Adjoint Ice Sheet Model (ADISM): Documentation 1.0

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August 2013

1 Building ADISM

ADISM (Adjoint Ice Sheet Model) comprises four executables:

- `adism` — The forward model;
- `adism_sens` — Calculates approximate sensitivities using the forward model;
- `adism_sens_par` — Calculates approximate sensitivities using the forward model, but uses MPI to spread the load across multiple processors;
- `adism_adjoint` — The adjoint model.

The adjoint is generated by OpenAD using source-to-source translation, and if the user has OpenAD installed, this can be done using the supplied makefiles. However, source code for the adjoint is also supplied in the model tarball, and can be built without OpenAD being present.

In both cases, there are is a preliminary requirement to obtain the BLAS and UMFPACK2.2 libraries. These are not distributed with the code because of licensing restrictions. However, a script (`getLibs.sh`) is provided which automatically downloads the libraries and patches UMFPACK2.2 as required by the model.

The further requirements are as follows:

- GNU `make`
- `gfortran`
- A working MPI installation.

The model build was tested under Ubuntu and Linux Mint, using the `bash` shell.

1.1 Simple build

To build the forward model and adjoint without using OpenAD, the procedure is fairly simple:

1. execute `getLibs.sh` in the top-level directory. This will obtain and build BLAS and UMFPACK2.2.
2. Set the environment variable `FC=gfortran` (use `export` in `bash`).
3. Run `make` in the `src` directory.

This will build the four executables listed above. For convenience, symbolic links can be made to the executables from the experiment directories (see below).

1.2 Full build

To generate the adjoint code using source-to-source translation, OpenAD must be installed. OpenAD can be downloaded from `http://www.mcs.anl.gov/OpenAD/`, which includes build instructions. Where OpenAD has been obtained from the project's subversion repository, the latest version of OpenAD can be obtained with `OpenadUpdate`.

To build the adjoint using OpenAD, proceed as for the simple build, then run `make` in the `src/Adjoint` directory. This will make an `adism_adjoint` executable in that directory.

2 Using ADISM

2.1 Introduction

ADISM (Adjoint Ice Sheet Model) comprises three executables:

- `adism` — The forward model;
- `adism_sens` — Calculates approximate sensitivities using the forward model;
- `adism_adjoint` — The adjoint model.

The different executables are all run in the same way, from the command-line, with the user providing a configuration filename as an argument. For example,

```
adism e2a.config
```

will run the forward forward model using the `e2a.config` file for configuration. In all cases, diagnostic runtime information is output to the screen.

2.2 Configuration options: common to all exectuables

The same configuration files can be used to run all three exectuables. Most parts of the configuration file apply to all three executables, but each executable also has options which apply to it alone.

The configuration file is organised in named sections (denoted with square brackets), each of which contains key-value pairs, where the key and value may be separated by a colon or an equals sign. The sections of the file common to all three executables will be decribed in turn — see the supplied configuration files for examples of how this works.

2.2.1 `[grid]`: The model grid specification

The `[grid]` section defines the model domain:

Key	Meaning
`nx`	Number of points in x
`ny`	Number of points in y
`nz`	Number of vertical levels
`dx`	Node spacing in x (m)
`dy`	Node spacing in y (m)

2.2.2 `[timesteps]`: The model timestepping

The `[timesteps]` section defines the timestep and run length of the model:

Key	Meaning
`dt`	Length of timestep (years)
`nt`	Number of timesteps in run

2.2.3 `[params]`: Various physical parameters

The `[params]` section defines certain physical parameters used in the model:

Key	Meaning
`enFac`	Value of flow enhancement factor f in the temperature-dependence of Glen's Flow Law
`climate`	Selects the model forcing climate: (1: EISMINT 2, 2: EISMINT 3 (Greenland))
`calving`	Enables/disables the floatation parameterisation of calving (1: enabled, 0: disabled)
`sliding`	Enables/disables sliding in regions where the bed is at pressure melting point (1: enabled, 0: disabled)
`gthf`	Value of spatially-uniform geothermal heat flux (W m^{-2})

2.2.4 `[init]`: Model initialisation

File to read initial state from, if required. If this section is missing, a flat bed and zero ice thickness is used:

Key	Meaning
`fname`	Name of file to read.
`slice`	Time-slice of file.
`type`	Set to 0 to initialise ice temperature distribution from file, or 1 to set ice temperatures uniformly to -10° C.

2.3 Forward model (`adism`)

The forward model uses one additional configuration section, `[output]`, which configures the NetCDF output from the model. NetCDF output is disabled in the other two exectuables.

Key	Meaning
`fname`	Name of output file
`freq`	Number of timesteps between each slice written to file

2.4 FD sensitivity calculation (`adism_sens`)

This exectuable runs the forward model twice for every point with non-zero ice thickness, each time perturbing the mass-balance of the point in question, and calculating an approximation for the sensitivity. This is used to validate the adjoint model. One additional configuration section, `[FD]` is used, which has the following values:

Key	Meaning
`fname`	Name of output file
`pfac`	Perturbation factor (i.e. multiply the unperturbed value at the point by this factor to give the size of the perturbation)

The output file is in plain text format, giving the locations of each point and the approximate sensitivity in columns. These can be plotted using the Python routine supplied.

2.5 Adjoint model (`adism_adjoint`)

This executable runs the adjoint model for a given configuration, calculating the sensitivity to surface mass-balance accross the domain. An additional configuration section `[adjoint]`, with a single key (`fname`) is used to supply an output filename for the sensitivities.

Note that the adjoint model checkpointing scheme produces temporary files (`oad_cp.00000`, etc) which can be deleted when the model has finished executing.

3 Visualising output

For the NetCDF output from the forward model, we recommend a standard NetCDF viewer such as `ncview`.

The sensitivity output is produced in a simple plain text format by `adism_adjoint` and `adism_sens`. The first column is the x node number, the second is the y node number, and the third column is the sensitivity. These files can easily be viewed in Matlab or a similar package, but we provide a Python script (`plotSens.py`) for convenience.

`plotSens.py` requires the additional Python modules `matplotlib` and `numpy`, available as part of most Linux distributions. The syntax for calling the plotting script is as follows:

```
plotSens.py [-h] [-c FILENAME] [-l LOWER] [-u UPPER] [-p] FILENAME

positional arguments:
  FILENAME     The filename to plot

optional arguments:
  -h, --help   show this help message and exit
  -c FILENAME  A second filename to load and difference (for comparison)
  -l LOWER     Lower bound for contours
  -u UPPER     Upper bound for contours
```

As you can see, the `-c` flag allows a second file to be specified and the difference in senstivities calculated.

4 Running the experiments from the ADISM paper

We provide configuration files so that the user can run the experiments described in the paper which this document is a supplement to. They are as follows:

- **EISMINT 2 experiment A** (no sliding)
  - `e2a.config`: Run experiment A for 200k years

  - `e2a-sens.config`: Run experiment A for a further 100 years, for sensitivity calculations
- **EISMINT 2 experiment H** (sliding enabled)
  - `e2h.config`: Run experiment H for 200k years
  - `e2h-sens.config`: Run experiment H for a further 100 years, for sensitivity calculations
- **EISMINT 3 Greenland** (no sliding)
  - `greenland.config`: Run Greenland experiment for 100k years
  - `greenland-sens.config`: Run Greenland experiment for a further 100 years, for sensitivity calculations

In each case, the first configuration file is intended to be used with the forward model (`adism`) to provide a spun-up model state. The second configuration file (`*-sens.config`) can be used with `adism_sens` and `adism_adjoint` to calculate model sensitivities. The first configuration file must be run before the second confiration file, so that there is a spin up file available for the sensitivities.

5 Copyright and Licensing

ADISM is the work of multiple individuals, and the copyright vests in them and/or their employers. Details are given in the `COPYRIGHT` file. The model also incorporates code from Glimmer-CISM, and the forward model thickness solver is based on a `Matlab` model by Tony Payne.

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