run ($t = 0 \ldots 25$ ka) for modern climate conditions
    (unpublished).
  - File included for run v31_ant40_ss25ka
    $\longrightarrow$ Antarctic ice sheet without ice shelves, resolution 40 km,
    short steady-state run ($t = 0 \ldots 25$ ka) for modern climate conditions
    (unpublished).
  - Files included for runs v31_grl20_paleo01_init and v31_grl20_paleo01
    $\longrightarrow$ Greenland ice sheet, resolution 20 km,
    $t = -422 \ldots -250$ ka for the spin-up run (..._init), $t = -250 \ldots 0$ ka
    for the main run [similar to run hf_pmod2 by Greve (2005), but with
    the new topography data based on Bamber et al. (2013)].
  - Files included for runs v31_grl20_wre1000 and v31_grl10_wre1000
    $\longrightarrow$ Greenland ice sheet, resolution 20 / 10 km, $t = 1990$ CE $\ldots 2350$ CE
    [similar to run #11 by Greve and Otsu (2007), but with
    the new topography data based on Bamber et al. (2013)].

- File included for run v31_nhem80_nt012_new
  $\longrightarrow$ northern hemisphere, resolution 80 km, $t = -250 \ldots 0$ ka
  [similar to run nt012 by Greve et al. (1999)].
- Files included for runs v31_grl20_sr_paleo44_xxx (xxx = init100a, fixtopo1, fixtopo2, 100a), v31_grl20_sr_future44_ctl and v31_grl20_sr_future44_c2
  $\longrightarrow$ Greenland ice sheet, low-resolution (20 km) versions
  of the paleoclimatic spin-up ($t = -250 \ldots 0$ ka),
  experiment CTL ($t = 0 \ldots 500$ a, constant climate control run)
  and experiment C2 [$t = 0 \ldots 500$ 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 v31_ant40_sr_spinup01_xxx (xxx = init100a, fixtopo1, fixtopo2, fixtopo3, 20a), v31_ant40_sr_future01_ctl and v31_ant40_sr_future01_m2
  $\longrightarrow$ Antarctic ice sheet with ice shelves, low-resolution (40 km) versions
  of the paleoclimatic spin-up ($t = -250 \ldots 0$ ka),
  experiment CTL ($t = 0 \ldots 500$ a, constant climate control run)
  and experiment M2
  ($t = 0 \ldots 500$ a, sub-ice-shelf melting increased to 20 m i. eq. a^{-1})
  carried out for the SeaRISE community effort (Sato and Greve 2012).
- File included for run v31_heino_st
  $\longrightarrow$ ISMIP HEINO standard run ST,
  resolution 50 km, $t = 0 \ldots 200$ ka (Calov et al. 2010).

- **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/heino**: subroutines specific for the ISMIP HEINO experiments.
  - Subdirectory **subroutines/nhem**: subroutines specific for the northern hemisphere.

  - Accordingly for Austfonna, Scandinavia, Tibet 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 **emtp2sge**: input files specific for the EISMINT Phase 2 Simplified Geometry Experiments.
  - Subdirectory **grl**: input files specific for the Greenland ice sheet.
  - Subdirectory **heino**: input files specific for the ISMIP HEINO experiments.
  - Subdirectory **nhem**: input files specific for the northern hemisphere.
  - Accordingly for Austfonna, Scandinavia, Tibet and the north and south polar caps of Mars.

- **sico_out**:

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

- **docu**:

  Directory that contains some documentation.

  - Subdirectory **quick_start**:
    LaTeX source for this manual (PDF must be built with make).
  - Subdirectory **doxygen**:
    Documentation created by Doxygen.
    * html/index.html $\longrightarrow$ Source code browser.
    * latex/refman.pdf (must be built with make) $\longrightarrow$ 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.

   As for the Fortran compiler, make sure that the environment variable FC is set to either ifort (Intel Fortran Compiler) or gfortran (GNU Fortran). If you wish to use a different compiler, you must modify the script sico.job accordingly.

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 v31_grl20_ss25ka, use the script sico.job. The command is

     ```
     (./sico.job v31_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 2×6-Core Intel Xeon X5670 (2.93 GHz) PC under openSUSE 12.2 (64 bit), are listed in Table 1.

Run	Model time	Time step†	CPU time‡
v31_emtp2sge_expA	200 ka	200 a	2.8 min
v31_grl20_ss25ka	25 ka	5 a	10.8 min
v31_ant40_ss25ka	25 ka	2 / 10 a†	22.9 min
v31_grl20_paleo01_init	172 ka	5 a	1.2 hrs
v31_grl20_paleo01	250 ka	5 a	1.9 hrs
v31_grl20_wre1000	360 a	5 a	9.4 sec
v31_grl10_wre1000*	360 a	1 a	3.0 min
v31_nhem80_nt012_new	250 ka	5 a	2.2 hrs
v31_grl20_sr_paleo44_init100a	100 a	5 a	5.8 sec
v31_grl20_sr_paleo44_fixtopo1	125 ka	5 a	0.8 hrs
v31_grl20_sr_paleo44_fixtopo2	124.9 ka	5 a	0.8 hrs
v31_grl20_sr_paleo44_100a	100 a	5 a	3.5 sec
v31_grl20_sr_future44_ctl	500 a	1 a	1.1 min
v31_grl20_sr_future44_c2	500 a	1 a	1.1 min
v31_ant40_sr_spinup01_init100a	100 a	2 / 10 a†	16.2 sec
v31_ant40_sr_spinup01_fixtopo1	5 ka	1 / 5 a†	26.4 min
v31_ant40_sr_spinup01_fixtopo2	120 ka	2 / 10 a†	6.4 hrs
v31_ant40_sr_spinup01_fixtopo3	124.98 ka	2 / 10 a†	5.3 hrs
v31_ant40_sr_spinup01_20a	20 a	1 / 5 a†	7.1 sec
v31_ant40_sr_future01_ctl	500 a	1 / 5 a†	2.7 min
v31_ant40_sr_future01_m2	500 a	1 / 5 a†	1.8 min
v31_heino_st	200 ka	0.25 a	27.9 hrs

Table 1: Model times, time steps and computing (CPU) times for the simulations (see main text for details).
†: 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 (†) symbol), the first one is the dynamic, the second one the thermodynamic time step.
‡: All runs were done on one core only. The v31_ant40_sr_xxx runs that include ice shelves can be done on multiple cores using OpenMP for the SSA solver; however, at the employed, rather low resolution of 40 km the solver does not scale well, and the gain in wall clock time by using multiple cores is very small.
*: 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), Kohnen (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 v31_grl20_ss25ka produces three files v31_grl20_ss25ka0001.nc, v31_grl20_ss25ka0002.nc and v31_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. 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. As for the Fortran compiler, make sure that the environment variable FC is set to either ifort (Intel Fortran Compiler) or gfortran (GNU Fortran). If you wish to use a different compiler, you must modify the script sicograph.job accordingly.

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 v31_grl20_ss25ka, use the script sicograph.job interactively:

```
./sicograph.job v31_grl20_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 v31_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 v31_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 v31_grl10_wre1000 (10 km resolution) requires the resolution-doubled final output of run v31_grl20_paleo01 (20 km resolution) as initial conditions. So in order to create it, execute the resolution doubler for run v31_grl20_paleo01 and enter

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

  This will convert the original time-slice file v31_grl20_paleo010003.nc to the resolution-doubled file v31_grl20_paleo01_dbl_0003.nc that serves as initial conditions for run v31_grl10_wre1000.

- Subdirectory **matlab**:
  MATLAB functions for reading SICOPOLIS output files (see Sect. 6).

References

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