# iGMT: Interactive Mapping of Geoscientific Datasets. User manual for version 1.2

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**Abstract**

iGMT is a Tcl/Tk package for interactive mapping of geoscientific datasets, built around the generic mapping tools (GMT). Our software is intended to assist in the creation of GMT scripts and has built-in data processing capabilities for raster data sets such as topography, sea-floor age, free air-gravity, the geoid, and various polygon data files such as earthquake hypocentre lists or hot-spot locations.

iGMT is used world-wide at more than 220 institutions for everyday map-making and teaching GMT. Our program should run on any UNIX-type computer since it is entirely based on open-source software. iGMT itself is distributed under the GNU public license but should be used in accordance with the Student Pugwash pledge.

This manual briefly describes how iGMT is used and explains some technical details that may be helpful if the user wishes to extent or modify iGMT. *Please note that some of the comments in this manual may be outdated, so please proceed with caution.*

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# Contents

# 1 Copyright and warranty disclaimer

# 2 Credits and history

Many users have helped to improve iGMT with their comments, contributions, and problem reports. For example, Simon McClusky of MIT provided provided his velocity vector facility for iGMT 1.0. This support is very important for us and we encourage you to contact us if you find bugs or inconsistencies, be it with the software itself or with this manual.

iGMT uses the GMT software by Wessel and Smith (1991, 1995, 1998) for mapping, and is based on the Tcl/Tk toolkit by John Ousterhout. Small parts of the routines and templates were taken directly from the Tcl/Tk book by Ousterhout (1993) or the GMT documentation. Some of the initial Tk frame packing was done with the `XF` software by Sven Delmas. iGMT makes use of the `convert` tool of the ImageMagick distribution.

The researchers making the data sets available that iGMT works with have to be mentioned for their great contribution. Besides other sources datasets of NOAA (1988); Smith and Sandwell (1997); Sandwell and Smith (1997); Müller et al. (1997b); Dunbar et al. (1997); DeMets et al. (1990); Steinberger (2000); Simkin and Siebert (1994); Dziewoński and Woodhouse (1983) and Rapp et al. (1991) are processed by iGMT.

iGMT was formerly known as (A)GIS which stands for "A Geophysical Information System". Since the program has no full GIS functionality yet[1] we changed the name to avoid confusion. Further details of the version history can be found at iGMT's web site.

We officially announced iGMT in 1998 in *EOS Transactions*, the newspaper of the American Geophysical Union. A reference to cite iGMT is therefore

Thorsten W. Becker and Alexander Braun: New program maps Geoscience data sets interactively, *EOS Transactions, 79*, 505, 1998.

and we encourage you to mention iGMT if you find it helpful. May we also suggest that you register at

`http://op.gfz-potsdam.de/igmt/userform.html`

so that we can keep you posted if we discover bugs or a new version comes out. In addition, we are always eager to add your dot to our user distribution maps which can be found at

`http://op.gfz-potsdam.de/igmt/users.html`.

[1] All that's missing is basically some geographical sorting which could be implemented using GMT functions as well.

# 3 Quick start and installation instructions

1. Make sure you have a working version of Unix, Tcl/Tk, and GMT; this should be fine on most Linux like systems, and on OS-X once GMT is installed via fink. Particularly, every user will have to have `$GMTHOME` set properly (see the GMT documentation)

2. Install the iGMT tcl source code and smaller datasets into some directory, say `/usr/local/src/igmt_1.2/`, by typing

   ```
   cd /usr/local/src/
   gunzip -c igmt_v1.2-20051208.tar.gz | tar xv
   cd igmt_1.2
   ./configure_script
   ```

   where the last step should make sure that the main paths are set properly.

3. If you want a shortcut to install all the geophysical data we list on `http://www.seismology.harvard.edu/~becker/igmt/`, you can download a **300MB big** gzipped tar file from `href=http://geodynamics.usc.edu/~becker/ftp/igmt_data_comp.tgz`. Remember that we are providing this collection only for your convenience, that all copyrights remain with the original authors, and the obligation to properly cite lies with you. If you decide this package, put the tar file to some shared directory, say /wrk/data/, it will expand into subdirectories that hold most of the data that is listed below.

What follows is a long version of the installation and software documentation.

# 4 Software requirements

The current version of iGMT is intended for use on UNIX systems[2] and was first developed running IRIX 6.3-6.5, and from 2002 on purely on Linux. However, it should be easily modified to run on other hardware platforms without much effort since all the software that iGMT relies on or an equivalent is available for most operating systems. We have heard of successful installations on the following operating systems: MacOS X (10.x), SunOS 5.6, Solaris 2.5.1-2.6, HP-UX10.01, DEC OSF, IBM AIX 4.1.x, 4.2.1, IRIX 4.0.5, 6.2-6.5 and LINUX (SuSE 5.1, 5.2, Redhat 4.2, 5.2, 6.0, 7.1 Debian, Fedora cores). Mac OSX installation is a bit trickier and described on the web page.

The iGMT script package that comes with this documentation, some example plots and small datasets are available at the iGMT home page

```
http://www.seismology.harvard.edu/~becker/igmt/
```

These website are also the places to check for updates, bug reports etc. iGMT assumes that you have the following software installed and accessible either via the user's `$path` variable or the binary paths set in `igmt_configure.tcl` or the `igmt_siteconfig.tcl` file (see sec. 5). This software requirement should be

[2] It will be assumed that the user has some familiarity with the UNIX operating system and basics will not be explained here (for UNIX and shell scripting reference see, e.g., Gilly, 1994). Also ask your favorite system administrator if things sound Greek to you.

automatically fulfilled if you are running a LINUX system from any of the major distribution, e.g. Redhat 7.1. If any of this does not make sense to you, please ask your system administrator.

**Tcl/Tk:** iGMT is mostly written in Tcl/Tk, a convenient language for constructing graphical user interfaces.

The Tcl script language and the Tk toolkit (Ousterhout, 1993) are currently available at `http://www.tcltk.com/` or `http://dev.ajubasolutions.com/`. Version 8.0 of Tcl/Tk was used for developing, older versions may work as well. From the newer releases, we found that 8.2.1 gave problems while 8.3 seems to work fine. Tcl is available for UNIX, PC, Mac and other platforms.

**GMT:** The generic mapping tools (Wessel and Smith, 1991, 1995, 1998) do the mapping part, they are called by a script file produced from within iGMT. The source code distribution of GMT as well as documentation is available at

`http://www.soest.hawaii.edu/wessel/gmt.html`.

GMT itself has some additional software requirements, such as the availability of the netcdf library (see the GMT documentation).

iGMT can handle GMT versions 3.4.5 and 4.0, we have included the option to change the binary directories according to the GMT version that is selected. To modify these optional directories, set the iGMT variables `higher_version_gmtbins` and `lower_version_gmtbins` (see sec. 5).

**gawk:** The `awk` command family (`awk` itself, the math-included version `nawk`, and usually the GNU-version `gawk`) is available on all UNIX systems such as AIX, IRIX, SOLARIS, HPUX or LINUX. AWK or some GNU flavors of it such as `gawk`, which is used by iGMT per default, runs also on PCs and Macs. (To change the default `awk`-type binary, modify the iGMT variable `our_awk` (see sec. 5). If `gawk` is not available, use `nawk` instead of simple `awk` since our scripts might rely on math functions which might or might not be accessible from within `awk`.)

**ghostview:** iGMT uses the GNU software `ghostview` as a postscript display program. A possible postscript viewer alternative would be `showps` or `ghostscript`, available for PC and Mac (change iGMT variable `psviewer` (see sec. 5)). iGMT works fine without any postscript displayer at all as long as you do not need to view the PS files that GMT produces before printing them.

**convert:** The `convert` tool of the ImageMagick software

`http://www.wizards.dupont.com/cristy/ImageMagick.html`

is used to convert from PS to the GIF format so that GMT output can be judged right away. (iGMT variable `ps_to_gif_converter` (see sec. 5).)

You might as well use `ghostscript` to convert from postscript or change the graphic format that is used for previewing to something completely different. [3] iGMT works fine without a converting tool

[3] At the moment, *standard* Tcl photo image displaying works only with `GIF` and `ppm` images. Since `ppms` are usually much bigger than `GIF` images, we chose `GIF` to be the standard. If you choose ppm (not interfering with possible copyright issues), and continue to use `convert`, just change the name of the converted file for `convert` in `igmt_siteconfig.tcl` to have a `ppm` suffix. For ghostscript, you need to change the command line used for the conversion operating system call (see the comments in the `igmt_configure.tcl` file).

User E. Suarez has implemented another graphic format which is smaller (png) but for this to work, a non-standard extension of Tcl/Tk is needed. This is why we still stick to GIF and will probably change the graphic format only in the next version.

From now on, we use the acronym “GIF” to refer to whatever graphic format you chose.

even though you might get an error message when you use “Map it!”.

If you have installed the tools mentioned above you should be ready to use the basic version of iGMT. While the requirements above might seem complicated, it should be kept in mind that nowadays most UNIX or LINUX systems come with all of the above except GMT when the system software is installed. GMT, on the other hand, is widely in use in the earth sciences already. In addition, all of the software needed to run iGMT is freeware or shareware of some kind and most of it is subjected to an open developing policy.

# 5 Installation and configuration

To get iGMT running, extract the distribution `igmt_v1.2.tar.gz` (or, alternatively, its slim version `igmt_v1.2_wo.tar.gz`) –if you have not already done so– in a directory where you typically store Tcl/Tk scripts. This could well be at the single user level on multi-user systems (non-root priveliges installation) since the package itself is relatively small. Installing multiple copies would allow every user to modify the iGMT code themselves.

From here, you can either choose to use the script `configure_script` which we provide or proceed to do a few changes manually. If you choose the “automatic” way, you will have to enter the iGMT directory that you just created by expanding the tar-file and type `./configure_script`. After answering a couple of questions, you should be all set.

If, on the other hand, you would like to stay in control, simply check the following steps:

1. An environment variable `$igmt_root` can be set to point to the directory where iGMT resides. With `csh` this would be done by adding a line like
   `setenvigmt_root$HOME/tcltk/igmt_dir/`
   to the `$HOME/.login` file. For `bash` you would add
   `exportigmt_root=$HOME/tcltk/igmt_dir/`
   to the `.profile` file. Alternatively, you will have to modify the main iGMT script (startup script file) `igmt` and change line 39 to point to the root directory.

2. The `igmt` script calls the Tcl/Tk shell `wish` using the explicit call to `/usr/bin/wish` in line 75. If `wish` is somewhere else on your system (try typing `whichwish` or `typewhich`), either change the corresponding line in `igmt` or set the another environment variable `$wish_cmd`. After verifying the settings, `igmt` should be executable and iGMT can be started by typing `$igmt_root/igmt` at the command line. (Of course this can be facilitated by adding an alias or linking `$igmt_root/igmt` to some place where your shell looks for executables.)

3. iGMT needs to know where the GMT binaries (old (up to 3.4.5) and new (4.0 and up)) are located. In a similar fashion as above for `wish`, find out where that is (say, in `/usr/local/bin`) and add two lines like
   ```
   sethigher_version_gmtbins/usr/local/bin/
   setlower_version_gmtbins/usr/local/oldgmt/bin/
   ```
   to your `igmt_siteconfig.tcl` file that holds all the necessary modifications to get iGMT running in your environment.

4. You will also have to modify the location of the large raster datasets, either by editing their individual pathnames in `igmt_siteconfig.tcl`, or by following our naming convention and changing only the `$rasterpath` variable, which is intended to point to the directory that holds all the individual datasets.

As mentioned above, you can change many of the other default settings of iGMT such as the helping applications and the pathnames of dataset locations by modifying the corresponding iGMT variables. Most of these variables are set in the Tcl program file `igmt_configure.tcl`. You can modify settings by searching for the variable or topic in question and replacing the iGMT variable value directly in the `igmt_configure.tcl` file. The preferred way, however, is to create a `igmt_siteconfig.tcl` file and insert the corresponding line there. This file is read by iGMT after the initialization of the variables (by means of `igmt_config.tcl`) so that all settings will be overwritten by the users preferences. By doing things this way, it will be easier to install future versions of iGMT since all local modifications, such as different data locations, don't have to be changed again.

### 5.1 Examples of modifying default variables

The GMT binaries are not in the path the shell checks routinely. Therefore, search for the corresponding iGMT variable in `igmt_configure.tcl`. Its name is `gmtbins`, and it is set to `""` by default (ie., only the normal path is searched). To change this behavior, modify or create a file named `igmt_siteconfig.tcl`, and include the line `set gmtbins "/path/bin/"`, where `path` is the location of your GMT commands.

Similarly, if the man pages are not accessible by default, change the `setgmtmanpage` command. If you don't have `gawk` on your system, change the default awk-like program by resetting the variable `$our_awk` to whatever your `awk` is called, maybe "awk".

## 6 Datasets handled by iGMT

While iGMT is lacking the database query functions of full blown GIS systems it is capable of combining multiple geoscientific data sets and handling large amounts of data in an efficient way. (Indeed, this is an achievement of the GMT software and iGMT's approach does not constrain this feature.) Excellent data is available on the web these days and iGMT is based upon these publicly available collections. Since GMT has grown into a *de-facto* standard in parts of the geophysical community, it seems natural to use GMT to handle the data.

With the requirements that are explained in section 4 you should now be able to interactively use the GMT command `pscoast` that is used for plotting maps of land and sea coverage with political boundaries etc. [4]

If you want to take advantage of the built-in handling capabilities for various datasets, you need to get the data or tell iGMT where it can find it if the data is already around on your system. All path names can be changed together with all other global variables in the `igmt_configure.tcl` or a site specific `igmt_siteconfig.tcl` file (see sec. 5). Furthermore, the user has the option to specify one raster grd-file and two custom polygon data sets. The `igmt_configure.tcl` is commented so it should be easy to find what you are looking for. In addition, some of the datasets require special converting software. We have put some links to datasets on our web page for your convenience.

### 6.1 Raster data

Besides `pscoast` land and sea coverage and shorelines, the following raster data files are supported (all can be downloaded in one huge package from `href=http://geodynamics.usc.edu/~becker/ftp/igmt_`

[4] Man pages and other documentation are available for the GMT commands. Therefore, the explicit usage will not be explained in this manual. Refer, e.g., to the man page function provided by iGMT or to `http://www.soest.hawaii.edu/wessel/gmt/gmt_doc.html`.

data_comp.tgz):

**ETOPO5 topography:** The ETOPO5 topography/bathymetry (NOAA, 1988, available at http://www.ngdc.noaa.gov/) is supported in combination with the grdraster tool which is (as psvelomeca) part of the supplementary package that is available together with the GMT main distribution. The ETOPO5 data set is about 19MB in i2 binary format.

**ETOPO2 topography:** The composite ETOPO2 topography/bathymetry dataset is desribed at http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html\#GriddedF and supported as a GMT grd file which can be obtained from
http://dss.ucar.edu/datasets/ds759.3/data/.

**"GTOPO30" topography:** The GTOPO30 DEM model (EDC, 1996) was greatly expanded by Smith and Sandwell (1997). It is supported in the form suggested by Smith & Sandwell using img2grd. Data and other tools can be found at

http://topex.ucsd.edu/marine_topo/mar_topo.html.

The img format file is 137MB.

**Sea-floor age:** The sea-floor age data of Müller et al. (1997b) was published as a GMT grdfile and is used in the form as available at

http://Omphacite.es.su.oz.au/StaffProfiles/dietmar/Agegrid/agegrid.html.

The data is about 23MB in grd format and roughly 10MB in i2 binary which could be read by grdraster as ETOPO5 (to do this, change the corresponding lines in igmt_plotting.tcl). By default, iGMT expects the global, grid-file version (age data version 1.5).

**Free-air gravity:** Sea-floor gravity anomalies as published by Sandwell and Smith (1997) are used as a grdfile as found at

http://topex.ucsd.edu/marine_grav/mar_grav.html.

As GTOPO30, this file is 137MB big.

**Geoid:** iGMT supports plotting the geoid and comes with an adequate colormap. As an example, we evaluated the spherical harmonic coefficients of the EGM360 model of Rapp et al. (1991, 1996) from order 2 to 360, corrected for the hydrostatic shape of the Earth (Nakiboglu, 1982), and included them in quarter arc minute resolution as a GMT grd-file in our raster data set. Alternatively, we also offer the OSU91A model of Rapp et al. (1991) as a "typical" geoid representation grd-file. You can download both files from our web site.

**Global free-air gravity:** Derived from the EGM360 model of Rapp et al. (1991, 1996) from order 2 to 360, and included in quarter arc minute resolution as a GMT grd-file in our raster data set. Obtained from the file above by multiplying the spherical harmonic coefficients by $g(l-1)/R$ where $g$ is gravitational acceleration, $R$ the radius of the Earth and $l$ the order of the spherical harmonics.

You can download this file from our web site.

**Sediment thickness:** Sediment thickness is important for seismological studies and the comparison between half-space cooling model prediction and bathymetry. We have included a data handling routines for the Laske and Masters (1997) dataset. The data itself is available as a grd-file on our web site.

**GSHAP peak ground acceleration** The Global Seismic Hazard Assessment Program (GSHAP, Giardini et al., 1999, 2000) has compiled a world-wide 6 minute on-land dataset of estimated peak ground accelerations that can be expected with a 10% probability within the next 50 years (see `http://seismo.ethz.ch/gshap/global/global.html`). We provide a plotting facility for this type of data, the grid file can be obtained from
`http://seismo.ethz.ch/gshap/global/caution.html`.

**Custom data:** You can choose an arbitrary GMT grd file to be plotted as the base data layer and provide your own colormap, too.

## 6.2 Polygon data

Some example handling procedures for polygon data are included as well:

**Plate boundary data:** The plate boundaries as given by DeMets et al. (1990) are part of the iGMT distribution as the file `nuvel.yx` in a slightly modified form. Any polygon data file supported by `psxy` can be substituted for this data set.

**Hotspot locations:** iGMT uses a list of hotspots compiled by Steinberger (2000) to plot their location and a name tag, if selected.

**Volcano locations:** The Smithsonian Institution Global Volcanism Program's list of volcanoes (Simkin and Siebert, 1994) is supported in the form found at
`http://www.volcano.si.edu/gvp/volcdata/index.htm`.
As for the hotspot data, the user can select a symbol, the color and toggle a name tag. A version of this list as of April 1998 is included. If you want to install an update, just download the data from the web and replace the adequate file. The same holds true for the earthquake catalogs since iGMT was programmed to handle the original data.

**CMT fault plane solutions:** iGMT uses `psvelomeca` from the GMT supplements package to plot the double couple part of the Harvard CMT centroid moment tensor solutions (e.g. Dziewoński and Woodhouse, 1983) as found at
`http://www.seismology.harvard.edu/CMTsearch.html`.
A list of all events in the catalog of the first 60 days of 1998 is included as an example.

**Significant earthquakes:** Dunbar et al. (1997) have compiled a list of significant earthquakes starting 2000 B.C., their catalog is accessible at
`http://www.ngdc.noaa.gov/seg/hazard/sigintro.html`.
After quoting all lines without data by inserting a hash sign ("# "), the format produced by this engine can be read directly into iGMT. (Internally, all that iGMT does is to use awk to check if lines are quoted and for exporting of the relevant columns.) iGMT plots only earthquakes that have a magnitude assigned, you might want to change the relevant `awk` lines in `igmt_plotting.tcl`.

**PDE earthquakes:** The United States Geological Survey keeps different hypocenter catalogs at the National Earthquake Information Center
URL: `http://wwwneic.cr.usgs.gov/neis/epic/epic_global.html`).
The "Screen File Format" can be read by iGMT.

**Slab contours:** Gudmundsson and Sambridge (1998) define contours of the upper edge of subducting slabs from the relocated hypocentres of Engdahl et al. (1998). These seismicity contours are available from

http://rses.anu.edu.au/seismology/projects/RUM/rum_download.html,

we have included them in a format readable by GMT.

**Velocity vectors:** Simon McClusky provided a routine that handles velocity solution plotting using `psvelomeca`. A typical application would be the mapping of results from GPS studies such as the `gps.vel` global data example we have included.

**Vector fields:** Given two user-supplied GMT `grd` files with $v_x$ and $v_y$ components of a vector field $v$, iGMT plots this field using `grdvector`.[5] You can change the color and width of the vectors via the normal color and linewidth menus for polygon data. Additional parameters can be changed under "Data parameters"/"Vector field parameters".

**World Stress Map:** The World Stress Map (WSM) Project (e.g., Zoback, 1992; Müller et al., 2000; Reinecker et al., 2003),

http://www.world-stress-map.org,

compiles stress measurements all over the world. We supply a routine that can read the WSM's ASCII format data base (Müller et al., 1997a, 2000).[6] It plots either only the compressive directions of the horizontal stress regime (as it is commonly done), or different style vector pairs on basis of the focal mechanism classification for the horizontal plane projection. The different vector style plots two equal length vectors (one compressional, one extensional) if the focal mechanism is labeled "strike-slip", one compressional (extensional) vector if the focal mechanism is purely compressional (extensional), and it uses one half-length and one full length vector for compressional or extensional mechanisms with a strike-slip component in the horizontal plane.

**Major cities:** We have supplied a (rather inaccurate) data set of 726 cities with their names and locations. This data set can be restricted to the major 235 cities. The corresponding data sets are `wcity.dat` and `wcity_major.dat` (the latter is a subset of the full data set).

**Custom "xys" files:** iGMT can plot two custom ASCII data files specified by the user. They have to be in a columnar ASCII format (separator is a white space or tab, comment lines can be introduced by a number sign, "#"), similar to the polygon data described above, and need at least longitude and latitude in every line. Size values can be given optionally, hence "xys". (For instance, for earthquakes hypocentres you would give longitude, latitude, and magnitude. The magnitude will be used to scale each symbol that is plotted on your map. To change all symbol sizes in an absolute sense, you can choose `sizespolygondata` in the `Dataparameters` menu. When you use polygon drawing by choosing "line" or "close polygon" as a symbol in `Symbolspolygondata` for your polygon file, the `sizespolygondata` item will change the width of the line.) GMT type polygon files where individual polygons are separated by an "¿" sign in a single line are supported.

You can interactively choose the column numbers (ie., use the eight and ninth column instead of the first and second) which hold the x and y values, if you leave the column number for size blank, xy-plotting is assumed. The magnification factor is a pre-multiplier for the size entry that is later modified by the standard size of the symbols (see also section 7.2).

[5] An example for such datafiles would be the expansions of plate velocity Euler poles you can find at our website.

[6] Our script can read the 1997, 2000, 2003, and 2005 formats of the WSM data format (they are different as to the addition of the "ISO" field in 2000).

Technical details how these files are handled are explained later in the text and in the comments found in `igmt_plotting.tcl`. You might also wish to refer to the iGMT web site where you can find a more detailed description of the datasets listed above and links to the sites providing the data:

```
http://www.seismology.harvard.edu/$\sim$becker/igmt/
```

In addition, this is where you can obtabin the plate velocity and potential field grids mentioned above.

# 7 Usage of iGMT

In the following we assume that you have a running version of iGMT. The usage will be explained by going through all menu points that show up at the start-up screen. The basic idea of iGMT is to use GUI facilities to select important plotting parameters, produce a GMT script and run it from within the program. When this is done successfully, the produced postscript code is converted to a GIF image and then displayed. By doing this, it is easy to create a basic script that can then be modified for more complex applications when the limits of iGMT are reached.

The menu list is divided into six pull down menus, `File/Plot`, `Datasets`, `Dataparameters`, `Mapparameters`,`Scriptin` `Options` and `GMTmanpages` as well as two buttons, `Mapit!` and `Quit`.[7]

## 7.1 Menu `File`

This menu takes care of the main file handling and general input/output functions of iGMT. The first item, `CreatePS...`, leads to the identical action as the `Mapit!` button, that is:

- a GMT script is created and executed;
- if a postscript file was created, this is converted into a GIF;
- the GIF map display underneath the menu bar is updated.

The next three items allow the user to create a postscript file only or individually display the postscript. This might be helpful if you have trouble installing a PS-to-GIF converter. The filenames used for this process default to `/tmp/igmt_$USER_tmp.ps` and `/tmp/igmt_$USER_tmp.gif` (again, this can be changed in `igmt_configure.tcl` or `igmt_siteconfig.tcl`). "`$USER`" is replaced by the UNIX user name to avoid conflicts with write permissions if more than one user operates iGMT on a single machine. If the produced map files are to be kept, the user can either copy them to another place by hand or use the following two items in the menu list, `SavePSfile` and `SaveGIFfile`.

`Load` and `Save parameters` use a file to dump or restore almost all iGMT parameter settings so that a session can be restarted at a later time without having to redo all the fine tuning. iGMT comes with four example parameter files (`example?.dat`) that can be loaded to experiment with the software. `ParameterFormat` allows the user to select which version of the iGMT parameter files should be loaded and written to allow backward compatibility down to iGMT1.0. `Displaymanual` displays this manual with the postscript software if installed and `AboutiGMT` shows a short description of the software.

[7] For ease of use, these menus can be detached under Tcl/Tk by choosing the dashed line on top of each list and moving them to the work space.

### 7.2 Menu `Datasets`

The first item in the `Datasets` menu leads to the raster data choice dialog where the files to choose from are those described in section 6. The same holds true for the polygon datasets of the second item. In contrast to the raster data sets, polygon sets can be plotted on top of each other. Future versions of iGMT will allow multiple layers of raster data as well.

The next part of the `Datasets` menu allows the user to choose the custom GMT grd-file he wants to plot, whereas `Change... file` in the next six lines modify the respective custom polygon data files.

The polygon menu comes with the option of plotting two user defined data sets as mentioned above. The following two items in the menu list bring up two identical dialogs where the names of the custom `xys` files, the columns for latitude, longitude and size as well as a magnification factors for the size can be specified. Internally, all data sets are of course handled by a trivial `awk` script that can be viewed in the GMT script file or in the source code, that is `igmt_plotting.tcl`.

### 7.3 Menu `Data parameters`

This and the next menu are used to set all the parameters for the data and mapping part of the GMT script.

**Menu items for** `pscoast` The first three items deal with pscoast. A small subset of the polygon data that can be plotted by this routine are mentioned in the `Pscoast polygon selection` list. The next item allows changing the color of the land and sea coverage, while the last pscoast item is responsible for changing some linewidths.

**Raster data set items** Toggle the automatically provided legends/colorbars for the gravity, age, geoid and topography data sets on and off and select the grid resolution. If the value you choose (in arc minutes) is smaller than the minimum value supported by the specific data set, iGMT increases the value automatically. There will be a warning when a large number of data points are about to be processed. Keep in mind that small machines might have a hard time if the resolution is too high and/or the map size is too big.

"Change colormap" lets the user choose a colormap other than the ones used automatically when a predefined raster data file is selected. If you change the raster data set to one of the predefined ones after choosing your own colormap, you have to reenter the selection.

"Create colormap" uses the GMT tool `grd2cpt` to automatically create a colormap for the default grd-file that is set. For GMT versions higher than 3.2, the user can select from different colormap schemes (see the man page for `grd2cpt`), otherwise it's "rainbow". Since the colormap is based on a histogram of the grd-file, colormap creation might take a while with slow machines and/or large datasets.

Use "Shade raster data" to toggle the shading that is done for topographic and gravity datasets using `grdgradient`.

Following is the "Contour lines" item which you can use to switch the plotting of contour lines of the grdfile values to overlay (on top of grdimage produced plot), only contourlines ("solely"), or off. In addition, you can select the color of contour lines, set the width of contour lines, the contour line density, and the annotation text size. By default, iGMT will use black for the color, contour line density of unity (which corresponds to on the order of ten contour lines), linewidth 2 for normal lines. Every second contour line is annotated and has double width. Also, annotations will be 14pt size, set them to "-" if no annotation is wanted.

**Polygon data set items** The next four menu items change roughly what they say, `Symbols...`, `Sizes...`, `Color`, and `Linewidths` of the polygon data. Sizes are in fractions of the mapwidth and get multiplied by another factor with the size column of the `xys` data. The symbols types that are implemented are, again, only a subset of what GMT can do.[8]

Name tags can be switched on and off for hot-spots and volcano data sets with the next item. "GPS velocity vector parameters" is used to adjust the parameters for the GPS/psvelo vectors, "Vector field parameters" is used to adjust vector field plotting, and "WSM parameters" can be used to select the plotting type for stress data, the minimum quality and the types (Müller et al., 2000). Finally, "City type" selects between the full and the restricted city data set.

## 7.4 Menu `Map parameters`

**Item** `Region` This item brings up the region selection dialog. Where the eastern, northern etc. boundaries are self-explaining, the "Center of map projection" is needed for whole earth viewing projections. Clicking on "The whole thing!" expands the geographical boundaries as far as possible for the checked projection. ""Square" it" attempts to make a square-like map by setting the difference between the boundaries equal. "Center" sets the center of map projection values to the averages of the boundaries and adjusts the reference meridian to the average latitude (needed for some projections). "0/180 ¡-¿ 0/360" attempts to go from one system of specifying longitudinal ranges to another.

**Item** `Projection` The projection order chosen for the dialog box follows the GMT manual

URL: `http://www.soest.hawaii.edu/wessel/gmt/gmt_doc.html`

closely. Projections themselves are explained briefly in the `pscoast` man page. The last check-box, "custom projection", allows the user to specify the projection with the magnification factor in the GMT format explicitly. This might be needed since formatting is not perfectly done by iGMT and not all GMT projections are implemented. Some of the projections adjust the geographic region to be plotted as suitable.

**Items for map grid line and frames** `Gridlines` and `Frame annotation` are on/off-type switches. By default, the gridlines are twice as densely spaced as the outer annotation intervals along the map frame.[9] You can choose to annotate on all four sides of the plot (default), or only on the southern and eastern sides. The mapscale the user can switch on by selecting "Fancy", "Plain", or "Off" is positioned in the lower left corner of the map and calculated to be correct at center latitudes.

**Miscellaneous plotting items** Add a title to the plot and change the page size and orientation here. The offsets in $x$ and $y$ direction default to one inch each, which is usually ok. Don't expect perfect results in terms of title placement or centering of the final map on the produced postscript file, though. Reasonable results should be achievable with the built in functions of iGMT, while final copies will probably need some hands-on modification of the GMT script.

## 7.5 Menu `Script`

The first item, `Show GMT script`, shows the file that is created and executed by iGMT to get GMT to produce the postscript file we are viewing. This is intended to do two things: Show the inexperienced user what can

[8] Some symbols disregard the `-G` option (e.g. crosses) so that they will appear in boring black whatever you do with the color sliders. You will have to fix this by replacing the `-GRRR/GGG/BBB` option with `-Wsize/RRR/GGG/BBB` in the final script.

[9] Change this in `igmt_plotting.tcl`, if you like.

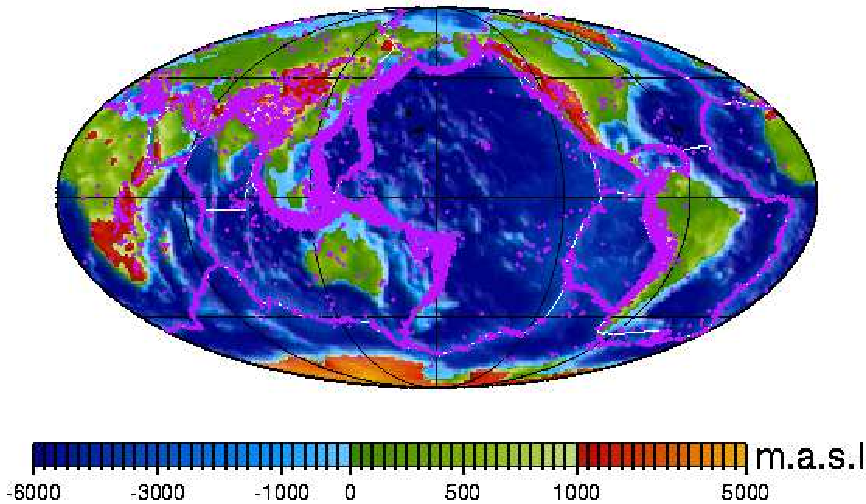


**Figure 1:** ETOPO5, NUVEL1 plate boundaries and PDE hypocenter distribution as of `example1.ps`, resolution reduced. Data from DeMets et al. (1990); NOAA (1988); USGS/NEIC (1998).

be done (in addition to the introduction in the GMT manual) and give the experienced user a fast tool to get to a start script for more complicated applications. This file is called `$HOME/igmt_parameters.dat` by default. `Addstufftothepscoastline` lets the user add additional commands to the last `pscoast` command of the script file without having to exit from iGMT and run the script independently. The file presented by `Showscripterrors` contains the stderr output of the GMT commands invoked and should be helpful for debugging. By default, GMT is "verbose". `GMTversion` lets the user change between the old GMT version 3.0 and one of the newer versions, such as 3.4. The last item of this menu lets the user switch the GMT logo on and off. By default, it is off since it would interfere with the colorbars.

### 7.6 Menu `GMT help`

This menu list is intended to provide fast access to the GMT man pages for reference. At the time of the first call, a temporary file is created from the `man` command and afterwards displayed every time the user selects the same command man page again. If the GMT man pages are not in the usual place where the `man` command looks for them, uncomment the line

Finally, the two buttons on the right hand side of the menu bar do what they say.

## 8 Examples

The following examples were produced by running iGMT with the full data sets as described above. They can be reproduced if the data is available locally by loading the parameters file given in the distribution.

**Hypocentres from the NEIC dataset** Figure 1 shows the map of `example1.ps` from the iGMT distribution, the whole Earth in the Mollweide projection. ETOPO5 in 60 arc minute resolution is the ground raster

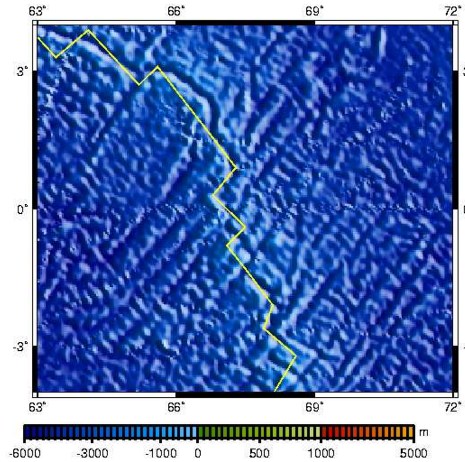


**Figure 2:** A part of the Carlsberg ridge in the Indian Ocean as of `example2.ps`, parameters can be loaded from `example2.dat`. The original file has extremely high resolution and was quite big. The reduced image shown here was shrunk to 81dpi using `xv`. Bathymetry data is from Smith and Sandwell (1997), plate boundary from DeMets et al. (1990), scale is the same than in Fig. 1.

layer. All hypocentres of the USGS/NEIC dataset from 1973 – 1997 with magnitude greater than five and NUVEL1 plate boundaries are superimposed. Load `example1.dat` to produce this plot. To reduce the size of this documentation, the postscript file is not exactly that produced by iGMT but a converted GIF with lower resolution.

**Smith & Sandwell/GTOPO30 topography** Figure 2 of example number two shows a part of the Indian ocean and the Indian subcontinent. It was produced using the Smith & Sandwell/GTOPO30 dataset in full resolution and has the pscoast shoreline data in high resolution superimposed. The original map has fascinating detail that might be lost in this reproduction.

**Sea-floor age of Müller et al.** Example 3 as resp-resented by Fig. 3 and the files `example3.ps` and `example3.dat` shows the North Atlantic region sea-floor age data coverage together with plate boundaries (Stereographic projection).

**Gravity anomalies from Sandwell and Smith (1997)** The last example (`example4.*`) of Fig. 4 shows gravity anomalies in the Indian ocean. **ATTENTION:** This example is quite resource hungry and might lead to problems on smaller machines if actually run with the original data set!

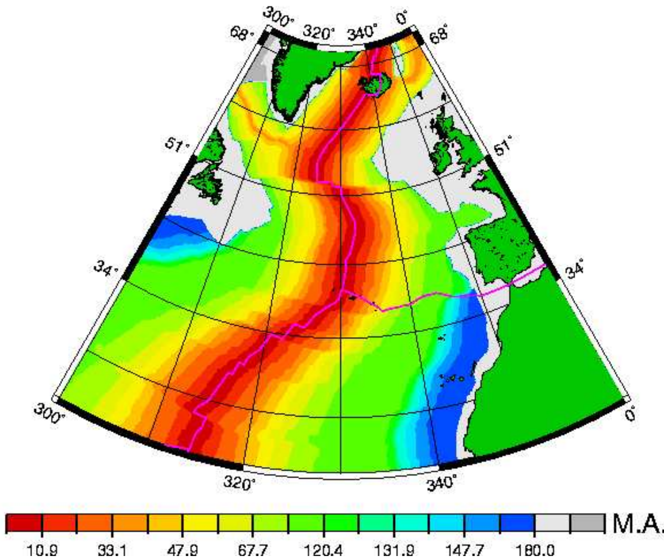


**Figure 3:** Sea-floor age version 1.3 of Müller et al. (1997b) and plates from DeMets et al. (1990).

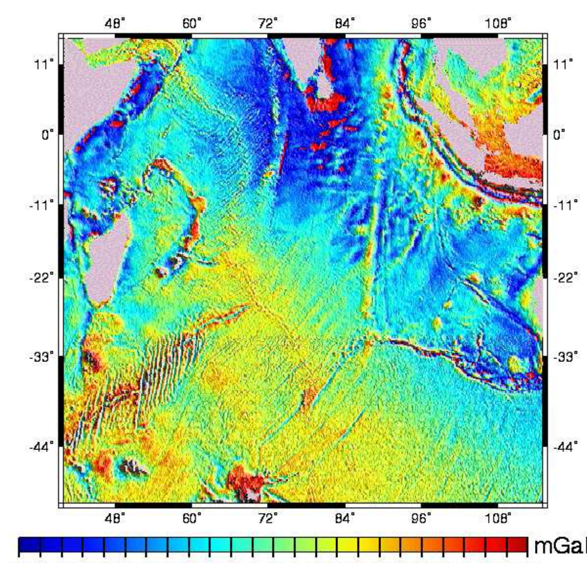


**Figure 4:** Free-air gravity anomalies in a part of the Indian ocean from Sandwell and Smith (1997). Dominant features are the Carlsberg, Southwest Indian and Southeast Indian ridges, the Bengal fan and the Ninety-east ridge. Resolution was restricted to 10 instead of 2 arc minutes.

# 9 Conclusion

The iGMT software package was programmed in a modular way. Every routine is commented, so it should be fairly easy to modify the code and add extensions to the software. If you do so, that's fine, but please do not call it iGMT when you distribute it and make reference to the original software. Please keep in mind that while GMT offers a large number of interesting and useful mapping options and iGMT tries to make use of them, iGMT can't be as flexible as GMT. In addition, it is pretty hard to test every single combination of what-might-go-wrong-if. Hence, iGMT can be expected to fail to produce useful maps under certain circumstances. Of course, the software is provided as is, no guarantee whatsoever is given and no responsibility for possible damage is taken.

Hopefully, iGMT demonstrates what can be done nowadays that great geophysical data sets and mapping software is available. If iGMT helps in making the research work of earth scientists easier, we are happy.

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# Appendix

# A Technical details

## A.1 Organization of the iGMT software

After unpacking the `igmt_v1.2.tar` file the directory should look something like this

```
> ls -F
COPYING             formatcpt.awk            igmt_helper_create_ci_file*
COPYRIGHT           igmt*                    igmt_helper_create_man_page*
INSTALL.TXT         igmt.tcl                 igmt_helper_handle_gmtdefaults*
NOTES.TXT           igmt_configure.tcl       igmt_helper_rmtmp_silent*
README.TXT          igmt_datasets.tcl        igmt_init.tcl
colminmax.awk       igmt_def.gif             igmt_iomisc.tcl
colormaps/          igmt_gmtdefaults_3.0     igmt_menus.tcl
configure_script*   igmt_gmtdefaults_3.1     igmt_parameters.tcl
example1.dat        igmt_gmtdefaults_3.2     igmt_plotting.tcl
example2.dat        igmt_gmtdefaults_3.3     img2grd*
example3.dat        igmt_gmtdefaults_3.4     sortwsm.awk
example4.dat        igmt_helper_checkfile*
```

where the `colormaps` directory contains the color tables for GMT.

```
> ls
bathymetry.cpt   col.11.cpt   col.23.cpt   col.35.cpt          sediment.2.cpt
col.00.cpt       col.12.cpt   col.24.cpt   col.36.cpt          sediment.cpt
col.01.cpt       col.13.cpt   col.25.cpt   col.37.cpt          tomo.cpt
col.02.cpt       col.14.cpt   col.26.cpt   col.th.1.cpt        tomo2.cpt*
col.03.cpt       col.15.cpt   col.27.cpt   colgeoid.cpt        topo.bw.cpt
col.04.cpt       col.16.cpt   col.28.cpt   geoid.cpt           topo.cpt
col.05.cpt       col.17.cpt   col.29.cpt   geoid2.cpt          topo1.cpt
col.06.cpt       col.18.cpt   col.30.cpt   geoid3.cpt          topo2.cpt
col.07.cpt       col.19.cpt   col.31.cpt   geoid5.cpt          topo3.cpt
col.08.cpt       col.20.cpt   col.32.cpt   gravity.cpt         topo4.cpt
col.09.cpt       col.21.cpt   col.33.cpt   seafloor_age.cpt
col.10.cpt       col.22.cpt   col.34.cpt   seafloor_age2.cpt
```

The files in this distribution can be classified as follows:

**Copyright:** `COPYING` and `COPYRIGHT` deal with legal issues. iGMT is distributed under the GNU public license but should be used in accordance with the Student Pugwash Pledge, see the file `COPYING`.

**configure_script:** This short script is supposed to take over the installation process as described in sec. 5.

**img2grd:** Script from the GMT distribution that is supposed to be a patch when `img2latlongrd` is not available, included starting from GMT 3.3.6.

**The `igmt` file:** A `bash` script that is used to check if the environment variable `$igmt_root` and `wish` is available at the places iGMT is looking. If all is fine, `wish` is invoked with `igmt.tcl`. `igmt_def.gif` is the start-up screen.

**Tcl files:** All files with the tcl extension contain the tcl code that runs iGMT. igmt.tcl is the main file, it contains source commands and builds up some frames. igmt_configure.tcl has all global variables and the default settings for plotting whereas igmt_init.tcl handles the startup sequence. The file igmt_menu.tcl holds the definition for the main menu line and the procedures found in igmt_datasets.tcl, igmt_parameters.tcl and igmt_plotting.tcl correspond roughly to all possible actions in the individual pull-down menus. Finally, igmt_iomisc.tcl contains most of the input/output routines and some additional tcl procedures.

All of these files should be fairly well commented so that we won't go into any detail here.

igmt_helper_ **files** These contain small bash scripts that are called by iGMT' tcl routines and handle more operating system based processes. Most of them could be integrated into the main tcl code but it seemed more transparent for possible porting to other operating systems to keep them external.

example.dat **and** .ps**:** The dat files contain the parameter dump that was created with iGMT after the examples presented in section 8 were produced. The postscript files are packed with gzip and correspond to the shrinked figures in this manual and are not identical to the real postscript files produced (they were too big to be included in the distribution).

**Documentation and data** The file manual.ps is the manual you are reading as a postscript file. nuvel.yx is the modified plate boundary polygon file after DeMets et al. (1990), 01_02-98.cmt contains the Harvard CMT double couple fault plane solution for the first 60 days of 1998 as an example, vocanoes.dat the volcano locations after Simkin and Siebert (1994), allslabs_rum.gmt the slab seismicity contours of Gudmundsson and Sambridge (1998) and hotspots.dat the hotspot list of Steinberger (2000).

**Colormaps:** The colormaps directory contains the colormaps that are used by iGMT to map the default datasets. col.00.cpt through col.35.cpt are generic colormaps which span the data range from $-1\ldots1$. If you want to convert these colormaps to suit your data, use an awk script like colminmax.awk which comes with the iGMT distribution.

```
# script to convert the data range of colorscale files for GMT
# by rescaling
BEGIN{
  if(min==0)min=-1.;
  if(max==0)max=1.;
  mean=(max+min)/2.;
  range=(max-min)/2.;
  printevery=50;
}
{
  if(NR<256){
    if(printevery - NR > 0)
      print($1*range+mean,$2,$3,$4,$5*range+mean,$6,$7,$8,$9);
    else {
      print($1*range+mean,$2,$3,$4,$5*range+mean,$6,$7,$8,$9,"L");
      printevery=NR+printevery;
    }
  }
  else
```

```
    print($0);

}
```

If your data sets contains values between $-2$ and 3, say, and you would like to use the rainbow colored colorscale `col.13.cpt`, use

```
awk-f$igmt_root/colminmax.awkmin=-2max=3\ldots\\$igmt_root/colormaps/col.13.cpt>
new_colormap.cpt.
```

Here, "..." means that the above should be in one line.

Also, you might want to use the `grd2cpt` function of GMT that can be accessed over `createcolormap` menu item.

# B Modifying iGMT

iGMT may be freely modified and distributed as long as modified versions are not called iGMT. There are plenty of easy possible future enhancements one could think of, for instance interactive design of colormaps, support of more complicated user data sets and multiple layers of raster data. When this extensions become available, they will be included in future versions. Some common modification (as opposed to extension or enhancement) tasks are described below:

**Using other path names for the data sets.** All pathnames to data locations are assigned in `igmt_configure.tcl`. All raster data sets have two variables assigned to them: `raster_data(i)` and `raster_colormap(i)`, they refer to the location of the raster data set number `i` and the location of the default colormap, respectively. Simply add a line like `setraster_data(3)"/home/user/gtopo30/topo_6.2.img"` to your `igmt_siteconfig.tcl` file, if your GTOPO30 dataset (number 3 internally) is in `/home/user/gtopo30/`. The equivalent variables for polygon data are called `poly_data(i)`, and it is simplest to search for the appropriated variable names in `igmt_configure.tcl`.

**Including new data sets.** You will have to do these things: (**to be expanded**)

1. Add the data location and its parameters to the `igmt_configure.tcl` file.

   This should be easier now with version 1.2 since we have replaced most global variables for raster and polygon data issues with arrays, such that you can simply add one more entry at the back. Right now, raster data sets are reserved from 1 to 11, with the limit being set to (variable: `nr_of_raster_data`) 20 raster data sets in total. Polygon data sets are restricted to 25, and right now all sets up to 20 are filled. Read through `igmt_configure.tcl` to see how the default data sets are implemented here.

   Parameters for raster data are: location of data file, default colormap, geographical limits (East, West, South, and North boundaries), integer boundaries only (on/off), the maximum resolution (in arc minutes), and resampling at other than default grid spacing (on/off). For polygon data: location of data, symbol size, symbol color, ...

2. Add the data selection choice to the `Datasets` menus. This is done in `igmt_menues.tcl` and `igmt_datasets.tcl`.

3. Add the data plotting routine to `igmt_plotting.tcl`, taking the old datasets as an example. Make use of the predefined standard procedures for raster data.