M_Map: User's Guide v1.4

1. Getting started

First, get all the files, either as a zip archive or a gzipped tar-file and unpack them. If you are unpacking the zip file MAKE SURE YOU ALSO UNPACK SUBDIRECTORIES! Now, start up Matlab (version 5 or higher). Make sure that the toolbox is in your path. This can be done simply by `cd`'ing to the correct directory.

Alternatively, if you have unpacked them into directory `/users/rich/m_map` (and `/users/rich/m_map/private`), then you can add this to your search path:

```
path(path,'/users/rich/m_map');
```

or

```
addpath /users/rich/m_map
```

To follow along with this document, you would then use a Web-browser to open `file:/users/rich/m_map/map.html`, that is, this HTML document.

Note: you may want to install M_Map as a toolbox accessible to all users. To do this, unpack the files into $MATLAB/toolbox/m_map, add that directory to the list defined in $MATLAB/toolbox/local/pathdef.m, and update the cache file using

```
rehash toolboxcache
```

Instructions for installing the (optional) high-resolution bathymetry database are given in Section 9 , and instructions for installing the (optional) high-resolution GSHHS coastline database is given in Section 10 . However, we should first check that the basic setup is OK.

To see an example map, try this:

```
m_proj('oblique mercator');
m_coast;
m_grid;
```

This is a line map of the Oregon/British Columbia coast, using an Oblique Mercator projection (A few more complex maps can be generated by running the demo function `m_demo`).

The first line initializes the projection. Defaults are set for the different projection, so you can easily see what a specific projection looks like, but all projections have a number of optional parameters as well. To get the same map without using the defaults, you would use

```
m_proj('oblique mercator','longitudes',[-132 -125], ...
       'latitudes',[56 40],'direction','vertical','aspect',.5);
```

The exact meanings of the various options is given in Section 2 . However, notice that longitudes are specified using a *signed* notation - East longitudes are positive, whereas West longitudes are negative (Also note that a decimal degree notation is used, so that a longitude of 120 30'W is specified as -120.5).

The second line draws a coastline, using the 1/4 degree database. Coastlines with greater resolution can be drawn, using your own database (see also Section 7). `m_coast` can be called with various line parameters. For example,

```
m_coast('linewidth',2,'color','r');
```

draws a thicker red coastline. Filled coastlines can also be drawn, using the `'patch'` option (followed by any of the usual PATCH property/value pairs).

```
m_coast('patch',[.7 .7 .7],'edgecolor','none');
```

draws a coastline with a gray fill and no border.

The third line superimposes a grid. Although there are many possible options that can be used to customize the appearance of the grid, defaults can always be used (as in the example). These options are discussed in Section 4 . You can get a list of the options using the GET syntax:

```
m_grid get
```

which acts somewhat like the `get(gca)` syntax for regular plots.

Finally, suppose you want to show and label the location of, say, a mooring at 129W, 48 30'N.

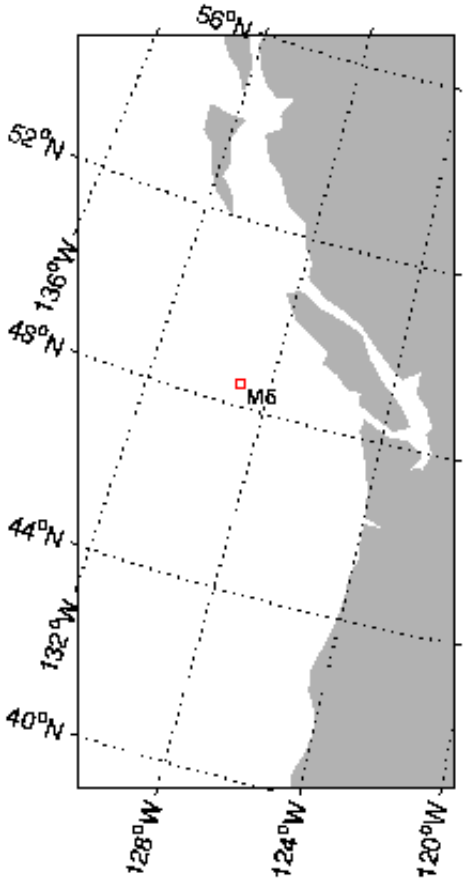
```
[X,Y]=m_ll2xy(-129,48.5);
line(X,Y,'marker','square','markersize',4,'color','r');
text(X,Y,' M5','vertical','top');
```

`m_ll2xy` (and its inverse `m_xy2ll`) convert from longitude/latitude coordinates to those of the projection. Various clipping options can also be specified in converting to projection coordinates. If you are willing to accept default clipping setting, you can use the built-in functions `m_line` and `m_text` :

```
m_line(-129,48.5,'marker','square','markersize',4,'color','r');
m_text(-129,48.5,' M5','vertical','top');
```

Finally (!), we may want to alter the grid details slightly. Note that, a given map must only be initialized once.

```
clf
m_coast('patch',[.7 .7 .7],'edgecolor','none');
m_grid('xlabeldir','end','fontsize',10);
m_line(-129,48.5,'marker','square','markersize',4,'color','r');
m_text(-129,48.5,' M5','vertical','top');
```



---

2. Specifying projections

In order to get a list of the current projections,

```
m_proj get
```

or

```
m_proj('set');
```

Which currently return the following list:

```
Available projections are:
     Stereographic
     Orthographic
     Azimuthal Equal-area
     Azimuthal Equidistant
     Gnomonic
     Satellite
     Albers Equal-Area Conic
     Lambert Conformal Conic
     Mercator
     Miller Cylindrical
     Equidistant Cylindrical
     Oblique Mercator
     Transverse Mercator
     Sinusoidal
     Gall-Peters
     Hammer-Aitoff
     Mollweide
```

```
   Robinson
  UTM
```

If you want details about the possible options for any of these projections, add its name to the above command, e.g.

```
m_proj('set','stereographic');
     'Stereographic'
     <,'lon<gitude>',center_long>
     <,'lat<itude>', center_lat>
     <,'rad<ius>', ( degrees | [longitude latitude] )>
     <,'rec<tbox>', ( 'on' | 'off' )>
```

You can also get details about the current projection. For example, in order to see what the default parameters are for the sinusoidal projection, we first initialize it, and then use the `'set'` option:

```
m_proj('sinusoidal');
m_proj get
Current mapping parameters -
 Projection: Sinusoidal  (function: mp_tmerc)
 longitudes: -90  30 (centered at -30)
 latitudes: -65  65
 Rectangular border: off
```

In order to initialize a projection, you usually specify some location parameters that define the geometry of the projection (longitudinal limits, central parallel, etc.), as well as parameters that define the extent of the map (whether it is in a rectangular axis, what the border points are, etc.). These vary slightly from projection to projection.

Two useful properties for projections are (1) the ability the preserve angles for differentially small regions, and (2) the ability to preserve area. Projections satisfying the first condition are called *conformal* , those satisfying the second are called *equal-area* . No projection can be both. Many projections (especially global projections) are neither, instead an attempt has been made to aesthetically balance the errors in both conditions.

Note: Most projections are currently *spherical* rather than ellipsoidal. UTM is an ellipsoidal projection, and both the lambert conformal conic and albers equal-area conic can be specified with ellipses if desired. This is sometime useful when you have data (e.g. from a GIS package) at scales of Canadian provinces or US states, which are often mapped using one of these projections. It is unlikely that this will be a problem in normal usage.

1. Azimuthal projections

Azimuthal projections are those in which points on the globe are projected onto a flat tangent plane. Maps using these projections have the property that direction or azimuth from the center point to all other points is shown correctly. Great circle routes passing through the central point appear as straight lines (although great circles not passing through the central point may appear curved). These maps are usually drawn with circular boundaries. The following parameters are needed to define an azimuthal projection:

```
<,'lon<gitude>',center_long>
<,'lat<itude>', center_lat>
```

These parameters define the center point of the map. Maps are aligned so that the specified

longitude is vertical at the map center, with its northern end at the top (but see option `rotangle` below).

`<,'rad<ius>', ( degrees | [longitude latitude] )>`

This defines the extent of the map. Either an angular distance in degrees can be given (e.g. 90 for a hemisphere), or the coordinates of a point on the boundary can be specified.

`<,'rec<tbox>', ( 'on' | 'off' | 'circle' )>`

The default is to enclose the map in a circular boundary (chosen using either of the latter two options), but a rectangular one can also be specified. However, rectangular maps are usually better drawn using a cylindrical or conic projection of some sort.

`<,'rot<angle>', degrees CCW>`

This rotates the figure so that the central longitude is not vertical.

1. **Stereographic**

   The stereographic projection is conformal, but not equal-area. This projection is often used for polar regions.

2. **Orthographic**

   This projection is neither equal-area nor conformal, but resembles a perspective view of the globe.

3. **Azimuthal Equal-Area**

   Sometimes called the Lambert azimuthal equal-area projection, this mapping is equal-area but not conformal.

4. **Azimuthal Equidistant**

   This projection is neither equal-area nor conformal, but all distances and directions from the central point are true.

5. **Gnomonic**

   This projection is neither equal-area nor conformal, but all straight lines on the map (not just those through the center) are great circle routes. There is, however, a great degree of distortion at the edges of the map, so maximum radii should be kept fairly small - 20 or 30 degrees at most.

6. **Satellite**

   This is a perspective view of the earth, as seen by a satellite at a specified altitude. Instead of

specifying a `radius` for the map, the viewpoint altitude is specified:

```
<,'alt<itude>', altitude_fraction >
```

the numerical value assigned to this property represents the height of the viewpoint in units of earth radii. For example, a satellite in an orbit of radius 3 earth radii would have an altitude of 2.

2. Cylindrical and Pseudo-cylindrical Projections

Cylindrical projections are formed by projecting points onto a plane wrapped around the globe, touching only along some great circle. These are very useful projections for showing regions of great lateral extent, and are also commonly used for global maps of mid-latitude regions only. Also included here are two pseudo-cylindrical projections, the sinusoidal and Gall-Peters, which have some similarities to the cylindrical projections (see below).

These maps are usually drawn with rectangular boundaries (with the exception of the sinusoidal and sometimes the transverse mercator).

1. Mercator

This is a conformal map, based on a tangent cylinder wrapped around the equator. Straight lines on this projection are rhumb lines (i.e. the track followed by a course of constant bearing). The following properties affect this projection:

```
<,'lon<gitude>',( [min max] | center)>
```

Either longitude limits can be set, or a central longitude defined implying a global map.

```
<,'lat<itude>', ( maxlat | [min max])>
```

Latitude limits are most usually the same in both N and S latitude, and can be specified with a single value, but (if desired) unequal limits can also be used.

2. Miller Cylindrical

This projection is neither equal-area nor conformal, but "looks nice" for world maps. Properties are the same as for the Mercator, above.

3. Equidistant cylindrical

This projection is neither equal-area nor conformal. It consists of equally-spaced latitude and longitude lines, and is very often used for quick plotting of data. It is included here simply so that such maps can take advantage of the grid generation routines. Also known as the Plate Carree. Properties are the same as for the Mercator, above.

4. Oblique Mercator

The oblique mercator arises when the great circle of tangency is arbitrary. This is a useful projection for, e.g., long coastlines or other awkwardly shaped or aligned regions. It is conformal but not equal area. The following properties govern this projection:

```
<,'lon<gitude>',[ G1 G2 ]>
<,'lat<itude>', [ L1 L2 ]>
```

Two points specify a great circle, and thus the limits of this map (it is assumed that the region near the shortest of the two arcs is desired). The 2 points (G1,L1) and (G2,L2) are thus at the center of either the top/bottom or left/right sides of the map (depending on the `'direction'` property).

```
<,'asp<ect>',value>
```

This specifies the size of the map in the direction perpendicular to the great circle of tangency, as a proportion of the length shown. An aspect ratio of 1 results in a square map, smaller numbers result in skinnier maps. Aspect ratios >1 are possible, but not recommended.

```
<,'dir<ection>',( 'horizontal' | 'vertical' )
```

This specifies whether the great circle of tangency will be horizontal on the page (for making short wide maps), or vertical (for tall thin maps).

5. Transverse Mercator

The Transverse Mercator is a special case of the oblique mercator when the great circle of tangency lies along a meridian of longitude, and is therefore conformal. It is often used for large-scale maps and charts. The following properties govern this projection:

```
<,'lon<gitude>',[min max]>
<,'lat<itude>',[min max]>
```

These specify the limits of the map.

```
<,'clo<ngitude>',value>
```

Although it makes most sense in general to specify the central meridian as the meridian of tangency (this is the default), certain map classification systems (noteably UTM) use only a fixed set of central longitudes, which may not be in the map center.

```
<,'rec<tbox>', ( 'on' | 'off' )>
```

The map limits can either be based on latitude/longitude (the default), or the map boundaries can form an exact rectangle. The difference is small for large-scale maps. Note: Although this projection is similar to the Universal Transverse Mercator (UTM) projection, the latter is actually ellipsoidal in nature.

6. Universal Transverse Mercator (UTM)

UTM maps are needed only for high-quality maps of small regions of the globe (less than a few degrees in longitude). This is an ellipsoidal projection. Options are similar to those of the Transverse Mercator, with the addition of

```
<,'zon<e>', value 1-60>
```

```
<,'hem<isphere>',value 0=N,1=S>
```

These are computed automatically if not specified. The ellipsoid defaults to `'normal'`, a spherical earth of radius 1 unit, but other options can also be chosen using the following property:

```
<,'ell<ipsoid>', ellipsoid>
```

For a list of available ellipsoids try `m_proj('set','utm')`.

The big difference between UTM and all the other projections is that for ellipsoids other than `'normal'` the projection coordinates are in meters of easting and northing. To take full advantage of this it is often useful to call `m_proj` with `'rectbox'` set to `'on'` and not to use the long/lat grid generated by `m_grid` (since the regular matlab grid will be in units of meters).

7. Sinusoidal

This projection is usually called "pseudo-cylindrical" since parallels of latitude appear as straight lines, similar to their appearance in cylindrical projections tangent to the equator. However, meridians curve together in this projection in a sinusoidal way (hence the name), making this map equal-area.

8. Gall-Peters

Parallels of latitude and meridians both appear as straight lines, but the vertical scale is distorted so that area is preserved. This is useful for tropical areas, but the distortion in polar areas is extreme.

3. Conic Projections

Conic projections result from projecting onto a cone wrapped around the sphere. The vertex of the cone lies on the rotational axis of the sphere. The cone is either tangent at a single latitude, or can intersect the sphere at two separated latitudes. It is a useful projection for mid-latitude areas of large east-west extent. The following properties affect these projections:

```
<,'lon<gitude>',[min max]>
<,'lat<itude>',[min max]>
```

These specify the limits of the map.

```
<,'clo<ngitude>',value>
```

The central longitude appears as a vertical on the page. The default value is the mean longitude,

although it may be set to any value (even one outside the limits).

<,'par<allels>',[lat1 lat2]>

The standard parallels can be specified. Either one or two parallels can be given, the default is a single parallel at the mean latitude

<,'rec<tbox>', ('on' | 'off')>

The map limits can either be based on latitude/longitude (the default), or the map boundaries can form an exact rectangle which contain the given limits. Unless the region being mapped is small, it is best to leave this `'off'` .

The default is to use a spherical earth model for the mapping transformations. However, ellipsoidal coordinates can also be specified. This tends to be useful only for doing coordinate transformations (e.g., if a particular gridded database in in this kind of projection, and you want to find lat/long data), since the difference would be impossible to see by eye on a plot. The particular ellipsoid used can be chosen using the following property:

<,'ell<ipsoid>', ellipsoid>

For a list of available ellipsoids try `m_proj('set','albers')`.

1. **Albers Equal-Area Conic**

   This projection is equal-area, but not conformal

2. **Lambert Conformal Conic**

   This projection is conformal, but not equal-area.

4. Miscellaneous global projections

There are a number of projections which don't really fit into any of the above categories. Mostly these are global projections (i.e. they show the whole world), and they have been designed to be "pleasing to the eye". I'm not sure what use they are in general, but they make nice logos!

1. **Hammer-Aitoff**

   An equal-area projection with curved meridians and parallels.

2. **Mollweide**

   Also called the Elliptical or Homolographic Equal-Area Projection. Parallels are straight (and parallel) in this projection. Note that example 4 shows a rather sophisticated use designed to reduce distortion, a more standard map can be made using

   ```
   m_proj('mollweide');
   m_coast('patch','r');
   ```

```
m_grid('xaxislocation','middle');
```

3. Robinson

Not equal-area OR conformal, but supposedly "pleasing to the eye".

5. Yeah, but which projection should I use?

Well, it depends really on how large an area you are mapping. Usually, maps of the whole world are Mercator, although often the Miller Cylindrical projection looks better because it doesn't emphasize the polar areas as much. Another choice is the Hammer-Aitoff or Mollweide (which has meridians curving together near the poles). Both are equal-area. It's probably not a good idea to use these projections for maps that don't have the equator somewhere near the middle. The Robinson projection is not equal-area or conformal, but was the choice of National Geographic (for a while, anyway), and also appears in the IPCC reports.

If you are plotting something with a large north/south extent, but not very wide (say, North and South America, or the North and South Atlantic), then the Sinusoidal or Mollweide projections will look pretty good. Another choice is the Transverse Mercator, although that is usually used only for very large-scale maps.

For smaller areas within one hemisphere or other (say, Australia, the United States, the Mediterranean, the North Atlantic) you might pick a conic projection. The differences between the two available conic projections are subtle, and if you don't know much about projections it probably won't make much difference which one you use.

If you get smaller than that, it doesn't matter a whole lot which projection you use. One projection I find useful in many cases is the Oblique Mercator, since you can align it along a long (but narrow) coastal area. If map limits along lines of longitude/latitude are OK, use a Transverse Mercator or Conic Projection. The UTM projection is also useful.

Polar areas are traditionally mapped using a Stereographic projection, since for some reason it looks nice to have a "bullseye" pattern of latitude lines.

If you want to get a quick idea of what any projection looks like, default parameters for all functions are set for a "typical" usage, i.e. to get a quick idea of what any projection looks like, you can do so without having to figure out a lot of numerical values:

```
m_proj('stereographic');  % Example for stereographic projection
m_coast;
m_grid;
```

6. Map scales

M_Map usually scales the map so that it fits exactly within the current axes. If you just want a nice picture (which is mostly the case) then this is exactly what you need. On the other hand, sometimes you want to print things out at some exact scale (i.e. if you really much prefer sitting at your desk with a ruler and a piece of paper trying to figure out how far apart Bangkok and Tokyo are). Use the `m_scale` primitive for this - for a 1:250000 map, call

```
m_scale(250000);
```

after you have drawn everything (Be careful - a 1:250000 map of the world is a lot bigger than 8.5"x11" sheet of paper).

This option is usually only useful for large-scale maps, i.e. maps of very small areas).

If you wish to know the current scale, calling `m_scale` without any parameters will calculate and return that value.

To return to the default scaling call `m_scale('auto')`.

(PS - If you do want to find distances from Bangkok to anywhere, plot an azimuthal equidistant projection of the world centered on Bangkok (13 44'N, 100 30'E), and choose a fairly small scale, like 1:200,000,000). Another option would be to use range rings, see example 11.

7. Map coordinate systems - geographic and geomagnetic.

Latitude/Longitude is the usual coordinate system for maps. In some cases UTM coords are also used, but these are really just a simple transformation based on the location of the equator and certain lines of longitude. On the other hand, there are occasions when a coordinate system based on some other set of axes is useful. For example, in space physics data is often projected in coordinates based on the magnetic poles. M_Map has a limited capabality to deal with data in these other coordinate systems. m_coord allows you to chnage the coordinate system from geographic to geomagnetic. The following code gives you the idea:

```
 lat=[25*ones(1,100) 50*ones(1,100) 25];
lon=[-99:0 0:-1:-99 -99];

clf
subplot(121);
m_coord('IGRF2000-geomagnetic'); % Treat all lat/longs as geomagnetic
m_proj('stereographic');
m_coast;
m_grid;
m_line(lon,lat,'color','r');     % "lat/ln" assumed geomagnetic on the geomagnetic map
m_coord('geographic');           % Switch to assuming geographic
m_line(lon,lat,'color','c');     % Now they are treated as geographic

subplot(122);
m_coord('geographic');           % Define all in geographic
m_proj('stereographic');
m_coast;
m_grid;
m_line(lon,lat,'color','c');
m_coord('IGRF2000-geomagnetic'); % Now assume that values are in geomagnetic
m_line(lon,lat,'color','r');
```

Note that this option is not used very much, hence is not fully supported. In particular, filled coastlines may not work properly.

---

3. Coastlines and Bathymetry

M_Map includes two fairly simple databases for coastlines and global elevation data. Highly-detailed databases are not included in this release because they are a) extremely large and b) extremely time-consuming to process (loops are inherently involved). If more detailed maps are required, section 9 and section 10 give instructions on how to add some freely-available high-resolution datasets. Read section 7 and section 8 if you want to add your own coastline/bathymetry data.

1. Coastline options

M_Map includes a 1/4 degree resolution coastline database. This is suitable for maps covering large portions of the globe, but is noticeably coarse for many large-scale applications. Users not satisfied with their regional map are directed to section 7 and/or section 10 for more information on creating and using high-resolution coastlines. The M_Map database is accessed using the `m_coast` function. Coastlines can be drawn as simple lines, using

```
m_coast('line', ...optional line arguments );
```

or

```
m_coast( optional line arguments );
```

where the optional arguments are all the standard arguments for specifying line style, width, color, etc. Coastlines can also be drawn as filled patches using

```
m_coast('patch', ...optional patch arguments );
```

where the optional trailing arguments are the standard patch properties. For example,

```
m_coast('patch',[.7 .7 .7],'edgecolor','g');
```

draws gray land, outlined in green. When patches are being drawn, lakes and inland seas are given the axes background colour.

Many older (ocean) maps are created with speckled land boundaries, which looks very nice in black and white. You can get a speckled boundary with

```
m_coast('speckle', ....optional m_hatch arguments);
```

which calls `m_hatch`. This only looks nice if there aren't too many very tiny islands and/or lakes in the image (see Example 13).

Note that line coastlines are usually drawn rather rapidly. Filled coastlines take considerably more time to generate (because map limits are not necessarily rectangular, clipping must be accomplished in m-files).

2. Topography/Bathymetry options

M_Map can access a 1-degree resolution global elevation database (actually, this database is is included in the Matlab distribution, used by of `$MATLAB/toolbox/matlab/demos/earthmap.m`). A contour map of elevations at default levels can be drawn using

```
m_elev;
```

Different levels can also be specified:

```
m_elev('contour',LEVELS, optional contour arguments);
```

For example, if you want all the contours to be dark blue, use:

```
m_elev('contour',LEVELS,'edgecolor','b');
```

Filled contours are also possible:

```
m_elev('contourf',LEVELS, optional contourf arguments);
```

Finally, if you want to simply extract the elevation data for your own purposes,

```
[Z,LONG,LAT]=m_elev([LONG_MIN LONG_MAX LAT_MIN LAT_MAX]);
```

returns rectangular matrices for depths Z at locations LONG,LAT.

---

4. Customizing axes

1. Grid lines and labels

In order to get the perfect grid, you may want to experiment with different grid options. Two functions are useful here, M_GRID which draws a grid, and M_UNGRID which erases the current grid (but leaves all coastlines and user-specified data alone). Try

```
m_proj('Lambert');
m_coast;
m_grid;
```

to get a Lambert conic projection of North America. Now try

```
m_ungrid
```

The coastline is still there, but the grid has disappeared and the axes shows raw X/Y projection coordinates. Now, try this:

```
m_grid('xtick',10,'tickdir','out','yaxislocation','right','fontsize',7);
```

The various options that can be changed are:

`'box',( 'on' | 'off' | 'fancy' )`

This specifies whether or not an outline box is drawn. Three types of outline boxes are available: `'on'`, the default, is a a simple line. Two types of fancy outline boxes are available. If `'tickdir'` is `'in'`, then alternating black and white patches are made (see example 2). If `'tickdir'` is set to `'out'`, then a more complex line pattern is drawn (see example 6). Fancy boxes are in general only available for maps bounded by lat/long limits (i.e. not for azimuthal projections), but if this option is chosen inappropriately a warning message is issued.

`'xtick',( num | [value1 value2 ...])`

This specifies the number/location of the longitude grid. If a single number is specified, grid lines/values are drawn for approximately that number of equally-spaced locations (the number is only approximate because the M_GRID attempts to find "nice" intervals, i.e. it rounds to even increments). Exact locations can be specified by using a vector of location values. There is an analagous `'ytick'` property.

`'xticklabels',[label1;label2 ...]`

Special labels can be specified. Labels can either be numerical values (which are then formatted by M_GRID), or string values which are used without change. There is an analagous `'yticklabels'` property

`'xlabeldir', ( 'middle' | 'end' )`

Longitude labels are either middled onto the ends of their prespective grid lines (and drawn perpendicular to those lines), or are drawn extending outwards fro the ends of those lines. There is an analagous `'ylabeldir'` property.

`'ticklen',value`

Specifies the length of tickmarks (as a fraction of plot width)

`'tickdir',( 'in' | 'out' )`

Specifies whether tickmarks point inwards or outwards. If `'box'` is set to `'fancy'`, this specifies the form of the fancy outline box.

`'tickstyle',( 'dd' | 'dm' )`

Specified whether axis labels are in decimal degrees (dd) or degrees-minutes (dm, default).

```
'color',colorspec
'linewidth', value
'linestyle', ( linespec | 'none' )
'fontsize',value
'fontname',name
```

Specify various line/text properties for the grid and its labels.

`'XaxisLocation',( 'bottom' | 'middle' | 'top' )`

Specifies where the X-axis will be drawn, either at the bottom (southermost) end, at the top (northernmost) end, or in the middle.

`'YaxisLocation',( 'left' | 'middle' | 'right' )`

Specifies where the Y-axis will be drawn, either at the left (westernmostmost) end, at the right (easternmost) end, or in the middle.

2. Titles and x/ylabels

Titles and x/ylabels can be added to maps using the `title` and `x/ylabel` functions in the usual way (this is a change from v1.0 in which the 'visible' property had to be explicitly set to 'on'; this is now done within m_grid).

3. Legend Boxes

A legend box can be added to the map using `m_legend`. Only some of the functionality of `legend` is currently included. The legend box can be dragged and dropped using the mouse button.

4. Scale Bars

A scale bar can be added to the map using `m_ruler`. The bar is drawn horizontally or vertically, and will create a 'nice' number of ticks (although this can be changed with another calling parameter). The location is specified in normalized coordinates (i.e. between 0 and 1) so you can adjust placement on the map. It is probably best to call this AFTER calling `m_grid` since `m_grid` resets the normalization.

WARNING - the scalebar is probably not useful for any global (i.e. whole-world) or even a significant-part-of-the-globe map, but I won't stop you using it. Caveat user!

---

5. Adding your own data

The purpose of this package is to allow you to map your own data! Once a suitable grid and (possibly) a coastline have been chosen, you can add your own lines, text, or contour plots using built-in M_Map drawing functions which handle the conversion from longitude/latitude coordinates to projection coordinates. These drawing functions are very similar to the standard Matlab plotting functions, and are described in the next section.

Sometimes you may want to convert between longitude/latitude and projection coordinates without immediately plotting the data. This might happen if you want to interactively select points using `ginput`, or if you want to draw labels tied to a specific point on the screen rather than a particular longitude/latitude. Projection conversion routines are described in sections 5.2 and 5.3. Once raw longitude/latitude coordinates are converted into projection coordinates, standard Matlab plotting functions can be used.

Maps are drawn to fit within the boundaries of the plot axes. Thus their scale is somewhat arbitrary. If you are interested in making a map to a given scale, e.g. 1:200000 or something like that, you can do so by using the `m_scale` primitive, see section 2.6 . The data units are the projection coordinates, which are distances expressed as a fraction of earth radii. To get a map "distance" between two points, use the Cartesian distance between the points in the projection coordinate system and multiply by your favourite value for the earth's radius, usually around 6370 km (exception - the UTM projection uses coordinates of northing and easting in meters, so no conversion is necessary).

Caution: One problem that sometimes occurs is that data does not appear on the plot due to ambiguities in longitude values. For example, if plot longitude limits are [-180 180], a point with a longitude of, say, 200, may not appear in cylindrical and conic projections. This is not a bug. Handling the clipping in

"wrapped around" curves requires adding points (rather than just moving them) and is therefore incompatible with various other requirements (such as keeping input and output matrices the same size in the conversion routines described below).

1. Drawing lines, text, arrows, patches, hatches, speckles and contours

For most purposes you do not need to know what the projection coordinates actually are - you just want to plot something at a specified longitude/latitude. Most of the time you when you want to plot something on a map you want to do so by specifying longitude/latitude coordinates, instead of the usual X/Y locations. To do so in M_Map, replace calls to `plot, line, text, quiver, patch, contour, and contourf` with M_Map equivalents that recognize lontgitude/latitude coordinates by prepending "m_" to the function name. For example,

```
m_plot(LONG,LAT,...line properties)   % draw a line on a map (erase current plot)
m_line(LONG,LAT,...line properties)   % draw a line on a map
m_quiver(LONG,LAT,U,V,S)              % A quiver plot
m_text(LONG,LAT,'string')             % Text
m_patch(LONG,LAT,..patch properties)  % Patches.
```

Each of these functions will handle the coordinate conversion internally, and will return a vector of handles to the graphic objects if desired. The only difference between these functions and the standard Matlab functions is that the first two arguments MUST be longitude and latitude.

One caveat applies to `m_patch`. For compatibility reasons this uses the same code that applies to coastline filling. Coastlines come either as either "islands" or "lakes", and M_Map keeps track of the difference by assuming curves are oriented so that the filled area ("land") is always on the right as we go around the curve. This is slightly different than the convention used in `patch` which always fills the inside. Keeping track of this difference is relatively straightforward in a Cartesian system, but not so easy in spherical coordinates. In the absence of other information `m_patch` tries to do the right thing, but (especially when the patch intersects a map boundary) it can get confused. If a patch isn't filling correctly, try reversing the order of points using `flipud` or `fliplr`.

Data gridded in longitude and latitude can also be contoured:

```
m_contour(LONG,LAT,VALUES)
m_contourf(LONG,LAT,VALUES)
```

Again, these functions will return handles to graphics objects, allowing (for example) the drawing of labelled contours:

```
[cs,h]=m_contour(LONG,LAT,VALUES)
clabel(cs,h,'fontsize',6);
```

Fancy arrows (i.e. with width, head shape, and colour specifications) can be generated using `m_vec.m` . See the on-line help for more details about the use of `m_vec`.

You can also get hatched areas by calling `m_hatch`:

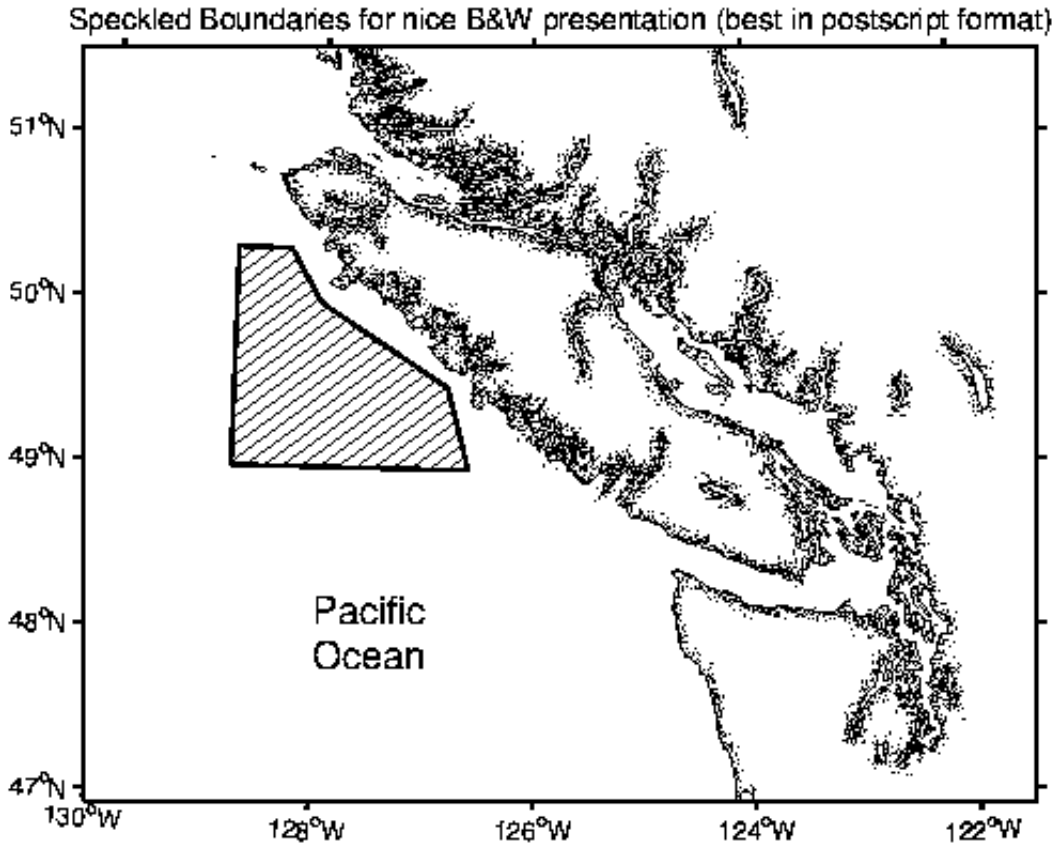
```
m_hatch('single',LONG,LAT,...hatch properties)    % Interior Single Hatches.
m_hatch('cross',LONG,LAT,...hatch properties)     % Interior Crossed Hatches.
```

Note that this call does not generate the edge lines (an additional `m_line` is required for this. In

addition, we can speckle the inside edges of patches using:

```
m_hatch('speckle',LONG,LAT,...speckle properties)  % Speckled edges.
```

See the on-line help and/or Example 13 for more details about using `m_hatch`.



2. Drawing images and p_color

`m_pcolor` is a drop-in replacement for `p_color`, but you must be careful with its use near map boundaries. Ideally one would want data to extend up to (but not across) a map boundary (i.e. polygons are clipped). However, due to the way in which matlab handles surfaces this is not easily done. Instead - unless you are using a simple cylindrical or conic projection - you will probably get a ragged edge for the coloured surface.

There is no `m_image`. the `image()` function plots data in rectangular pixels only, and in general projected data will NOT appear as rectangular pixels. If you want to display a large pixel image on your map, there are several options:

1. If your georeferenced image is in lat/long coordinates (i.e. each data row is along a line of constant latitude, each column a line of equal longitude), then you can use `m_pcolor` with `shading flat`. This is reasonably satisfactory (although it can be slow for large images), but you MUST remember to offset your coordinates by one-half of the pixel spacing. This is because of the different behaviors of `p_color` and `image` when given the same data.
    1. `image` will center the drawn (i,j) pixel on the (i,j)th entry of the X/Y matrices.
    2. `p_color` with shading flat will draw a panel between the (i,j),(i+1,j),(i+1,j+1),(i,j+1) coordinates of the X/Y matrices with a color corresponding to the data value at (i,j).

Thus everything will appear shifted by one half a pixel spacing.

Satellite data from mid-latitudes is sometime amenable to this solution. See the examples of satellite data manipulation.

2. If your figure has already been placed in some projection, and if you know the exact parameters of that projection, you can probably use a straight image call and then overplot an M_Map map. For example, polar satellite images are often in a polar stereographic projection. In this case you should use m_ll2xy to get the screen coordinates of the image corners, then use those points in an image() call before overplotting your data. See in particular This example .

   HINT - check to see that coastlines overplot to make sure this is working correctly.

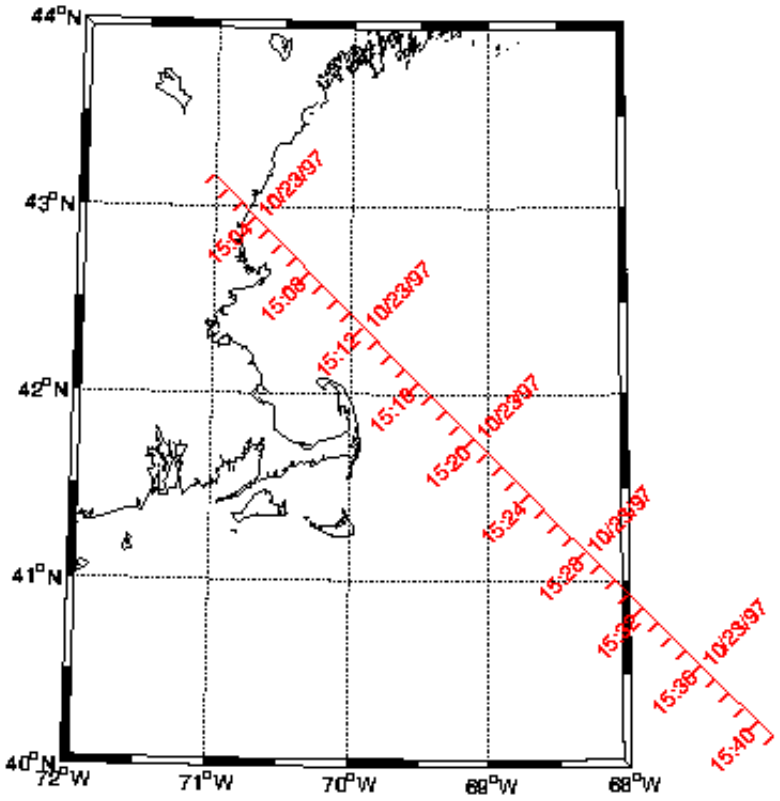
3. Drawing tracklines

It is sometimes useful to annotate lines representing the time-varying location of a ship, aircraft, or satellite with time and date annotations. This can be done using `m_track`.

```
m_proj('UTM','long',[-72 -68],'lat',[40 44]);
m_gshhs_i('color','k');
m_grid('box','fancy','tickdir','out');

% fake up a trackline
lons=[-71:.1:-67];
lats=60*cos((lons+115)*pi/180);
dates=datenum(1997,10,23,15,1:41,zeros(1,41));

m_track(lons,lats,dates,'ticks',0,'times',4,'dates',8,...
        'clip','off','color','r','orient','upright');
```



See the on-line help for more details about the use of `m_track`, and the different options for setting fontsize, tick spacing, date formats, etc.

While fiddling with the various parameters, it is often handy to be able to erase the plotted tracks without erasing the coastline and grid. This can be done using

```
m_ungrid track
```

or

```
m_ungrid('track')
```

4. Drawing range rings and geodesics

One nifty thing that is sometimes useful is the ability to draw circles at a given range or ranges from a specific location. This can be done using `m_range_ring`, which has 3 required calling parameters: LONG, LAT, RANGE, followed by any number of (optional) line specification property/value pairs. Example 11 illustrates how to use `m_range_ring`.

If you want to plot circular geodesics (i.e. curves which are perpedicular to the range rings at all ranges), `m_lldist` can find both distances and points along the geodesics between points. Example 13 illustrates how to use `m_lldist`.

If you care about the difference between great circle and ellipsoidal geodesics (a very very small proportion of users I would bet) then `m_fdist` (which computes the position at a given range/bearing from another), `m_idist` (distance and bearings between points), and `m_geodesic` (points along the geodesic) can be used with a variety of (user-specified) ellipses. The calling sequence for these is different than for `m_lldist` for historical reasons.

5. Converting longitude/latitude to projection coordinates

If you want to use projection coordinates (perhaps you want to compute map areas, or distances, or you want to make a legend in the upper left corner), the following command converts longitude/latitude coordinates to projection coordinates.

```
[X,Y]=m_ll2xy(LONG,LAT, ...optional clipping arguments )
```

where LONG, LAT, X, and Y are matrices of the same size. Projection coordinates are equal to true distances near the center of the map, and are expressed as fractions of an earth radius. To get a distance, multiply by the radius of the earth (about 6370km). The exception is the UTM projection which provides coordinates of northing and easting in meters.

The possible clipping arguments are

`'clip','on'`

This is the default. Columns of LONG and LAT are assumed to form lines, and these are clipped to the map limits. The first point outside the map is therefore moved to the map edge, and all other points are converted the NaN.

`'clip','off'`

No clipping is performed. This is sometimes useful for debugging purposes.

`'clip','point'`

Points are tested against the map limits. Those outside the limits are converted to NaN, those inside are converted to projection coordinates. No points are moved. This option is useful for point data (such as station locations).

`'clip','patch'`

Points are tested against the map limits. Those outside the limits changed into a point exactly on the limits. Those inside are converted to projection coordinates. This option may be useful when trying to draw patches, however it probably won't work well.

6. Converting projection coordinates to longitude/latitude

Conversion from projection coordinates to longitude/latitude is straightforward:

```
[LONG,LAT]=m_xy2ll(X,Y)
```

There are no options.

7. Computing distances between points

Geodesic (great circle) distances on a spherical earth can be computed between pairs of either geographic (long/lat) or map (X/Y) coordinates using the functions `m_lldist` and `m_xydist`. For example,

```
DIST=m_lldist([20 30],[44 45])
```

computes the distance from 20E, 44N to 30E, 45N. Alternatively, if you want to compute the distance between two points selected by the mouse:

```
[X,Y]=ginput(2);
DIST=m_xydist(X,Y)
```

will return that distance. Because of the inaccuracies implicit in a spherical earth approximation the true geodesic distances may differ by 1% or so from the computed distances.

If you want greater accuracy, then you must calculate geodesics on an ellipsoidal earth. There is a very accurate numerical algorithm for doing so (Vincenty's algorithm), which is implemented in the functions `m_idist`, `m_fdist`, and `m_geodesic`. For example,

```
 [distance,a12,a21] = m_idist(lon1,lat1,lon2,lat2,spheroid)
```

computes the `distance` in meters between two points `(lon1,lat1)` and `(lon2,lat2)` on the specified spheroid (`'wgs84'` is the default, for other options see the code or use on of the options shown by `m_proj('get','utm')`). Forward and reverse azimuths `a12` and `a21` in degrees are also computed.

`m_fdist` is used to get the location of a point at a given bearing and distance from a specified point.

Finally, if you want to plot a geodesic on a map, then `m_geodesic` can be used to generate a vector

of points along the elliptical geodesic between two specified points. If you ever find yourself needing this, I'd be interested in knowing about it!

---

6. More complex plots

For ideas on how to make more complex plots, see the Examples. These plots are also included in the function `m_demo`.

---

7. Removing data from a plot

Once a given map includes several elements a certain amount of fiddling is usually necessary to satisfy the natural human urge to give the image a certain aesthetic quality. If the image includes complicated coastlines which take a long time to draw (e.g. those discussed below) than clearing the figure and redrawing soon becomes tedious. The `m_ungrid` command introduced above can be used to selectively remove parts of the figure. For example:

```
m_proj('lambert','long',[-160 -40],'lat',[30 80]);
m_coast;
m_range_ring(-123,49,[1e3:1e3:10e3],'color','r');
```

draws range rings at 1000km increments from my office. But I am unsatisfied with this, and want to redraw using only 200km increments. I can remove the effects of `m_range_ring` and redraw using:

```
m_ungrid range_ring
m_range_ring(-123,49,[200:200:2000],'color','r');
```

In general the results of `m_ANYTHING` can be deleted by calling `m_ungrid ANYTHING`.

`m_ungrid` can recognize and delete specific elements by searching the `'tag'` property of all plot elements, which is set by the various different M_Map routines.

---

8. Adding your own coastlines

If you are interested in a particular area and want a higher-resolution coastline than that used by `m_coast`, the best procedure is to

1. Get a subset of points from some high-resolution database, and
2. convert to screen coordinates using `m_ll2xy`, and plot.

One place where high-resolution coastline data can be obtained is The Coastline Extractor. Follow the instructions there to get coastline data in a matlab-readable file, and download to your computer. If the file is saved as "coast.dat", you can plot it (as lines) using the following:

```
load coast.dat
m_line(coast(:,1),coast(:,2));
```

Filled coastlines will require more work. You should first read the instructions there on joining the coastline data into continuous segments. If you are lucky, (i.e. no lakes or anything else), you *may*

achieve success with

```
load coast.dat
[X,Y]=m_ll2xy(coast(:,1),coast(:,2),'clip','patch');
k=[find(isnan(X(:,1)))];
for i=1:length(k)-1,
    x=coast([k(i)+1:(k(i+1)-1) k(i)+1],1);
    y=coast([k(i)+1:(k(i+1)-1) k(i)+1],2);
    patch(x,y,'r');
end;
```

If this does not work, read the comments in `private/mu_coast`, orient the curves in the desired fashion, and use `m_usercoast` to load your own data.

1. DCW political boundaries

As of 2011 the DCW web site has been decommissioned. The following information is retained for historical reasons only. New users see the next section on shapefiles.

Files containing political boundaries for various countries and US states can be downloaded from http://www.maproom.psu.edu/dcw/. Select an area and choose the "download points" option (rather than "download data"). Once downloaded to your machine use `m_plotbndry` to access and plot the desired boundary. For example, if you downloaded various US states into a subdirectory "states:,

```
m_plotbndry('states/arizona','color,'r')
```

would plot arizona on the current map.

2. ESRI Shapefiles and Natural Earth Political Boundaries

A de facto standard for the interchange of vector data are ESRI shapefiles. A dataset comes in (at minimum) 3 files, each with the same root name but with `.dbf`, `.shp`, and `.shx` extensions. Files can contain point, line or polygon information, as well as other fields in a self-describing way. For more information see this description .

Many (all?) shapefiles can be read in using `m_shaperead`, which returns a data structure containing the information in the files. However, figuring out what to do with the contents requires you to examine the contents of the data structure. It may also be useful to examine projection information in the `.prj` text file, which contains information about map projections, especially if you are overlaying data from different sources.

You can usually at least create a simple plot of the data stored in files `datafile.shp`, `datafile.shx` and `datafile.dbf` using

```
M=m_shaperead('datafile');
clf;
for k=1:length(M.ncst),
  line(M.ncst{k}(:,1),M.ncst{k}(:,2));
end;
```

Political Boundary info is available in shapefile format from Natural Earth.

---

9. Adding your own topography/bathymetry

A number of global and regional topography databases are available at NCAR . Several are available for free from their ftp site.

As long as the data is stored in a mat-file as a rectangular matrix in longitude/latitude, then `m_contour` or `m_contourf` can be used to plot that data.

1. **Sandwell and Smith Bathymetry**

   A recent new bathymetry with approximately 1km resolution in lower latitude areas is being used by many people. This dataset is described at http://topex.ucsd.edu/marine_topo/ and is available as a 134Mb binary file at ftp://topex.ucsd.edu/pub/global_topo_2min/ (get the file topo_X.Y.img where X.Y is the version number). The authors have included an m-file (mygrid_sand.m) which can extract portions of the data (you will have to modiy path names within the code). Once this database (and the m-file) is installed on your computer, you can use it in M_Map very easily. A typical usage is as follows:

   ```
   % Extract data
   [elevations,lat,lon]=mygrid_sand([lat_south lat_north long_west long_east]);

   % Use in M_Map command
   m_contour(lon,lat,elevations);
   ```

   For some projections, you must make sure that the 'lon' values returned by `mygrid_sand.m` fall within the range used in this projection (i.e. you may have to add/subtract 360). This seems to happen all the time for areas in the west (i.e. negative longitudes), if you forget this you often end up with bewildering error messages about empty vectors!

---

10. Using TerrainBase 5-minute or ETOPO 2- or 1-minute global bathymetry/topography

1. For many purposes the elevation database accessed by M_Map provides adequate resolution. However, there are also many cases when more detail is desired. I have not included a higher-resolution database because it would greatly increase the size of the package. However, v1.2 includes m-files to access and plot a popular global 5-minute bathymetry/topography database, after a few minutes of work.

   This section provides instructions on how to download TerrainBase, and convert it from a 56Mb ASCII file to a 18Mb binary file using `m_tba2b.m`. It is then straightforward to access and plot bathymetry from this file using `m_tbase.m`, which is in every way functionally identical to `m_elev` (see Section 3.2).

   TerrainBase is also available on CDrom, and is also commonly stored in netcdf (or other) binary format somewhere on many academic networks. If you modify `m_tbase.m` to access data from one of these sources, let me know!

   How to install TerrainBase:

1. get and uncompress the tbase.Z file from http://dss.ucar.edu/datasets/ds759.2/ into the m_map directory.

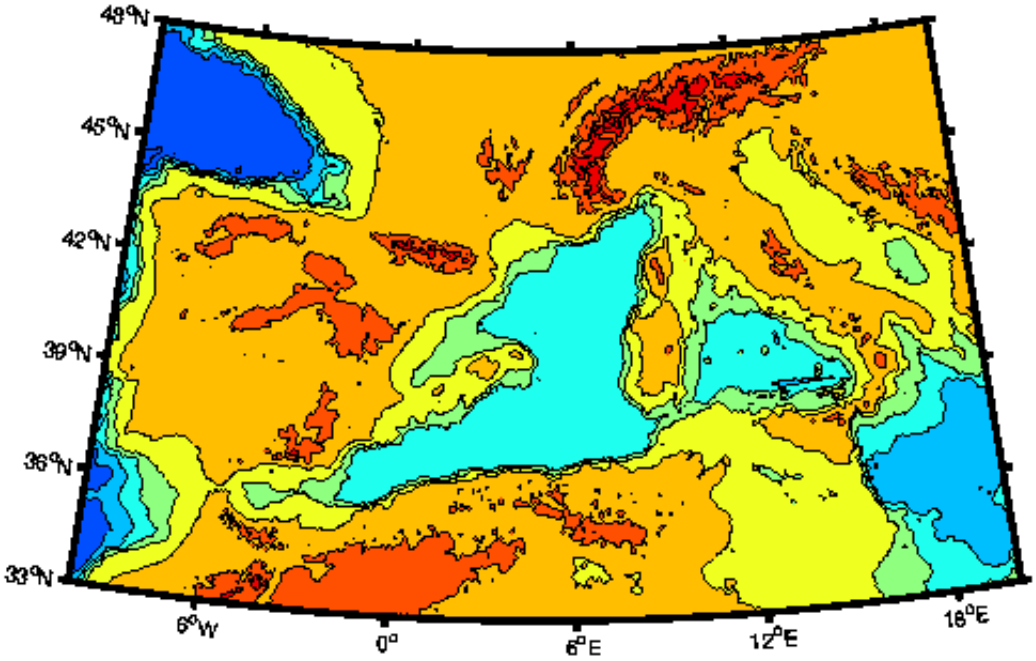
2. Run `m_tba2b('PATHNAME')` to store the resulting 18Mb binary file as `PATHNAME/tbase.int`.

3. Delete the original ASCII file `tbase`.

4. Edit the `PATHNAME` setting in `m_tbase` to point to the location of this file.

That's it! Test things out with this map of the western mediterranean:

```
m_proj('lambert','lon',[-10 20],'lat',[33 48]);
m_tbase('contourf');
m_grid('linestyle','none','tickdir','out','linewidth',3);
```



2. As of Apr 2006, there is a corrected higher-resolution (2 minute) database ETOPO2. Download http://rda.ucar.edu/dsszone/ds759.3/etopo2_2006apr/etopo2_2006apr.raw.gz (a gzipped binary), gunzip it into a 116Mb file, edit the `PATHNAME` setting in `m_etopo2` to point to the location of this file, and then use it in the same way as `m_tbase` and `m_elev`. UCAR requires users to register and the second link won't work without you doing this (go to first link and follow instructions).

3. In 2014, it was pointed out to me that the above is obsolete. First, there is a corrected 2-minute ETOPO database - ETOPO2v2 which you should be using instead. Now, ETOPO2v2 is a little more complicated, because it comes in 4 version - big-endian and little-endian, in both cell-centered and grid-centered versions.

   It doesn't particularly matter if you get big- or little-endian since you can modify the `fopen` line in `m_etopo2` to account for this. I recommend getting the grid-centered version, since it works "better" when you are contouring the elevations (it will be more likely to extend all the way up to the map edge without weird little 'gaps').

   In any case, download one of the zipped binaries, unzip it, and then edit 4 lines in `m_etopo2` to set the `PATHNAME`, the filename in the `fopen` line, as well as setting the last option to `'b'` or `'l'` for big-endian or little-endian formats. Then make sure the `grid` and `resolution` parameters are set appropriately. If you forget (or get them wrong), code may run but it won't give the right

bathymetry!

4. If you want even higher resolution bathymetry, you can also use the 1-minute ETOPO1 . This appears to come in two versions: grid or cell-referenced, both little-endian. Again, I recommend the grid-referenced version. Modify the relevant lines in `m_etopo2` in the same way as for ETOPO2v2.

11. Using GSHHS high-resolution coastline database

1. Installing GSHHS

When drawing maps there is always a tradeoff between the execution time of the generating program and the resolution of the resulting map. Included in M_Map is a 1/4 degree coastline database which can be used to generate very fast maps, with adequate resolution for many purposes.

However, it is often desirable to be able to make detailed maps of limited geographic areas. For this purpose a higher-resolution coastline database is necessary. I have not included such a database in M_Map because it would greatly increase the size of the package. However, I have included m-files to access and use a popular high-resolution database called GSHHS

As distributed, GSHHS consists of a hierarchical set of databases at different resolutions. The lowest or "crude" resolution is not as good as the M_Map database, although it contains many more inland lakes. The "high" resolution consists of points about 200m apart. There is also an even finer "full" resolution. You can install part or all of the database (depending on how much disk space you have available). The "full" resolution occupies 90Mb of disk space, and successively coarser resolutions are smaller by about 1/4. Thus "high" resolution occupies 21Mb, "intermediate" uses 6Mb, and "low" uses 1.1Mb (one reason for not always using "high" resolution is that the entire 90Mb database must be read and processed each call, which may take some time).

How to install GSHHS:

1. Go to http://www.ngdc.noaa.gov/mgg/shorelines/data/gshhs/.
2. Get and uncompress any or all of the files `gshhs_c.b.gz, gshhs_l.b.gz, gshhs_i.b.gz` and/or `gshhs_h.b.gz` in a convenient directory. One useful place is in `m_map/private`. GSHHS data format has changed between v1.2 and 1.3, and again for v2.0, but m_map should be able to figure this out.
3. If the database files are not in subdirectory `m_map/private` , you must edit the `FILNAME` settings in `m_gshhs_c.m, m_gshhs_l.m, m_gshhs_i.m, m_gshhs_h.m` and/or `m_gshhs_f.m` to point to the appropriate files.

4. Using GSHHS effectively

The simplest calling mechanism is identical to that for `m_coast` (Section 3). For example, to draw a gray-filled high-resolution coastline,

```
m_gshhs_h('patch',[.5 .5 .5]);
```

is sufficient. However, execution times may be very, very long, as the entire database must be searched and processed. I would not recommend trying to draw world maps with the

intermediate or high-resolution coastlines! There are two ways to speed this up. The first is merely to use a lower-resolution database, with fewer points. The second is useful if you are going to be repeatedly drawing a map (because, for example, it's the base figure for your work). In this case I recommend that you save an intermediate processed (generally smaller) file as follows:

```
m_proj ...  % set up projection parameters

% This command does not draw anything - it merely processes the
% high-resolution database using the current projection parameters
% to generate a smaller coastline file called "gumby"

m_gshhs_h('save','gumby');

% Now we can draw a few maps of the same area much more quickly

figure(1);
m_usercoast('gumby','patch','r');
m_grid;

figure(2);
m_usercoast('gumby','linewidth',2,'color','b');
m_grid('tickdir','out','yaxisloc','left');

etc.
```

---

12. M_Map toolbox contents and description

1. Contents.m - toolbox contents
2. m_demo.m - demonstrates a few maps.

User-callable functions

1. m_proj.m - initializes projection
2. m_coord - geomagnstic to geographic coords

3. m_grid.m - draws grids
4. m_scale.m - forces map to a given scale
5. m_ruler - draws a scale bar

6. m_ungrid.m - erases map elements (if you want to change parameters)

7. m_coast.m - draws a coastline
8. m_elev.m - draws elevation data
9. m_tbase.m - draws elevation data from high-resolution database
10. m_etopo2.m - draws elevation data from (another) high-resolution database
11. m_gshhs_c.m - draws coastline from GSHHS crude database
12. m_gshhs_l.m - draws coastline from GSHHS low-resolution database
13. m_gshhs_i.m - draws coastline from GSHHS intermediate-resolution database
14. m_gshhs_h.m - draws coastline from GSHHS high-resolution database
15. m_gshhs_f.m - draws coastline from GSHHS full resolution database
16. m_plotbndry.m - draws a political boundary from the DCW
17. m_usercoast.m - draws a coastline using a user-specified subset database.
18. m_shaperead.m - reads ESRI shapefiles

19. m_plot.m - draws line data in map coords
20. m_line.m - draws line data in map coords
21. m_text.m - adds text data in map coords
22. m_legend.m - Draw a legend box
23. m_patch.m - adds patch data in map coords
24. m_pcolor - draws pcolor surface
25. m_quiver - draws arrows for vector data
26. m_contour - draws contour lines for gridded data
27. m_contourf - draws filled contours
28. m_track - draws annotated tracklines
29. m_range_ring - draws range rings

30. m_ll2xy.m - converts from long/lat to map coordinates
31. m_xy2ll.m - converts from map coordinates to long/lat
32. m_geo2mag - converts from magnetic to geographic coords
33. m_mag2geo - the reverse

34. m_lldist - distance between long/lat points
35. m_xydist - distance between map coordinate points

36. m_fdist - location of point at given range/bearing along ellipsoidal earth
37. m_idist - range/bearings between points on ellipsoidal earth
38. m_geodesic - points on geodesics between given points on ellipsoidal earth
39. m_tba2b.m - used in installing high-resolution elevation database.

40. m_vec.m - fancy arrows

Internal functions (not meant to be user-callable)

1. private/mp_azim.m - azimuthal projections
2. private/mp_cyl.m - cylindrical projections (equatorial)
3. private/mp_conic.m - conic projections
4. private/mp_tmerc.m - transverse cylindrical projections
5. private/mp_utm.m - elliptical universal transverse cylindrical projections
6. private/mp_omerc.m - oblique cylindrical projection

7. private/mu_util.m - various utility routines
8. private/mu_coast.m - routines to handle coastlines.
9. private/mc_coords - coordinate conversion.
10. private/clabel.m - patched version of clabel (matlab v5.1 version does not contain capabilities for different text properties).

11. private/m_coasts.mat - coastline data

HTML Documentation

1. map.html - documentation intro
2. private/mapug.html - users guide
3. various .gif - examples.

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13. Known Problems and Bugs

1. Running M_Map with Matlab5.0 (Student versions?) can sometimes produce errors since 5.0 has various bugs and "features" that do not appear in later versions. One in particular has

cropped up - the file `m_coast.mat` is sometimes not found when using `m_coast.m`. The easiest solution is to put `../m_map/private` into your path as well as `../m_map` (in later versions matlab can find the mat-file).

2. Running M_Map on a PC with Matlab5.1 can sometimes produce a lot of

   ```
   > Warning: Divide by zero.
   ```

   messages. This is due to a bug in Matlab (actually due to the compiler TMW used) that results in an incorrect warning flag being set when dividing some numbers by NaN. You can safely ignore these errors and wait for v5.2

3. **If plotted data is coloured white, this will be changed to black in the postscript output.** This is due to the workings of the `print` command. In order to avoid this, set the figure background to white, i.e.

   ```
   set(gcf,'color','white')
   ```

4. **Generally weird-looking stuff that happens when you use filled contours.** For some reason this has been a glory-hole for all kinds of weird bugs in MATLAB. Most of them relate somehow to the way in which the map background interacts with contourf patches, and how the 'renderer' (the internal matlab code that figures out what goes on top of what) works, or doesn't work. Unfortunately I can't think of way that works around the problem in all cases, but if you asee something weird, try:

   ```
   set(findobj('tag','m_grid_color'),'facecolor','none')
   ```

   after the

   ```
   m_grid
   ```

   call, or

   ```
   set(gcf,'renderer','opengl');
   ```

   (under Unix you may have to do this one on starting MATLAB)

5. **Things not appearing correctly in tiff output**. Matlab uses ghostscript to covert from ps to many other formats. But their version has some problems. It is better to print to postscript and do the conversion (say, to tiff) yourself.

14. OCTAVE Compatibility Issues

From their website: " GNU Octave is a high-level interpreted language, primarily intended for numerical computations. [...] The Octave language is quite similar to Matlab so that most programs are easily portable."

M_Map currently runs under Octave, sort of. In M_Map 1.4f a number of small incompatibilities have been addressed (mostly by spelling out the full names of graphics objects properties, rather than by using the shortened but unique versions allowable in MATLAB) and so it doesn't immediately bomb. However, there are still features that either don't work, or don't work properly.

Note: since "private" subdirectories are not implemented (as of Octave 3.2.3), you must add the

`m_map/private` subdirectory explicitly to the path:

```
addpath [whatever]/m_map
addpath [whatever]/m_map/private
```

Features that don't work, or don't work well, include:

1. Octave `line` commands do not accept MATRIX x/y parameters. This means your code might need to be changed when `m_line` is called.

2. 3D patch functionality is not completely implemented in Octave. This means that fancy box outlines will not work, and so these have been disabled in M_Map if it recognizes that Octave is being used.

3. 2D Patch functionality is still imperfect. Filled patches are not always correctly filled. This means filled coastlines, or filled contours, sometimes just look wrong. Stick with line plots.

4. Clipping functionality for line objects in Octave is imperfect. Sometimes lines outside the plot boundaries are not drawn even when `'clipping'` is set to `` `'off' ``. Live with it.

5. The simple bathymetry called by `m_elev` comes from a built-in Matlab demo .mat file and this is not available in Octave.

6. Things 'in front' or 'behind' other things in plots are not always correctly rendered as being in front or behind.

7. Text label alignment (especially for the lat/long grid) can be a bit odd sometimes. Live with it.

8. Hatching and speckled outlines require units of 'points' for the axis, and although you can change the units property to 'points' it doesn't seem to change the numbers returned for the position. So avoid hatching or speckles.

15. Changes since last release

1. Finally including m_pcolor. Actually I could have done this a long time ago, but there are some philosophical reasons not to - it doesn't really do the "right" thing. But on the other hand it does do *something* (and I give examples)

2. geomagnetic/geographic coordinate systems. Let me know if you use this. It was an interesting thing to add but perhaps a waste of time...

3. Super-accurate geodesics on the ellipsoidal earth!

4. Speckled coastlines for the old-fashioned hand-drawn look

5. A SHAPEFILE reader.

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Last changed 4/Dec/2011. Questions and comments to rich@eos.ubc.ca