

How to build a geographic sundial¹

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In order to build a geographic sundial, the earth globe must be projected with a gnomonic projection. This article explains how freeware programs downloadable from the web can be used to this purpose.

Introduction

A sundial is nothing else than the gnomonic projection of the celestial sphere on the dial plane. Because of the one to one correlation between celestial sphere and earth globe, hour lines are the projections of meridians and declination lines are the projections of latitude lines.

Therefore it is possible to design a sundial where the contours of continents and nations are traced together with hour and declination lines.

The style shadow will show the time as usual but it will also make known in which parts of the world it is noon at that same time and in which place the sun is exactly at the zenith of the observer.

In order to design such a kind of dials, geographical data including coasts and borders for the entire world should be available and then a geographic projection should be computed.

There are freeware programs on the web that can be used to this purpose.

This article explains how to use these programs and how to include the resulting maps in a dial designed with “Orologi Solari” (OS).

The GMT program

“Generic Mapping Tool” is an open source collection of about 60 software tools to handle geographic data (including filtering, extrapolation, projection etc.) and to generate as a result an Encapsulated PostScript (EPS) file.

GMT includes about 30 map projections and transformations and it is distributed together with geographic data containing coasts, borders and rivers lines.

To install GMT go to the web address <http://gmt.soest.hawaii.edu/>, “Download” section, “GMT Windows” page and then download and execute the following programs:

gmt-4.5.7_install32.exe (program and geographic data installation)

gmt-4.5.7_pdf_install.exe (documentation installation)

All the new files will be created in the C:\programs\GMT directory.

It is worth noting that the sub-directory share\doc\gmt\pdf contains the program manuals and share\doc\gmt\examples contains 30 examples for the main program features.

GMT output maps are formatted as EPS files while OS needs raster (bmp, png, gif etc.) images. Therefore the Ghostscript program, that is a PostScript language interpreter, is to be downloaded from

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<http://pages.cs.wisc.edu/~ghost/doc/GPL/gp1902.htm>: go to the bottom of the page, in the Microsoft Windows section, download and then execute *gs902w32.exe*.

How to create a map

GMT has been developed for Unix/Linux systems although it is available for Windows too.

As for the most part of Unix applications, GMT does not include a graphic interface and needs to be executed by means of a series of commands to be run from a DOS window.

The easiest way to proceed it is to create a batch file by means of a text editor writing the required commands one for each line. A double click on the file icon will then execute all the commands.

The *pause* command should be inserted at the end of the file in order to be able to see any displayed error before the DOS window is closed².

To create a map with a gnomonic projection the *pscoast* command must be used. Let's see for example how to create a gnomonic map centered at the coordinates 7.5°E and 45°N (all the command options are deeply described in the manual GMT_Manpages.pdf):

```
pscoast -Rg -JF7.5/45/70/18c -Bg15+7.5/g30 -Di -A5000 -Glightgray -Swhite -P -Na -T7.5/45/1c:: -W > output.ps
```

The main parts of the command are the following:

-JF7.5/45/70/18c specifies a gnomonic projection centered at 7.5°E³ and 45°N, requires 70° as the maximum distance α from the center and 18 cm as the dimension of the final resulting map.

-Bg15+7.5/g30 requires a grid with a step of 15° in longitude (with a 7.5° offset) and 30° in latitude.

-T7.5/45/1c:: draws a small symbol, 1 cm large, in the position 7.5°E and 45°N.

> output.ps redirects the output PostScript code to the "output.ps" file.

To obtain a raster image the following command must be added:

```
ps2raster output.ps -Tb -GC:\Programmi\gs\gs9.02\bin\gswin32c.exe
```

that will transform the file output.ps to the bitmap file output.bmp (the *-G* option must include the position in the file system of the file gswin32c.exe that was installed together with Ghostscript; in the example the typical path is shown).

How to use the map with OS

Now that we have obtained the gnomonic map we need, we can design a geographic sundial.

The OS program can be conveniently used to this purpose because it allows putting a raster image as the background of the dial design.

The map that we have previously obtained can be considered as the gnomonic projection to a horizontal plane centered in a place in the north of Italy. We can use OS⁴ to design a horizontal dial with coordinates 7.5°E and 45°N, then in the "background image" tab we must introduce the name of the file containing

² If the error "unknown command" is shown, verify that the path C:\programs\GMT\bin has been added to the environment variable "PATH".

³ The GMT program considers eastern longitudes as positive.

⁴ Revision 25.3 or later should be used in order to be able to rotate the map.

the map and set a rotation⁵ of 180°.

In order to assign the correct dimension to the map, the center C of the dial must be put on the symbol drawn in the center of the map and points 1 and 2 on the extreme points of a map diameter. The distance between points 1 and 2 must be set to a value that is depending on the maximum displayed distance α from the center (70° in the example) and on the length R of the ortho-style according to the formula:

$$2 * R * \tan(\alpha)$$

The result is shown in fig. 1.

The procedure is a little more complex for an inclined declining dial. As a first step the coordinates of the center of the map corresponding to the point at the zenith of the dial (that is the coordinates of the horizontal equivalent dial) must be computed. Moreover the rotation angle of the map, corresponding to the sub-style angle in the dial, must be found.

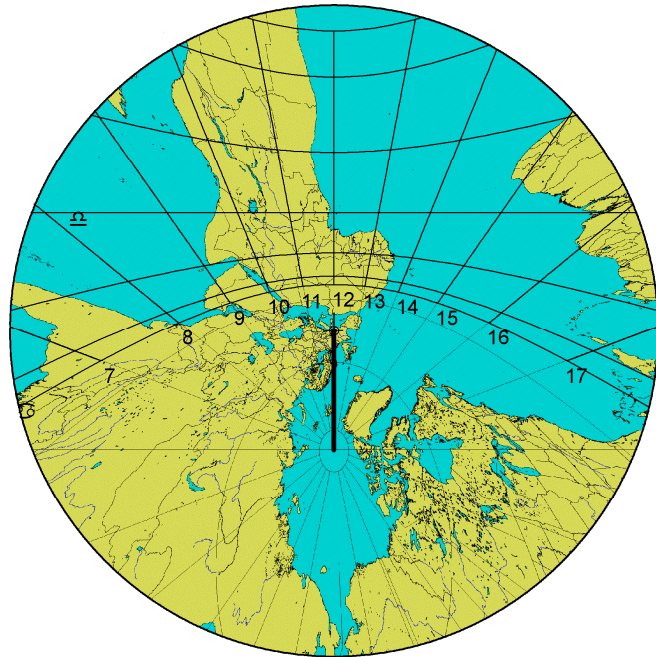


Fig. 1 – Horizontal sundial at 7.5°E 45°N

Consider the spherical triangle in fig. 2 having vertices in the North Pole N, the dial place Z (with latitude φ_0 and longitude λ_0) and the dial plane pole Q. The dial has inclination⁶ i and declination d . The unknown center of the map has coordinates φ_x and λ_x .

It can be found that:

$$\begin{aligned} \sin(\varphi_x) &= \cos(i) \sin(\varphi_0) - \sin(i) \cos(\varphi_0) \cos(d) \\ \tan(\lambda_x - \lambda_0) &= \sin(d) \tan(i) / \\ & [\cos(\varphi_0) + \sin(\varphi_0) \cos(d) \tan(i)] \end{aligned}$$

and the rotation σ of the map is:

$$\sin(\sigma) = \sin(d) \cos(\varphi_0) / \cos(\varphi_x)$$

As an example let's consider a vertical dial in a place with coordinates 7.5°E e 45°N having declination 10°W. We obtain:

$$\begin{aligned} \varphi_x &= 44.14^\circ\text{S} \\ \lambda_x &= 6.50^\circ\text{W} \\ \sigma &= 9.85^\circ \end{aligned}$$

Now let's design the map with GMT and then insert the map in OS as the background image with a rotation of -189.85° and dimensions as explained in the

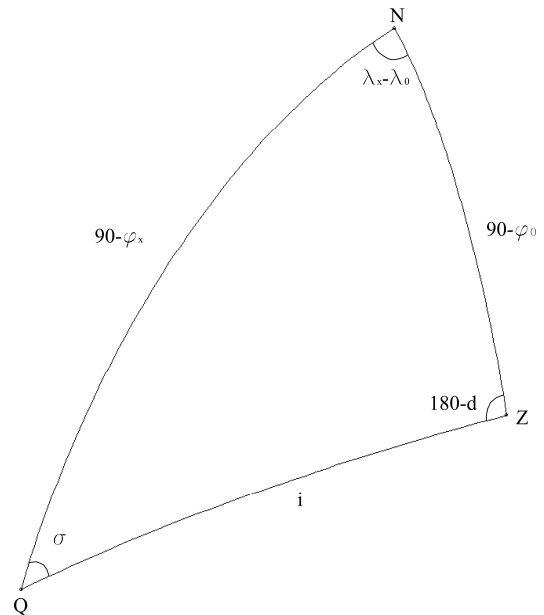


Fig. 2 – Reference spherical triangle

⁵ GMT projection is to a plane that is tangent to the defined coordinates; the result is that the map is rotated 180° with respect to the map that is projected to the dial plane.

⁶ Inclination i is between 0° e 180°, where 0° is for a horizontal and 90° for a vertical plane.

previous example. The resulting dial is shown in fig. 3.

Unfortunately for vertical geographic dials the resulting map is upside down. Only a double reflection (a mirror to reverse up down and a transparent dial plane to reverse left right the map) as suggested in [1] could solve the problem.

Other map projections

The GMT program can also be used for other types of sundials.

With the `-JG` option an orthographic projection is obtained and an azimuth orthographic dial can be created (fig. 4).

With the `-JS` option a stereographic projection is obtained and an azimuth stereographic sundial, also known as “horizontal astrolabe”, can be designed (fig. 5).

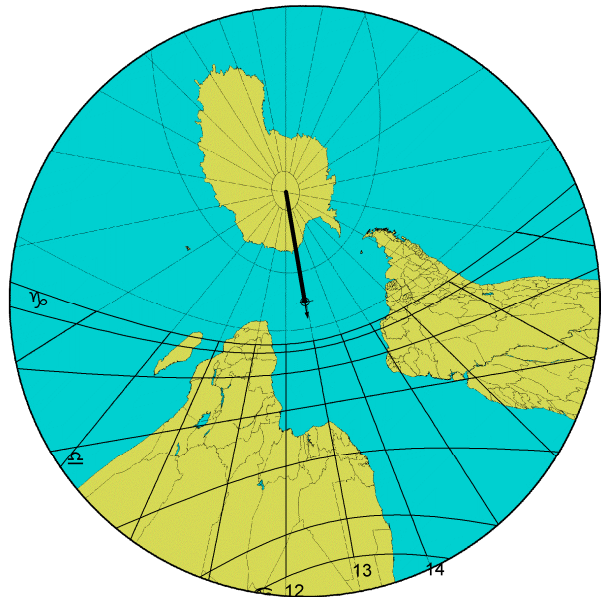


Fig. 3 – Vertical declining dial

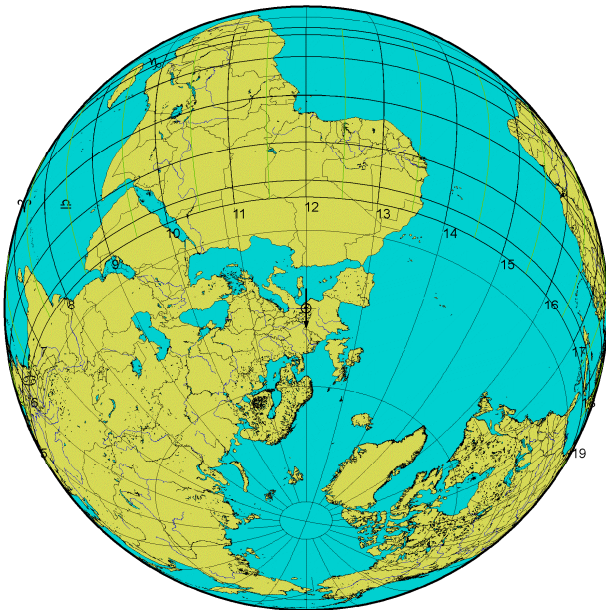


Fig. 4 – Azimuth orthographic dial



Fig. 5 – Azimuth stereographic dial

References

[1] FERRO MILONE F. , “Meridiane geografiche”, Gnomonica Italiana n. 24, June 2011

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