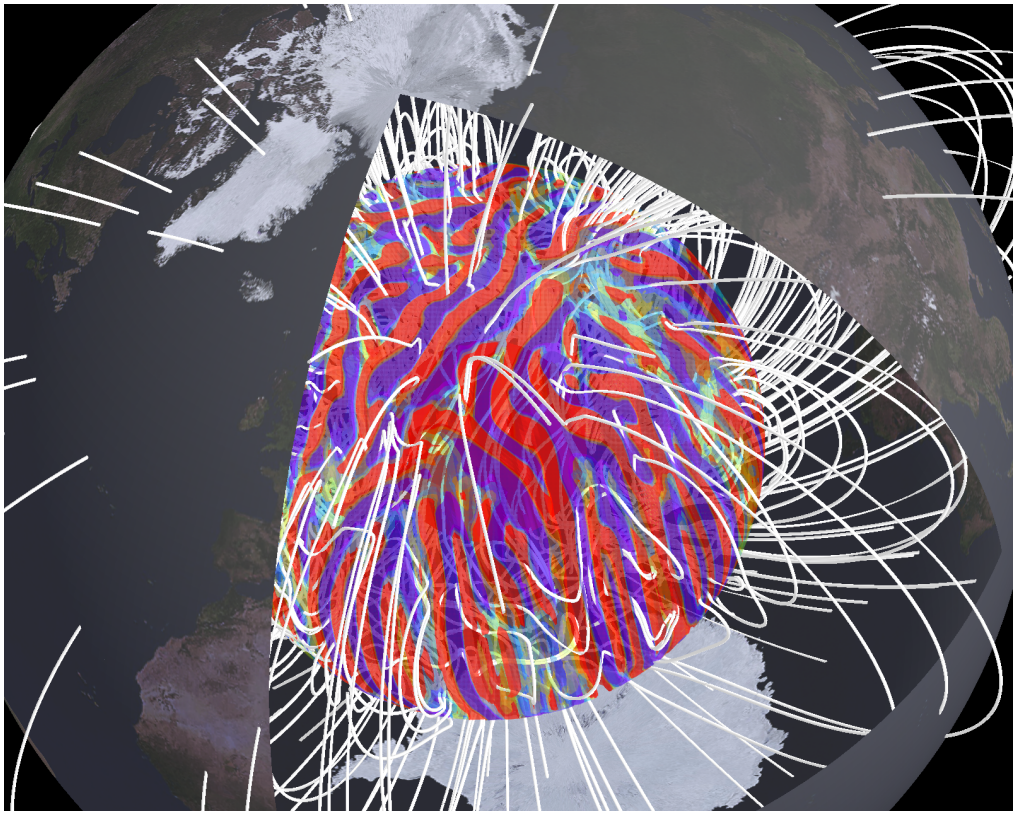
COMPUTATIONAL INFRASTRUCTURE FOR GEODYNAMICS (CIG)

Calypso

User Manual
Version 2.0



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Preface

CalypsoView is a date viewer program for sections and isosurfaces generated by Calypso. This program is intended to run on a desktop computer.

Contents

1 Introduction

CalypsoView is a date viewer program for sections and isosurfaces generated by Calypso. Calypso is a program package for magnetohydrodynamics (MHD) simulations in a rotating spherical shell for geodynamo problems. This program is intended to run on a desktop computer with a single process.

To make the program simple and small as posible, CalypsoView can only visualize cross section and isosurface results and saves image data. To visualize the data with whole volume, please use more powerful visualizaion program such as ParaView or VizIt.

This user guide provides instructions for the configuration and execution of CalypsoView.

2 History

Calypso has its origins in two earlier projects. One is a dynamo simulation code written by Hiroaki Matsui in 1990's using a spectral method. This code solves for the poloidal and toroidal spectral coefficients, like Calypso, but it calculates the nonlinear terms in the spectral domain using a parallelization for SMP architectures. The other project is the thermal convection version of GeoFEM, which is Finite Element Method (FEM) platform for massively parallel computational environment, originally written by Hiroshi Okuda in 2000. Under GeoFEM Project, Lee Chen developed cross sectioning, iso-surfacing, and volume rendering modules for data visualization for parallel computations.

In GeoFEM project, Yoshitaka Wada developed GppView, which is a mesh and surface viewer for FEM mesh data with GeoFEM format and cross sections and isosurfaces obtained by sectioning module from GeoFEM. In 2012, Hiroaki Matsui has developed the data viewer with a same features as GPPView because of the halting of the development of GPPView.

CalypsoView Ver. 0.1 supports the following features and capabilities

- Visualize cross sections and isosurface data from Calypso.
- Visualize on map using Aitoff projection for contour map.
- CalypsoView can display up to 10 sectioning and isosurface data in total.
- Ouptput sequential image files with rotating along with $x-$, $y-$, or $z-$axis (or movie file for Mac OS version)
- Ouptput time sequential image files (or movie file for Mac OS version)

- Attach image data as a texture using a spherical coordinate.

CalypsoView DOES NOT SUPPORT the following features and capabilities.

- Input result data with whole domain and construct isosurface or cross sections.

3 Acknowledgements

Calypso was primarily developed by Dr. Hiroaki Matsui in collaboration with Prof. Bruce Buffett at the University of California, Berkeley. The following NSF grants supported the development of Calypso,

- B.A. Buffett, NSF EAR-0509893; Models of sub-grid scale turbulence in the Earths core and the geodynamo; 2005 - 2007.
- B.A. Buffett and D. Lathrop, NSF EAR-0652882; CSEDI Collaborative Research: Integrating numerical and experimental geodynamo models, 2007 - 2009
- B.A. Buffett, NSF EAR-1045277; Development and application of turbulence models in numerical geodynamo simulations ; 2010 - 2012

4 Citation

Computational Infrastructure for Geodynamics (CIG) and the Calypso developers are making the source code to Calypso available to researchers in the hope that it will aid their research and teaching. A number of individuals have contributed a significant amount of time and energy into the development of Calypso. We request that you cite the appropriate papers and make acknowledgements as necessary. The Calypso development team asks that you cite the following papers:

Matsui, H., E. King, and B.A. Buffett, Multi-scale convection in a geodynamo simulation with uniform heat flux along the outer boundary, *Geochemistry, Geophysics, Geosystems*, **15**, 3212 – 3225, 2014.

5 Installation

CalypsoView has a MacOS version and Linux implimentaion. Installation procedure and look and feel are different between these implimentaion.

5.1 MacOS

CalypsoView has a binary application bundle in the package. This application needs simply to drag and drop into `/Application` folder (see Figure 1).

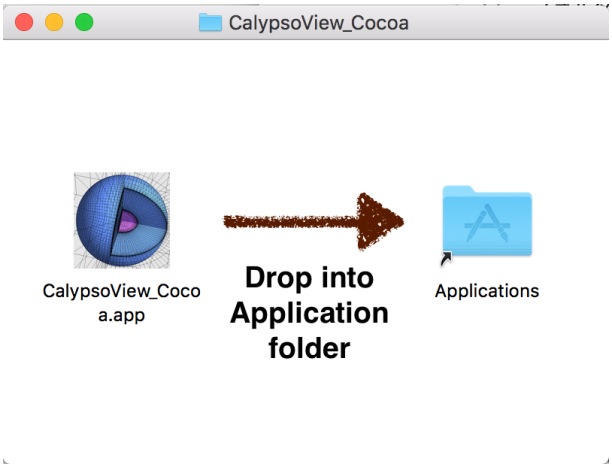

Figure 1: Folder of the MacOS binary

5.1.1 Compiler Requirements

Source code of CalypsoView_Cocoa is written in C and Objective-C. To hack and build the program, Xcode is required.

5.1.2 Library Requirements

Calypso requires the following libraries for MacOS version.

- Xcode (https://developer.apple.com)
- zlib (https://www.zlib.net)

zlib and other foundations are pre-installed in MacOS. Consequently, program should work witout installing any other libraries.

5.2 Linux

5.2.1 Compiler Requirements

Source code of CalypsoView_GLFW is written in C. Fortran90 is also used to make a C source code including shader program. Consequently, Fortran compiler is required. GCC, the GNU Compiler Collection (`https://gcc.gnu.org`) includes gfortran compiler in the most of Linux distributions. For MacOS, any fortran compiler needs to be installed because Xcode does not have fortran compiler.

5.2.2 Library Requirements

- GNU make
- zlib (https://www.zlib.net)
- libpng (http://www.libpng.org/pub/png/libpng.html)
- gtk+3 (https://developer.gnome.org/gtk3/stable/)
- OpenGL (https://www.opengl.org)
- GLFW (https://www.glfw.org)

Linux and MacOS use GNU make as a default 'make' command, but some system (e.g. BSD or SOLARIS) does not use GNU make as default. `configure` command searches and set correct GNU make command.

In the most of Linux distributions have these libraries as a default excepet for GLFW, but they sholud have a package to install GLFW.

5.3 Known problems

OpenGL on MacOS

Apple set OpenGL as a deprecated library. OpenGL is still supprted, but some alternative needs to be considered.

5.4 Directories

The top directory of Calypso (ex. `[CALYPSO_HOME]`) contains the following directories.

```
% cd [CALYPSO_HOME]
% ls
CMakeLists.txt Makefile.in configure.in examples
INSTALL bin doc src
LICENSE configure doxygen work
```

`bin`: directory for executable files

`cmake`: directory for cmake configurations

`cmake`: directory for document generated by doxygen

`doc`: documentations

`examples`: examples

`src`: source files

`work`: work directory. Compile is done in this directory.

5.5 Doxygen

Doxygen (`http://www.doxygen.org`) is an powerful document generation tool from source files. We only save a configuration file in this directory because thousands of html files generated by doxygen. The documents for source codes are generated by the following command:

```
% cd [CALYPSO_HOME]/doxygen
% doxygen ./Doxyfile_CALYPSO
```

The html documents can see by opening `[CALYPSO_HOME]/doxygen/html/index.html`. Automatically generated documentation is also available on the CIG website at `http://www.geodynamics.org/cig/software/calypso/`.

5.6 Install using `configure` command

5.6.1 Configuration using `configure` command

Calypso uses the configure script for configuration to install. The simplest way to install programs is the following process in the top directory of Calypso.

```
%pwd
[CALYPSO_HOME]
% ./configure
...
% make
...
% make install
```

After the installation, object modules can be deleted by the following command;

```
% make clean
```

./configure generates a Makefile in the current directory. Available options for `configure` can be checked using the `./configure --help` command. The following options are available in the `configure` command.

```
Optional Features:
--disable-option-checking  ignore unrecognized --enable/--with options
--disable-FEATURE       do not include FEATURE (same as --enable-FEATURE=no)
--enable-FEATURE[=ARG]  include FEATURE [ARG=yes]
--enable-silent-rules   less verbose build output (undo: "make V=1")
--disable-silent-rules  verbose build output (undo: "make V=0")
--enable-cocoa          Use Cocoa framework
--enable-dependency-tracking
do not reject slow dependency extractors
--disable-dependency-tracking
speeds up one-time build

Optional Packages:
--with-PACKAGE[=ARG]    use PACKAGE [ARG=yes]
--without-PACKAGE       do not use PACKAGE (same as --with-PACKAGE=no)
--with-zlib=DIR root directory path of zlib installation defaults to
/usr/local or /usr if not found in /usr/local
--without-zlib to disable zlib usage completely
--with-x                use the X Window System

Some influential environment variables:
CC          C compiler command
CFLAGS      C compiler flags
LDFLAGS     linker flags, e.g. -L<lib dir> if you have libraries in a
nonstandard directory <lib dir>
LIBS        libraries to pass to the linker, e.g. -l<library>
```

```
CPPFLAGS    (Objective) C/C++ preprocessor flags, e.g. -I<include dir> if
you have headers in a nonstandard directory <include dir>
PKG_CONFIG  path to pkg-config utility
CPP         C preprocessor
ZLIB_CFLAGS C compiler flags for ZLIB, overriding pkg-config
ZLIB_LIBS   linker flags for ZLIB, overriding pkg-config
PNG_CFLAGS  C compiler flags for PNG, overriding pkg-config
PNG_LIBS    linker flags for PNG, overriding pkg-config
GL_CFLAGS   C compiler flags for GL, overriding pkg-config
GL_LIBS     linker flags for GL, overriding pkg-config
GTK3_CFLAGS C compiler flags for GTK3, overriding pkg-config
GTK3_LIBS   linker flags for GTK3, overriding pkg-config
GLFW_CFLAGS C compiler flags for GLFW, overriding pkg-config
GLFW_LIBS   linker flags for GLFW, overriding pkg-config

Use these variables to override the choices made by 'configure' or to help
it to find libraries and programs with nonstandard names/locations.
```

At the end of the configuration, The following message can use to check if libraries can be refered correctly:

```
-----   Configuration summary   --------------------------------

host:        "x86_64-apple-darwin16.7.0"

Use Cocoa...           no
Use X Window...       yes

Use zlib ...          yes
Use PNG output...     yes

Use GTK3+...          yes
Use GLFW...           yes

-----------------------------------------------------------------
```

5.6.2 Compile

Compile is performed using the `make` command. The Makefile in the top directory is used to generate another Makefile in the `work` directory, which is automatically used to complete the compilation. The object file and libraries are compiled in the `work` directory.

Finally, the executive files are assembled in `bin` directory. You should find the following programs in the `bin` directory.

`kemoviewer_GLFW:`
: Viewer program

The following library files are also made in `work` directory.

`libcalypsoview.a:` CalypsoView library

5.6.3 Clean

The object and fortran module files in `work` directory is deleted by typing

```
% make clean
```

This command deletes files with the extension `.o`, `.mod`, `.par`, `.diag`, and .

5.6.4 Distclean

To revert the files and directory to the original package, use make distclean as

```
% make distclean
```

5.6.5 Install

The executive files are copied to the install directory `$(INSTDIR)/bin`. The install directory `$(INSTDIR)` is defined in Makefile, and can also set by `${--prefix}` option for `configure` command. Alternatively, you can use the programs in `${SRCDIR}/bin` directory without running `make install`. If directory `${PREFIX}` does not exist, `make install` creates `${PREFIX}`, `${PREFIX}/lib`, `${PREFIX}/bin`, and `${PREFIX}/include` directories. No files are installed in `${PREFIX}/lib` and `${PREFIX}/include`.

5.6.6 Construct dependecies (only for developper)

C source files need dependency among include files. Consequently, list of dependency of source files are saved in the file `Makefile.depends` in each directory. When you modify the source files with changing the module usage, `Makefile.depends` files need to be updated. To update the `Makefile.depends`files, use the `make` command at the `[CALYPSO_HOME]` directory as

```
% make depends
```

The dependency is generated by the gcc with `-MM -w -DDEPENDENCY_CHECK` option. Consequently, the dependencies need to be generated by the environment with gcc or compatible compiler. After generating the dependency, you can transfer the modified package and build without using gcc.

5.7 Install without using configure

It is possible to compile Calypso without using the `configure` command. To do this, you need to edit the `Makefile`. First, copy `Makefile` from template `Makefile.in` as

```
% cp Makefile.in Makefile
```

In Makefile, the following variables should be defined.

`SHELL` Name of shell command.

`SRCDIR` Directory of this Makefile.

`INSTDIR` Install directory.

`MPICHDIR` Directory names for MPI implementation. If you set fortran90 compiler name for MPI programs in `MPIF90`, you do not need to define this valuable.

`F90` Command name of local Fortran 90 compiler to make a C source file including GLSL shader sources.

`AR` Command name for archive program (ex. `ar`) to generate libraries. If you need some options for archive command, options are also included in this valuable.

`RANLIB` Command name for `ranlib` to generate index to the contents of an archive. If system does not have `ranlib`, set `true` in this valuable. `true` command does not do anything for libraries.

`OPTFLAGS` Optimization flags for C compiler

`BLAS_LIBS` Library lists for BLAS (ex. `-lblas`)

`ZLIB_CFLAGS` Option flags for zlib (ex. `-I/usr/include`)

`ZLIB_LIB` Library lists for zlib (ex. `-L/usr/lib -lz`)

`PNG_CFLAGS` Option flags for libpng (ex. `` `pkg-config --cflags libpng` ``)

`PNG_LIBS` Library lists for libpng (ex. `` `pkg-config --libs libpng` ``)

`X_CFLAGS` Option flags for X window (ex. `|pkg-config --cflags x11—`)

`X_LIBS` Library lists for X window (ex. `` `pkg-config --libs x11` ``)

`OPENGL_INC` Option flags for OpenGL (ex. `` `pkg-config --cflags glfw3` ``)

`OPENGL_LIBS` Library lists for OpenGL (ex. `` `pkg-config --libs gl` ``)

`GTK3_CFLAGS` Option flags for gtk+-3 (ex. `` `pkg-config --cflags gtk+-3.0` ``)

`GTK3_LIBS` Library lists for gtk+-3 (ex. `pkg-config --libs gtk+-3.0` `)

`GLFW_CFLAGS` Option flags for GLFW (ex. `` `pkg-config --cflags glfw3` ``)

`GLFW_LIBS` Library lists for GLFW (ex. `` `pkg-config --libs glfw3` ``)

5.8 Install using cmake

CMake is a cross-platform, open-source build system. CMake can be downloaded from http://www.cmake.org. The following procedure is required to install.

1. Create working directory (you can also use `[CALYPSO_HOME]/work`).
2. Generate Makefile and working directories by `cmake` command.
3. Compile programs by `make` command.

In this section, `[CALYPSO\_HOME]/work` is used as the working directory. Options for CMake can be checked by `cmake -i [CALYPSO_HOME]` command at `[CALYPSO_HOME]/work`. There are a number of options can be found, but the following valuables are important settings for installation:

- Install directory

  `CMAKE_INSTALL_PREFIX`
  : Install directory

- Compiler settings

`CMAKE_Fortran_COMPILER`
: Fortran90 compiler.

`CMAKE_c_COMPILER` C compiler.

`CMAKE_Fortran_FLAGS`
: Optimization flags for Fortran90 compiler.

`CMAKE_c_FLAGS`
: Optimization flags for C compiler.

- Manual settings for optional features

  `CMAKE_LIBRARY_PATH`
  : CMake library search paths. This directory is used to search FFTW3 library.

  `CMAKE_INCLUDE_PATH`
  : CMake include search paths. This directory is used to search include file for FFTW3.

The easiest example of using CMake on Mac OS X with gcc9 is the following:

```
% cd build
% cmake ~/CALYPSO/ -DCMAKE_Fortran_COMPILER=/opt/local/bin/gfortran-mp-9
? -DCMAKE_c_COMPILER=/opt/local/bin/gcc-mp-9 \
? -DCMAKE_Fortran_FLAGS="-O3 -g" -DCMAKE_c_FLAGS="-O3"
```

After configuration, compile and install are started by

```
% make
...
% make install
```

After running `make` command, execute files are built in `[CALYPSO_HOME]/work/bin` directory.

6 Start the program

6.1 Mac OS

The program will start by double clicking the application icon. Viewer window and menu window will open as shown in Figure 2.

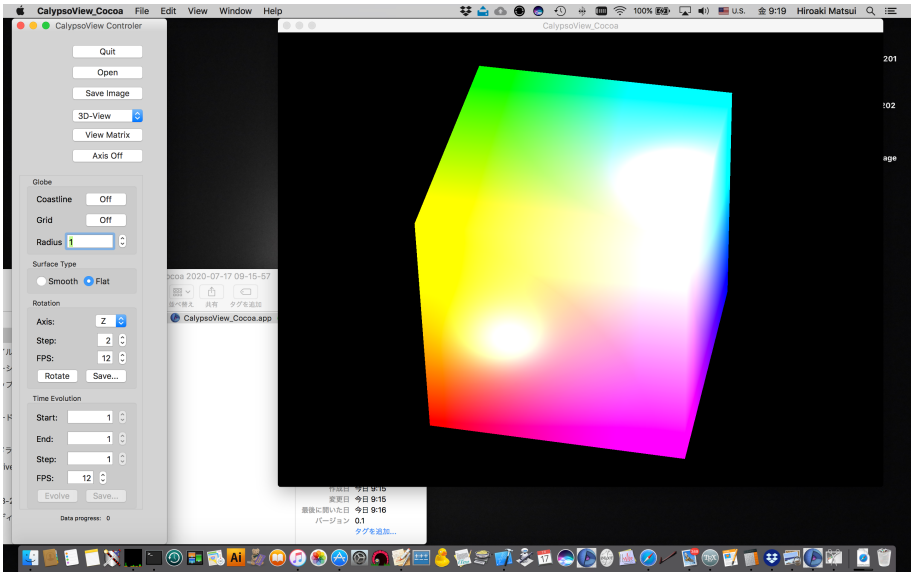

Figure 2: Windows of CalypsoView at starting.

6.2 Linux

The program is started by input the command in terminal as

```
% make
...
% [BINDIR]/CalypsoView_GLFW
```

The viewer window and menu window will be displayed as shown in Figure 3.

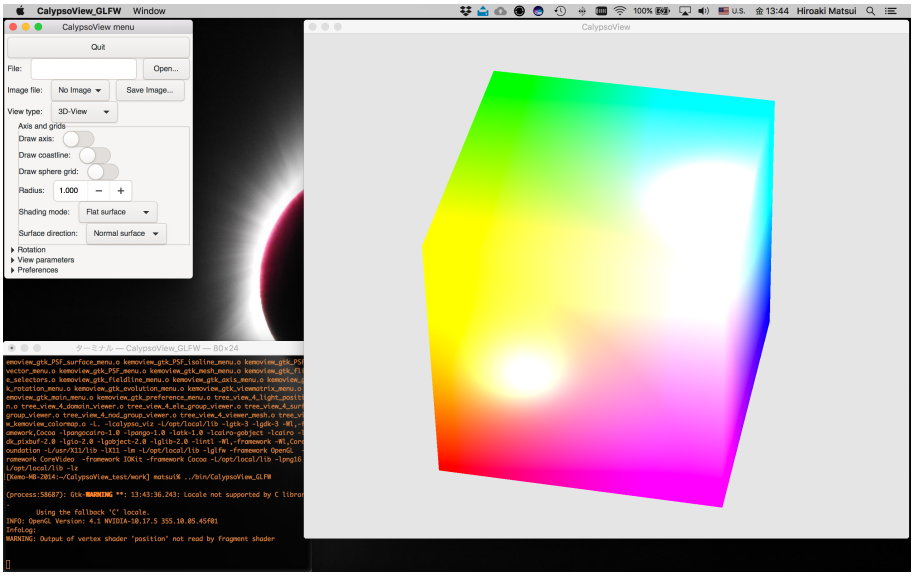

Figure 3: Windows of CalypsoView at starting.

7 Usage of program

The menu window at starting is shown in Figure 4. The program can finish by pushing ”Quit” button (1 in Figure 4).

7.1 Open file

First of all, data for visualization is required to be loaded. The file menu is opend by clicking ”Open” bottun (2 in Figure 4). In Mac version, the file can drag and drop into the viewer window. In Linux version, file name can input the file name box. CalypsoView can treat a unstructured grid data with triangle element or quadrature elements. The file name has to have a step number and extension as `[file_prefix].[step #].[extension]`. The avaiable data formats and extensions are listed in Table 1. For (compressed) sectioning binary data, the file for grid data `[file_prefix].0.sgd` or `[file_prefix].0.sgd.gz` is required in the same directory as the data file.

After loading the data, the menu is expanded to control surface visualization parameters as shown in Figure 6. CalypsoView can load up 10 surfacing data. The detailed control of the sectionig data is described in section 7.6.

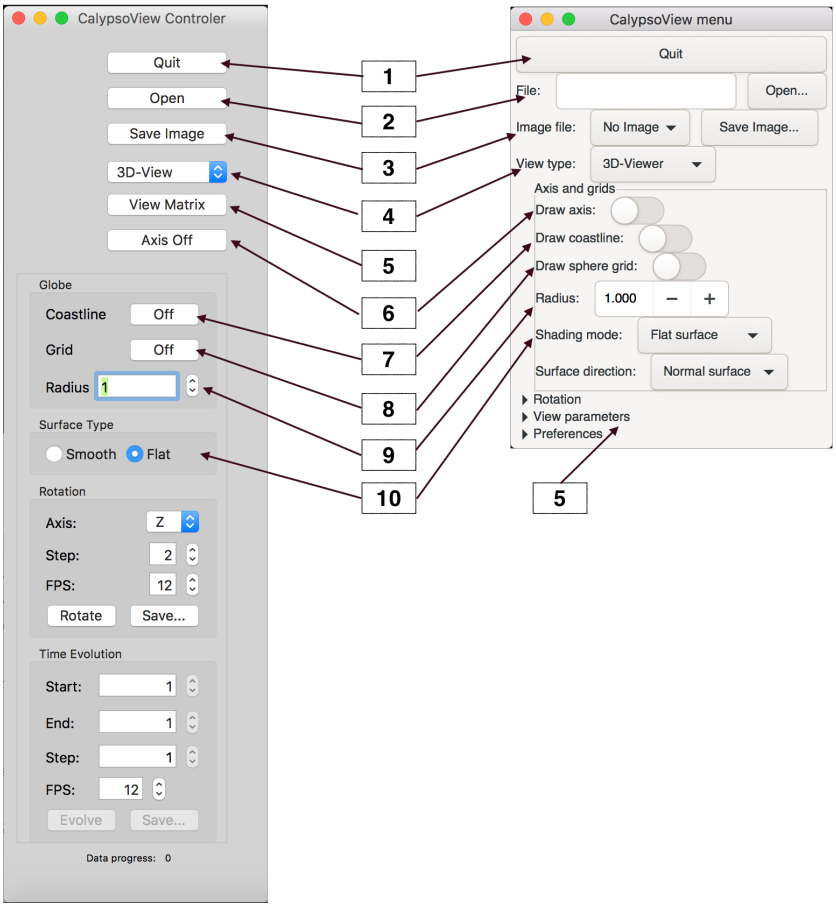

Figure 4: Menu windows of CalypsoView at starting.

Table 1: Data format and extensions for CalypsoView

File format	`extension`
VTK	`.vtk`
Compressed VTK	`.vtk.gz`
Sectioning binary	`.sdt`(*)
Compressed sectioning	`.sdt.gz`(*)
Isosurface Binary	`.sfm`
Compressed isosurface binary	`.sfm.gz`

(*) Grid data `[file_prefix].0.sgd` or `[file_prefix].0.sgd.gz` is required.

Note: At the first time using CalypsoView on MacOS, nothing could be displayed in the viewer window. In that case, lighting parameter may be missing. Please set light parameters in Preference menu.

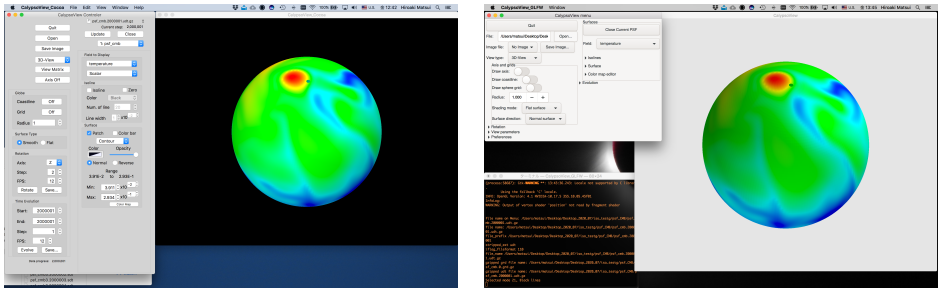

Figure 5: Desktop after loading data for MacOS (lest) and Linux (right).

7.2 Save image

To save image of the viewer window, click "Save image" bottun (3 in Figure 4) and set the image file name and direcotry to save in the file menu. Image data can save as PNG (`.png`) or bitmap (`.bmp`) format. PNG format is smaller size than bitmap format. If no file extension set in the file save menu, file format is chosen in the default faumat in the Preference menu (for Mac) or in the next of the "Save Image" bottun (Linux).

7.3 Interface of Viewer window and viewing mode

The visalised objects can move by mouse or trackpad. THe mouse interface depends on the viewing mode. The viewing mode is selected by View type menu (4 in Figure 4). The following viewing mode can choose:

3D-View: 3-dimentional view.

Streo-View: Streo view using anaglyph. Please use red and blue glass.

Map-View: Map projection using Aitof projection.
Map projection does not support griph (arrow) visualization.

XY-View: Display parallel with xy-plane.

XZ-View: Display parallel with xz-plane.

YZ-View: Display parallel with yz-plane.

The mouse interface is the follwing:

Push and drag:

3D-View and Streo-View Rotate object

Map-View, XY-View, XZ-View, and YZ-View Move object horizontally in screen.

Swipe by two finger: Zoom in and out.

Push two finger and drag: Move object horizontally in screen.

Push option and drag: Move object vertically in screen.

7.3.1 Axis and grids

The axis is drawn when "Axis" switch (6 in Figure 4) is turned on. The axis is not shown in the Map-View mode. The coastline is drawn when "Coastline" switch (7 in Figure 4) is turned on. A grid on a sphere with 30 degree increment is drawn when "grid" switch (8 in Figure 4). THe radius of the coastline and grid are set in the "Radius" box (9 in Figure 4). Example images for axis, coastline, and grid are shown in Figure **??**.

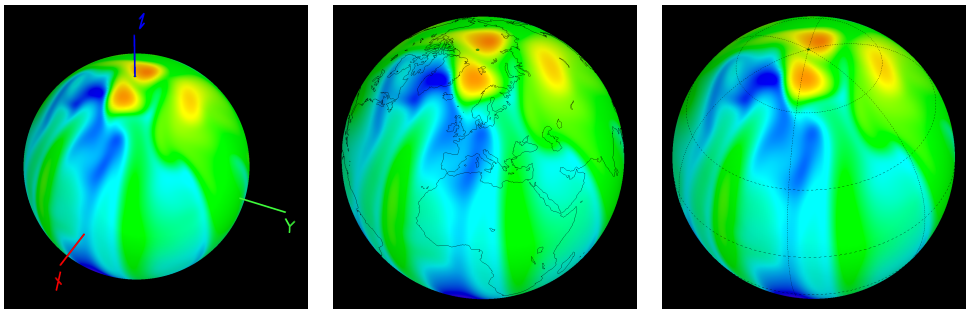

Figure 6: Images with axis(left), with coastline(middle), and sphere grid(right).

7.4 Preference menu

7.5 View transfer menu

7.6 Surfacing menu

References

[1] Bullard, E. C. and Gellman, H., Homogeneous dynamos and terrestrial magnetism, *Proc. of the Roy. Soc. of London*, **A247**, 213–278, 1954.

[2] Christensen, U.R., Aubert, J., Cardin, P., Dormy, E., Gibbons, S., Glatzmaier, G. A., Grote, E., Honkura, H., Jones, C., Kono, M., Matsushima, M., Sakuraba, A., Takahashi, F., Tilgner, A., Wicht, J. and Zhang, K., A numerical dynamo benchmark, *Physics of the Earth and Planetary Interiors*, **128**, 25–34, 2001.

Appendix A Definition of parameters for control files

A.1 Block `view_transform_ctl`

Parameters to construct view transform matrix and projection matrix are defined in this block.
(Back to Section 7.5)

A.1.1 Block `image_size_ctl`

Number of pixels of the image is defined in this block.

`x_pixel_ctl [NUM_PIXEL_X]`
Number of pixels in the horizontal direction `[NUM_PIXEL_X]` is defined by integer.

`y_pixel_ctl [NUM_PIXEL_Y]`
Number of pixels in the veritcal direction `[NUM_PIXEL_Y]` is defined by integer.

A.1.2 Array `viewpoint_in_viewer_ctl [DIRECTION] [POSITION]`

Position of eye in the viewer coordinate is defined in each `[DIRECTION]` and `[POSITION]`. `[DIRECTION]` is set by text (`x, y,` or `z`), and `[POSITION]` is set by real.

A.1.3 Array `look_at_point_ctl [DIRECTION] [POSITION]`

Position to look at is defined in each `[DIRECTION]` and `[POSITION]`. `[DIRECTION]` is set by text (`x, y,` or `z`), and `[POSITION]` is set by real.

A.1.4 `scale_factor_ctl [SCALE]`

Scale of the object is defined by real. In viewer coordinate, object is scaled by 1 / `[SCALE]` times.

A.1.5 Array `view_rotation_vec_ctl [DIRECTION] [POSITION]`

Direction of the rotation axis of the object is defined by `[DIRECTION]` and `POSITION]. \verb|DIREC`
is set by text (`x, y,` or `z`), and `[POSITION]` is set by real.

A.1.6 `view_rotation_deg_ctl [DEGREE]`

Angle of the rotation of the object is defined by `[DEGREE]`.

A.1.7 Block `projection_matrix_ctl`

Parameters of projection is defined in this block.

`perspective_angle_ctl [PERSPECTIVE]`
Angle of perspective `[PERSPECTIVE]` is defined by real.

`perspective_xy_ratio_ctl [XY_RATIO]`
Aspect ratio of horizontal and vertical screen `[XY_RATIO]` is defined by real.

`perspective_near_ctl [NEAR]`
Nearrest distance from eye `[NEAR]` is defined by real.

`perspective_far_ctl [FAR]`
Farest distance from eye `[FAR]` is defined by real.

A.1.8 Block `streo_view_parameter_ctl`

Parameters of streo image is defined in this block. This block is only used for the streo view.

`focal_point_ctl [FOCAL]`
Focal point `[FOCAL]` is defined by real.

`eye_separation_ctl [SEPARATION]`
Eye separation `[SEPARATION]` is defined by real.

A.2 Block `pvr_color_ctl`

Parameters to construct colormap and colorbar information in this block.
(Back to Section 7.5)

A.2.1 Block `colormap_ctl`

Parameters to construct colormap information in this block.

A.2.2 Block `colorbar_ctl`

Parameters to construct colorbar information in this block.

Appendix B GNU GENERAL PUBLIC LICENSE

Preamble

The licenses for most software are designed to take away your freedom to share and change it. By contrast, the GNU General Public License is intended to guarantee your freedom to share and change free software—to make sure the software is free for all its users. This General Public License applies to most of the Free Software Foundation's software and to any other program whose authors commit to using it. (Some other Free Software Foundation software is covered by the GNU Library General Public License instead.) You can apply it to your programs, too.

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