SICOPOLIS V3.3-dev
– Quick Start Manual –

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1 Requirements

- Unix-like system (e.g., Linux).
- Fortran compiler.
  So far, the Intel and GNU Fortran compilers are supported. Make sure that the environment variable FC is set to either ifort (Intel) or gfortran (GNU). If you wish to use a different compiler, please contact <help@sicopolis.net>.
- 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 (recommended), you need an installation of NetCDF version 3.6.x or newer (http://www.unidata.ucar.edu/software/netcdf/).
- For the shallow-shelf/shelfy-stream 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

- **Using subversion**

  The subversion repository of SICOPOLIS is kindly hosted by the FusionForge system AWIForge of the Alfred Wegener Institute for Polar and Marine Research (AWI) in Bremerhaven, Germany (front page: https://swrepo1.awi.de/projects/sicopolis/).

  1. Check out the latest revision ("bleeding edge") from the subversion repository:

     ```
     svn checkout --username anonsvn --password anonsvn \
       https://swrepo1.awi.de/svn/sicopolis/trunk sicopolis
     ```

     (or username/password from your own AWIForge account)

     Alternatively, check out any previous revision (no. REVNUM $\geq$ 667):

     ```
     svn checkout --username anonsvn --password anonsvn -r REVNUM \
       https://swrepo1.awi.de/svn/sicopolis/trunk sicopolis
     ```

     (or username/password from your own AWIForge account)

  2. You should then have a new directory "sicopolis" that contains the entire program package. In this directory, execute the script (bash) copy_templates.sh:

     ```
     ./copy_templates.sh
     ```

3 Initial configuration

3.1 Manual configuration [recommended]

1. Locate the file sico_configs.sh in the directory sicopolis/runs, and open it with a text editor.

2. Set the flags NETCDF_FLAG, LIS_FLAG, OPENMP_FLAG and LARGE_DATA_-FLAG according to your needs.
   Pre-selected is NETCDF_FLAG="true" (with NetCDF) and the rest "false".

   If you wish to create output in native binary format rather than in NetCDF format, set NETCDF_FLAG to "false". For simulations with shallow-shelf dynamics (for floating ice) or hybrid shallow-ice/shelfy-stream dynamics (for grounded ice), LIS_FLAG and OPENMP_FLAG must both be set to "true". For high-resolution simulations (e.g., Greenland/5 km or Antarctica/10 km), LARGE_DATA_FLAG must be set to "true".

3. If NETCDF_FLAG="true", set NETCDFHOME to the correct path of your NetCDF installation.

   If LIS_FLAG="true", set LISHOME to the correct path of your Lis installation.

4. Depending on your system, some additional settings might have to be added in sico_configs.sh (`module load` commands for dynamic loading etc.).

3.2 Building with GNU Autotools

As an alternative to the manual configuration described in Section 3.1, SICOPOLIS can also be built with the GNU Autotools. The configuration file sico_configs.sh can then be ignored. Instead, it is required to execute the script autogen.sh:

```
./autogen.sh [ --with-netcdf=/my_netcdf_path \
               --with-lis=/my_lis_path \
               --enable-openmp=yes \
               --enable-large_data=yes ]
```

The four options have the same function as the flags discussed in Section 3.1. If the NetCDF library is linked, set /my_netcdf_path to the correct path of your NetCDF installation. If the Lis library is linked, set /my_lis_path to the correct path of your Lis installation.

4 Files and directories in "sicopolis"

- **runs**:

  Configuration file sico_configs.sh
  (only needed for manual configuration; see Section 3.1).

  Shell script (bash) sico.sh for running a single simulation.

  Shell scripts (bash) multi_sico_1.sh and multi_sico_2.sh for running multiple simulations by repeated calls of sico.sh.

  Subdirectory **headers**: specification files sico_specs_*run_name*.h (*run_name*: name of run).

  - File included for run v33_emtp2sge25_expA
    $\longrightarrow$ EISMINT Phase 2 Simplified Geometry Experiment A,
    resolution 25 km, $t = 0 \ldots 200$ ka (Payne et al. 2000).
    The thermodynamics solver for this run is the one-layer melting-CTS enthalpy scheme (ENTM), while all other runs employ the polythermal two-layer scheme (POLY) (Greve and Blatter 2016).
  - File included for run v33_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 v33_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 v33_grl20_b2_paleo14a_init and v33_grl20_b2_paleo14a
    $\longrightarrow$ Greenland ice sheet, resolution 20 km,
    $t = -140 \ldots -135$ ka for the init run (..._init) without basal sliding,
    $t = -135 \ldots 0$ ka for the main paleoclimatic run
    [low-resolution version of the spin-up for ISMIP6 InitMIP;
    Greve et al. (2017)].
  - Files included for runs v33_grl10_b2_paleo14a and
    v33_grl10_b2_future14a_ctrl/..._asmb
    $\longrightarrow$ Greenland ice sheet, resolution 10 km,
    $t = -9 \ldots 0$ ka for the paleo run, $t = 0 \ldots 100$ a for the future runs
    [10-km version of the spin-up and the schematic future climate runs for ISMIP6 InitMIP; Greve et al. (2017)].

- Files included for runs v33_ant64_b2_spinup09_init100a,
  v33_ant64_b2_spinup09_fixtopo, v33_ant64_b2_spinup09 and
  v33_ant64_b2_future09_ctrl

  $\longrightarrow$ Antarctic ice sheet with hybrid shallow-ice–shelfy-stream dynamics and ice shelves, resolution 64 km,
  $t = -140.1 \ldots -140.0$ ka for the init run without basal sliding (..._init100a),
  $t = -140 \ldots 0$ ka for the fixed-topography run (..._fixtopo),
  basal sliding ramped up during the first 5 ka,
  $t = -0.5 \ldots 0$ ka for the final, freely-evolving-topography part of the spin-up (..._spinup09),
  $t = 0 \ldots 100$ a for the constant-climate control run (..._future09_ctrl)
  [64-km version of the spin-up and the constant-climate control run for ISMIP6 InitMIP; Greve and Galton-Fenzi (pers. comm. 2017)].

- Files included for runs v33_asf2_steady and v33_asf2_surge

  $\longrightarrow$ Austfonna, resolution 2 km, $t = 0 \ldots 10$ ka
  [similar to Dunse et al.'s (2011) Exp. 2 (steady fast flow) and Exp. 5 (surging-type flow), respectively].

- Files included for runs v33_nmars10_steady and v33_smars10_steady

  $\longrightarrow$ North-/south-polar cap of Mars, resolution 10 km, $t = -10\,\mathrm{Ma} \ldots 0$
  [steady-state runs by Greve (2007)].

- File included for run v33_nhem80_nt012_new

  $\longrightarrow$ northern hemisphere, resolution 80 km, $t = -250 \ldots 0$ ka
  [similar to run nt012 by Greve et al. (1999)].

- File included for run v33_heino50_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.

  - Accordingly subdirectories subroutines/asf, nhem, scand, tibet, nmars and smars for Austfonna, the northern hemisphere, Scandinavia, Tibet and the north and south polar caps of Mars, respectively.
  - Subdirectory **subroutines/xyz**: see Appendix A.

- **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.
  - Accordingly subdirectories asf, nhem, scand, tibet, nmars and smars for Austfonna, the northern hemisphere, Scandinavia, Tibet and the north and south polar caps of Mars, respectively.
  - Subdirectory **xyz**: see Appendix A.

- **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

1. It is recommended to run SICOPOLIS with output in NetCDF format. If you wish to create output in native binary format instead, set NETCDF to 1 (rather than 2) in all specification files sico_specs_*run_name*.h.

2. In order to run simulation v33_grl20_ss25ka, use the script sico.sh. The command is

   `(./sico.sh [-z] -m v33_grl20_ss25ka) >out_001.dat 2>&1 &`

   (from directory sicopolis/runs, bash required). Accordingly for the other simulations. The option `-z` is only required if SICOPOLIS was configured manually. If it was built with the GNU Autotools, omit it. For further options, try `./sico.sh -h`.

3. Alternatively, if you prefer to run all simulations consecutively, execute the script multi_sico_1.sh:

   `(./multi_sico_1.sh [-z]) >out_multi_100.dat 2>&1 &`

   Again, the option `-z` is only required if SICOPOLIS was configured manually. For further options, try `./multi_sico_1.sh -h`.

Computing times

The approximate computing times for the simulations, run with the Intel Fortran Compiler 17.0.1 for Linux (optimisation options -xHOST -O3 -no-prec-div) on a 2 × 14-Core Intel Xeon E5-2690 v4 (2.6 GHz) PC under openSUSE Leap 42.2, are listed in Table 1 (Appendix B).

6 Output files

Output files are written by default to the directory sicopolis/sico_out/*run_name* (this can be changed with the `-d` option). 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
- Volume of grounded ice, V_g
- Volume of floating ice, V_f
- Total ice area, A
- Area of grounded ice, A_g
- Area of floating ice, A_f
- Ice volume above flotation in sea level equivalent, V_sle
- Volume of temperate ice, V_t
- Area of temperate-based grounded ice, A_t
- Maximum ice thickness, H_max
- Maximum thickness of temperate ice, H_t_max
- Maximum surface elevation, zs_max
- Maximum surface speed, vs_max
- Maximum basal temperature (relative to pmp), Tbh_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

  For the Greenland ice sheet, these data are written for seven locations:
  GRIP (xxx=GR), GISP2 (xxx=G2), Dye 3 (xxx=D3), Camp Century (xxx=CC), NorthGRIP (xxx=NG), NEEM (xxx=NE), EastGRIP (xxx=EG).

  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).

- **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 v33_grl20_ss25ka produces three files v33_grl20_ss25ka0001.nc, v33_grl20_ss25ka0002.nc and v33_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 Producing plots

In order to plot the output of simulation v33_grl20_ss25ka, go to the directory sicopolis/tools and execute the script tools.sh interactively:

```
./tools.sh [-z] -p sicograph -m v33_grl20_ss25ka
```

(bash required; accordingly for the other simulations). The option `-z` is only required if SICOPOLIS was configured manually. If it was built with the GNU Autotools, omit it. For further options, try `./tools.sh -h`.

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 sicograph/gmt_scripts/plots as file v33_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 v33_grl20_ss25ka_V_tot.eps in the subdirectory sicograph/gmt_scripts/plots.

7.3 Manipulating plot appearance

For all types of plots, the files in the subdirectory sicograph/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 sicograph/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.

8.1 Program make_ismip_output

Generating ISMIP output (see http://tinyurl.com/clic-ismip6) from the NetCDF time-slice files produced by SICOPOLIS (see Sect. 6). For simulation *run_name*, to be executed by

```
./tools.sh [-z] -p make_ismip_output -m run_name
```

The option `-z` is only required if SICOPOLIS was configured manually. If it was built with the GNU Autotools, omit it. For further options, try `./tools.sh -h`.

8.2 Program resolution_doubler

Doubling the horizontal resolution of a NetCDF time-slice output file produced by SICOPOLIS (see Sect. 6). For simulation *run_name*, to be executed by

```
./tools.sh [-z] -p resolution_doubler -m run_name
```

Again, the option `-z` is only required if SICOPOLIS was configured manually. For further options, try `./tools.sh -h`.

For example, run v33_grl10_b2_paleo14a (10 km resolution) requires the resolution-doubled output of run v33_grl20_b2_paleo14a (20 km resolution) for $t = -9$ ka as initial condition. In order to create it, execute the resolution doubler for run v33_grl20_b2_paleo14a (i.e., with the option `-m v33_grl20_b2_paleo14a`) and enter

Number of time-slice file (with leading zeros, 4 digits) > `0004`

This will convert the original time-slice file v33_grl20_b2_paleo14a0004.nc to the resolution-doubled file v33_grl20_b2_paleo14a_dbl_0004.nc that serves as initial conditions for run v33_grl10_b2_paleo14a.

8.3 Subdirectory matlab

MATLAB functions for reading SICOPOLIS output files (see Sect. 6). These functions can be used for plotting with MATLAB.

A Domain XYZ

This framework allows creating new domains (Laurentide ice sheet, simple testing geometry etc.). The directory sicopolis/src/subroutines/xyz, which hosts the domain-specific subroutines, is by default empty. If you want to create a new domain, copy the subroutines from the most similar existing domain (northern hemisphere, EISMINT etc.), e.g.:

```
cp sicopolis/src/subroutines/nhem/*.F90 \
   sicopolis/src/subroutines/xyz/
```

Then modify the routines according to your needs. Input files (topography etc.) must be placed in sicopolis/sico_in/xyz and specified in the run-specification header file *.h as usual. The domain must be defined by the domain code '#define XYZ' in the header file. If the new domain requires new global variables, they can be defined in the module sicopolis/src/subroutines/xyz/sico_vars.F90.

The subroutines for ISMIP HEINO are available in sicopolis/src/subroutines/xyz/heino, and the input files are in sicopolis/sico_in/xyz. If you copy the subroutines from sicopolis/src/subroutines/xyz/heino to sicopolis/src/subroutines/xyz, you can run ISMIP HEINO experiments (e.g., the run v33_heino50_st for which a header file is available).

B Table: Simulations and computing times

Run	Model time	Time step†	CPU time‡
v33_emtp2sge25_expA	200 ka	20 a	6.8 min
v33_grl20_ss25ka	25 ka	5 a	8.5 min
v33_ant40_ss25ka	25 ka	10 a	9.1 min
v33_grl20_b2_paleo14a_init	5 ka	5 a	2.5 min
v33_grl20_b2_paleo14a	135 ka	5 a	1.3 hrs
v33_grl10_b2_paleo14a*	9 ka	1 a	1.6 hrs
v33_grl10_b2_future14a_ctrl	100 a	1 a	1.4 min
v33_grl10_b2_future14a_asmb	100 a	1 a	1.4 min
v33_ant64_b2_spinup09_init100a	100 a	2 / 10 a†	7.6 sec
v33_ant64_b2_spinup09_fixtopo	140 ka	10 / 10 a†	1.3 hrs
v33_ant64_b2_spinup09	500 a	2 / 10 a†	1.0 min
v33_ant64_b2_future09_ctrl	100 a	2 / 10 a†	13.0 sec

Table 1: Model times, time steps and computing (CPU) times for the EISMINT, Greenland and Antarctica simulations contained in the script multi_sico_1.sh, run with the Intel Fortran Compiler 17.0.1 for Linux (optimisation options -xHOST -O3 -no-prec-div) on a 2 × 14-Core Intel Xeon E5-2690 v4 (2.6 GHz) PC under openSUSE Leap 42.2.
†: 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 a single core only. The v33_ant64_b2_xxx runs that include ice shelves can be done on multiple cores using OpenMP for the SSA solver. However, at the employed, low resolution of 64 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. 8.2 on the tool resolution_doubler.

References

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