LOVECLIM-GSM Coupling

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1 Prerequisites

The coupled LOVECLIM-GSM model needs the following to be installed. The version numbers which are already tested are included in the brackets.

- Intel compiler (13.1.1)
- Ferret (6.96)
- GCC (4.4.7)
- Python (3.4.1)
- CDO (1.9.0)
- NCO (4.6.8)

2 Quick Start

To set up a test run:

1. ***envFile*** Set up the required paths in ./coupler/env/envFile (minimum first 2 lines)
2. ***paramFile*** **(optional)** Modify the run parameters in ./coupler/param/paramFile
3. ***submit*** Execute the *cpl* script using the appropriate options. e.g:
   ./cpl -p ./coupler/param/paramFile -e ./coupler/env/envFile -t PD -s run0001
4. ***log*** Check the progress in the log file in ${strDir}/log/ during the run. When complete, the log file is moved to trash directory in the results storage directory.
5. ***outputs*** Outputs are saved in ${strDir}/runName/main/

2.1 Coupler flags

cpl is the main script to start a coupled run, and accepts the following options:

- -p: parameter file (mandatory)
- -e: environmental file (mandatory)
- -s: specify a name for the simulation (eg: run0001) (mandatory)
- -t: time period of the simulation: inc/LGM/PD (mandatory)
- -d: debug mode (optional)

3 Model Directory Structure

The coupler, LOVECLIM, and GSM need the following directory structure to work properly:

modelsDir	Models main directoryx
coupler	Coupler main directory
scripts	Coupler scripts directory
forcing	Contains files to calculate orbital paramaters
readParam.sh	Read the *paramFile*
setFerret.sh	Set the required paths for Ferret
prepLoveEns.sh	Prepare LOVECLIM directory for the first step
orbSet	Modifies LOVECLIM with new orbital forcing parameters
prepLoveSpinMainEns.sh	Prepare LOVECLIM for switching from the spin-up mode to coupled mode
prepGSMEns.sh	Prepare the GSM directory for the first step
loveOutVarEnableEns.sh	Enable LOVECLIM variables for output
loveRunEns.sh	Execute LOVECLIM binary
cnvLoveGSMEns.sh	Convert from LOVECLIM grid to the GSM grid
bias.sh	Bias correct temperature and precipitation (if enabled)
ToceanExt.py	Extract ocean temperature profiles
cpLoveGSMEns.sh	Copy converted LOVECLIM files to the GSM directory
loveOutEns.sh	Copy LOVECLIM output files to ${strDir}
GSMRunEns	Execute the GSM binary
cnvGSMLoveEns.sh	Convert from the GSM grid to LOVECLIM
runoff.sh	Convert the GSM runoff to LOVECLIM
regrid.sh	Call the appropriate upscaling method
regrid_envelope.py	Upscaling (envelope method)
regrid_simpleAvg.py	Upscaling (simple average method)
regrid_silhouette.py	Upscaling (silhouette method)
cpGSMLove.sh	Copy converted GSM files to LOVECLIM directory
GSMOutEns.sh	Copy GSM output files to ${strDir}
prepLoveNextEns.sh	Prepare LOVECLIM for next coupling step
trash	Move runtime generated scripts and files to the *trash* directory

docs	Coupler documentation directory
conditions	Parent to directories containing initial and boundary condition files
bias	Contains precipitation and temperature bias correction files
GHG	Contains GHG files
IC	Parent to directories containing initial conditions (used by "*it*")
sampleFiles	Contains the sample files exchanged between the coupler and the GSM)
cpl	Coupler main script (starting script)
loveclim	LOVECLIM main directory
LOVECLIM	Contains LOVECLIM source code
RUN	LOVECLIM execution directory
TOOOLS	Contains other LOVECLIM files
make	Makefile script to prepare LOVECLIM
GSM	GSM main directory
bin	Contains GSM executable, rsiNE files, and GSM output generator
parm.dir	Contains a parameter file for GSM
set.dir	Contains a script to set GSM paths
GSMinputs	Contains GSM input files
$GSMmodules4LCice.F90$	Contains routines for interfacing the GSM with the LCice coupler, and for carrying out the advective precipitation corrections on the precipitation climatology (vPgcm) using the setPorog routine

4 Environmental File

A file used to set absolute paths, and must include the following paths:

Table 1: Paths defined in the envFile

Variable	Path	Description
USERroot	/path/to/models/parent/directory	The parent directory of the models
nodeDir	/path/to/compute/directory/	Compute node path in which the coupled model runs
COMPILER	/path/to/compiler/directory	Path to the directory containing "bin" and "lib" directories
NETCDF	/path/to/netcdf/directory	Path to the directory containing "include" and "lib" directories
HDF5	/path/to/ferret/hdf5/directory	Path to the directory containing "include" and "lib" directories
UDUNITS	/path/to/ferret/udunits/directory	Path to the directory containing "include" and "lib" directories
LAPACK	/path/to/ferret/lapack/directory	Path to the directory containing "bin" and "lib" directories
BLAS	/path/to/ferret/blas/directory	Path to the directory containing "bin" and "lib" directories
NCO	/path/to/ferret/nco/directory	Path to the directory containing "bin" and "lib" directories
CDO	/path/to/ferret/cdo/directory	Path to the directory containing "bin" and "lib" directories
FERRET	/path/to/ferret/directory	Path to the directory containing "bin" and "lib" directories
PYTHON	/path/to/python/directory	Path to the directory containing "bin" and "lib" directories
modelsDir	/path/to/models/directory/	The parent directory of the coupler, LOVECLIM, and GSM
strDir	/path/to/storage/directory/	Path to store the run outputs
cplDir	${modelsDir}/coupler/	Coupler main path
cplSrcDir	${cplDir}/code/scripts/	Coupler scripts path
cplCndDir	${cplDir}/conditions/	Directory containing initial/boundary condition files
cplPDclimDir	${cplCndDir}/PDclim/	Directory containing PD climatologies (for bias correction only)
cplParamDir	${cplDir}/param/	Directory containing run-specific parameter files
gsmDir	${modelsDir}/GSM/	GSM main path
gsmBinDir	${gsmDir}/bin/	GSM binary+rsiNE* path
gsmSetDir	${gsmDir}/set.dir/	GSM set directory path
loveSrcDir	${modelsDir}/loveclim/	LOVECLIM source code path

Modify the following file to generate new environmental files (*Note*: All the paths in the envFile must be global variables).

./coupler/env/envFile

5 Parameter File

A file used by the coupler to set the simulation parameters. It should include the following parameters:

Table 2: Parameters required in the paramFile

Parameter	Valid Values	Description
love	0/1	LOVECLIM enabled(1)/disable(0)
gsm	0/1	GSM enabled(1)/disabled(0)
orby	Integer (eg: -121000)	Orbital year to start the coupled transient run
noy	Integer (eg: 4100)	Number of years to spin-up LOVECLIM before the coupled run
noym	Integer (eg: 10000)	Number of years to run the coupled LOVECLIM-GSM
ic	String (eg: ic000000_360)	Name of the LOVECLIM restart tarball
it	String (eg: 21ka)	Name of the directory containing initial files (in ${cplCndDir}/IC/)
bs	0/1	Variable(1)/Fixed(0) Bering Strait
biasT	0/1	Temperature bias correction enable(1)/disabled(0)
biasP	0/1	Precipitation bias correction enable(1)/disabled(0)
loveYearStep	Integer (*e.g.*, : 20)	Number of years to run LOVECLIM for each coupling step
dOrby	Integer (*e.g.*, 20)	Change in orbital years in each coupling step
loveAve	Integer (*e.g.*, 10)	Number of last years to average from LOVECLIM
upscl	1/2/3	Upscaling method (1: Simple / 2: Envelope / 3: Silhouette)
lps	0/1	Dynamic vertical temperature lapse-rate enabled(1)/fixed to 6.5(0)
albice	0.0<Double<1.0 (eg 0.45)	Albedo of melting ice
alphd	0.0<Double<1.0 (eg 0.61)	Albedo of snow (thickness > 0.05)
alphdi	0.0<Double<1.0 (eg 0.35)	Albedo of thick bare ice
alphs7	0.0<Double<1.0 (eg 0.61)	Albedo of melting snow
cgren	Double (eg 0.04)	Correction of the snow or ice albedo to take into account effects of cloudiness
precth	0.0<Double<1.0 (eg 0.92)	Precipitation threshold
cloud	0/1	Cloud radiation parameterization enabled(1)/disabled(0)
ts	1	Surface temperature. *DO NOT CHANGE*
t2m	1	Sea-level temperature. *DO NOT CHANGE*
t4g	1	650 hPa temperature. *DO NOT CHANGE*
evap	1	Evaporation. *DO NOT CHANGE*
prec	1	Precipitation. *DO NOT CHANGE*
wind10m	0/1	Wind 10 m
wind200	0/1	Wind X/Y 200 hPa
wind500	0/1	Wind X/Y 500 hPa
wind800	1	Wind X/Y 800 hPa. *DO NOT CHANGE*
windStress	0/1	U/V-Stress
sp	0/1	Surface pressure
t2g	0/1	350 hPa temperature
t0g	0/1	Stratosphere temperature
dyprec	0/1	Dynamic precipitation
coprec	0/1	Convection precipitation
snow	0/1	Total snow
gph	0/1	Geopotential height
rh	0/1	Relative humidity

Modify the following file to generate new parameter files
./coupler/param/paramFile

6 Initial and Boundary Condition Files

The coupler needs the following files to be present in ${cplCndDir}/${it}:

Table 3: Files to be present in ${cplCndDir}/${it} before starting runs

File Name	Used by	Description
berg.nc	LOVECLIM	Topography file
icemask.nc	LOVECLIM	Ice mask
ic*_360.tar.gz	LOVECLIM	Restart files package
fort.360.10x5	GSM	North America + Greenland topographic slope
fort.365.10x5	GSM	Eurasia topographic slope
restartk1	GSM	Restart file (ONLY for LGM runs)
restartk2	GSM	Restart file (ONLY for LGM runs)
restartSGk1	GSM	Restart file (ONLY for LGM runs)
restartSGk2	GSM	Restart file (ONLY for LGM runs)
restartVE	GSM	Restart file (ONLY for LGM runs)

A sample set of files for a present-day simulation are in
./coupler/conditions/IC/PD/

6.1 GHG

The GHG files needed by LOVECLIM are located in ${cplCndDir}/${GHG}, and included in the coupler package. They can be found in
./coupler/conditions/GHG/

6.2 Bias Correction Files

If the bias correction is enabled, temperature and precipitation difference files should be placed in ${cplCndDir}/bias/tsDiffs and ${cplCndDir}/bias/prDiffs, respectively. The file names should be as follow:

ts_*runName*.nc
pr_*runName*.nc

Both files should include 12 months of data, with a similar spatial grid as of the LOVECLIM atmospheric model (ECBilt) (check **./coupler/conditions/bias/** sample files).

6.3 Simulation Era

The *-t* flag is used to specify the era the simulation is set up for. The coupler uses this option to whether use the GSM restart files (LGM) or do a GSM cold start (inception and present-day). It must be one of the followings:

- inc
- LGM
- PD

For LGM simulations, the GSM restart files should be present in the "*it*" directory (table 5).

7 Outputs

After executing the *cpl* script, a directory with the name specified by the "*-s*" option will be created in the ${strDir} directory. All the outputs generated by LOVECLIM and GSM during the simulation will be stored in the appropriate sub-directories. The directory will have the following structure:

🗀 ${strDir}	Path to the storage directory
🗀 log	Contains log files during the run
🗀 runName	Output main directory
🗀 ${ERA}	Simulation era
🗀 main	Directory containing LOVECLIM and GSM outputs
🗀 GSM	Contains GSM outputs
🗀 restart	Contains GSM restart files
🗀 slope	Contains topographic slopes used by GSM
🗀 topo	Contains topography files for each coupling step
🗀 loveclim	Main LOVECLIM output directory
🗀 dat	Contains LOVECLIM climatalogies needed by GSM
🗀 ic	Contains LOVECLIM restart files
🗀 nc	Contains LOVECLIM topography, ice-mask, and output atmospheric climatologies in net
🗀 stat	Contains LOVECLIM statistical outputs
🗀 spinup	Main LOVECLIM spin-up directory
🗀 ic	Contains LOVECLIM restart files at the end of spin-up period
🗀 nc	Contains LOVECLIM initial topography and ice-mask files
🗀 trash	Contains the submission script and the log file after the run
paramFile	Parameter file used to generate this run

7.1 Coupler to GSM

NOTE on GRID convention: the coupler has all fields to and from the GSM on a regular lat/lon grid for each ice sheet complex, with the following ordering:
SW corner cell
next cell east
...
NE corner cell value

The coupler generates the following files and passes them to the GSM at each time step:

Table 4: List of files needed by the GSM from the coupler

File Name	Description	Unit
fort.310	NA[a]+ Gr[b]ocean temperature	°C
fort.311	NA + Gr 2 m temperature	°C
fort.312	NA + Gr lapse-rate	K/km
fort.313	NA + Gr precipitation	cm/yr
fort.314	NA + Gr evaporation	cm/yr
fort.315	NA + Gr 2 m temperature standard deviation	°C
fort.320	EA[c]ocean temperature	°C
fort.321	EA 2 m temperature	°C
fort.322	EA lapse-rate	K/km
fort.323	EA precipitation	cm/yr
fort.324	EA evaporation	cm/yr
fort.325	EA 2 m temperature standard deviation	°C
fort.360	NA + Gr topographic slope	-
fort.361	NA + Gr 800 hPa wind velocity x-component	m/s
fort.362	NA + Gr 800 hPa wind velocity standard deviation x-component	m/s
fort.363	NA + Gr 800 hPa wind velocity y-component	m/s
fort.364	NA + Gr 800 hPa wind velocity standard deviation y-component	m/s
fort.365	EA topographic slope	-
fort.366	EA 800 hPa wind velocity x-component	m/s
fort.367	EA 800 hPa wind velocity standard deviation x-component	m/s
fort.368	EA 800 hPa wind velocity y-component	m/s
fort.369	EA 800 hPa wind velocity standard deviation y-component	m/s
ToceanSPECv1.EA.dat	NA + Gr ocean temperature profile source coordinates	lat-lon
ToceanSPECv1.NA.dat	EA ocean temperature profile source coordinates	lat-lon

[a] North America
[b] Greenland
[c] Eurasia

A sample set of the files are locate in the following path:
./coupler/sampleFiles/cpl2GSM/

Formats

The files passed to the GSM should have the following format:

fort.310 (NA/NG), fort.320(EA): ocean site temperature profiles

Note Each row contains the temperatures at different depths for each site
The ocean SPEC ID# has to match that in ToceanSPECv1.*.dat. It ensures the data file matches the corresponding SPEC file in case of multiple versions

Time numberOfRows numberOfLevels ocean SPEC ID#
blank line : END of HEADER
siteIndex1 COL2depth1Temperature COL3depth2Temp ...
...

fort.311 to fort.315, fort.321 to fort.325 : climate fields

Note Each column represents a different month (January to December).

 # fieldName, fileName, region
noOfLons noOfLats lonMin lonMax latMin latMax lonStep latStep
Time
blank line : END of HEADER
DATA row 1: *COL1jan COL2Feb COL3mar ... COL12dec*
...

fort.360, fort.365 (LOVECLIM surface slopes)

Note Column 1: Slopes in the x-direction
Column 2: Slopes in the y-direction

noOfLons noOfLats lonMin lonMax latMin latMax lonStep latStep
Time
blank line : END of HEADER
DATA row 1: *COL1slopex COL2slopey*
...

fort.361 to fort.364, fort.366 to fort.369, winds (m/s)

Note Each column represents a different month (January to December).

noOfLons noOfLats lonMin lonMax latMin latMax lonStep latStep
Time
blank line : END of HEADER

DATA row 1: *COL1jan COL2Feb ... COL12dec]*
...

ToceanSPECv1.NA.dat, ToceanSPECv1.EA.dat

Note Each row contains the coordinates for each site

fileName column labels
blank line
numberOfRows oceanSpecID# to match fort.310/320
siteIndex1 lonMin lonMax latMin latMax lonSiteRef latSiteRef
siteIndex2...

7.2 GSM to Coupler

The coupler receives the following files from the GSM at each time step.

Table 5: List of files received by the coupler from the GSM

File Name	Description	Unit
fort.201	NA[a]+ Gr[b]topography and ice thickness	m
fort.202	EA[c]topography and ice thickness	m
fort.254	NA + Gr runoff	m/yr
fort.264	EA runoff	m/yr

[a] North America
[b] Greenland
[c] Eurasia

These files are read by the "cnvGSMLoveEns.sh" script in **./coupler/scripts/**, using the sub-scripts "regrid.sh" and "runoff.sh".

A sample set of the files are locate in the following path:
./coupler/sampleFiles/GSM2cpl/

Formats

The files passed to the GSM have the following format:

fort.201, fort.202 : contemporaneous elevation, ice thickness, ground elevation, and lake depth

 # skipped line labelling columns
Time MeanSealevel(not used) numberOfPointsLon numberOfPointsLat
DATA row 1: *Elevation iceThickness baseElevation lake depth*
...

The coupler skips the number of lines assigned as header lines, so you need to modify the "cnvGSMLoveEns.sh" in order you need to use a different file format.

fort.254, fort.264 : freshwater discharge into ocean (m/year)

The coupler reads the values from the 6th column of the files for each region using the "runoff.sh" script. You can modify the script to adjust to your file format if neccessary.