

VISUALISATION OF MARINE DATA PRODUCTS USING GMT

WIZUALIZACJA DANYCH MORSKICH ZA POMOCĄ GMT

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Keywords: automation, mapping, visualisation, script, open source

Słowa kluczowe: automatyzacja, mapowanie, wizualizacja, skrypt, otwarte oprogramowanie

Introduction

There is a wide range of software for presentation of data in graphical form. The problem rises when operational data must be displayed, such as output from models or satellite imagery, because of the need for automation. In 1998–2004 the author developed tools utilizing the Golden Software Surfer ActiveX automation objects (Piliczewski, 2003). This solution was not satisfactory for operational products, because of problems with long term stability. Therefore, in 2005 the author decided to focus on Linux software and used the Generic Mapping Tools (GMT), package (Wessel and Smith, 1998). In 2006, an automated generation of daily hydrodynamic forecasts of the operational High Resolution Oceanographic Model of the Baltic Sea (HIROMB) was implemented (<http://baltyk.imgw.gdynia.pl/en/hiromb>). In 2008, a similar approach was applied for visualisation of sea surface temperature (SST) from NOAA/AVHRR in the Baltic Sea (<http://baltyk.imgw.gdynia.pl/en/sat>). This article describes author's work in the development of operational marine data products employing only freely available open source software. After reading this article you should have an overall idea how to create operational products using GMT.

GMT

The GMT (<http://gmt.soest.hawaii.edu>) is an open source collection of tools for manipulating geographic and Cartesian datasets and released under the free GNU General Public License (GPL). It was originally developed for Unix/Linux, but there are also versions for Windows, OS/2 and MacOS. This package includes facilities for filtering, trend fitting, gridding, projecting, contouring, 2D and 3D image maps, math calculations etc. It is equipped with high-resolution shorelines, lakes, rivers and political boundaries. Further data such as satellite imagery, bathymetry, or topography can be imported from other sources.

Interfacing with GMT

The general approach to interfacing GMT can be summarized as follows:

- prepare netCDF files,
- calculate and set key parameters,
- run GMT commands,
- export the graphical output in an appropriate format.

GMT programs receive all their parameters as command line arguments, so they can be called from shell scripts and pipes. The author's scripts have been developed in Bash on Fedora Core 4 Linux, but similar results could be achieved in any other scripting or programming language.

Preparing netCDF files

GMT supports data input/output in ASCII spreadsheets or netCDF grids, therefore before using other data types a conversion to supported formats is necessary. For example, a conversion from GRIB format, widely used in the meteorological community, can be done using the Climate Data Operators (CDO, <http://www.mpimet.mpg.de/fileadmin/software/cdo/>).

```
# convert from GRIB to netCDF
cdo -f nc input_GRIB_file output_netCDF_file
```

The author used NetCDF Operators (NCO, <http://nco.sourceforge.net>) for processing netCDF files. NCO is optimised to analyse large multi-dimensional datasets efficiently. This suite of Unix shell programs supports arithmetic operations, data permutation and metadata editing (Zender, 2008).

Settings and parameters in GMT

Although GMT does not handle multidimensional netCDF grids, it is possible to use their 2-D subsets by specifying variable names and indexes of other dimensions. The high quality graphical output is stored in PostScript (*.ps) or Encapsulated PostScript (*.eps) formats.

```
# input and output files
in='inputfile.nc?variable[0]'
out='output.ps'
```

The makecpt tool is intended for manual or automated creation of colour palette files, based either on standard or custom colour schemes.

```
# sample colour scale file: scale.cpt
# COLOR_MODEL = RGB
0 255 0 255 20 51 51 255
20 51 51 255 40 0 255 255
40 0 255 255 60 0 153 51
60 0 153 51 80 255 255 0
80 255 255 0 100 204 51 0
```

```
# custom colour scale filename
cpt='custom.cpt'
```

```
# make colour scale from another *.cpt file
makecpt -Cscale.cpt -T-2/28/0.2 -N > $cpt
```

The examples below specify a few frequently used parameters in GMT commands. The first three variables define an appearance of the colour scale. The data are plotted in a projection specified with the `-J` flag. The full listing of supported projections can be found in the GMT manual. Another useful option is the `-R` flag, which defines a region of interest. This enables plotting maps for sub areas from a single data file. A user can also specify frames, tickmarks, position of the map etc.

```
# colour scale
C='-C'$cpt

# position of colour scale
D='-D13.4c/7.5c/15c/0.5c'

# unit: °C
B1='-B2::/:@\217C:'

# projection: Cylindrical Equal-Area
# central meridian: 0, standard parallel: 60, scale: 1.16
J='-Jy0/60/1.16'

# region of interest (Baltic Sea)
R='-R53/66/9/31'

# tickmark interval and frame tick spacing
B2='-Ba2f1WSne'

# x-shift and y-shift
X='-X7.3'
Y='-Y0.85'
```

Some global attributes can be defined in global settings by using `gmtset`.

```
# custom global settings
gmtset COLOR_NAN 255/255/255 PAPER_MEDIA Custom_640x480 GRID_CROSS_SIZE 0
gmtset ANNOT_FONT_SIZE_PRIMARY 12 CHAR_ENCODING Standard+
```

Running GMT commands

The graphical output can be constructed by a series of different GMT commands. In such a case the `-K` flag, indicating that more PostScript code will be appended later, must be used in all of these commands except the last one, while the `-O` flag, selecting overlay plot mode, has to be used in all of them except the first one.

```
# create basemap frame
psbasemap $X $Y $J $R -B0 -P -K > $out

# add a coloured image from a 2-D netCDF grid file
grdimage $in $J $R $C -O -K >> $out

# add land
pscoast $J $R $B2 -Di -G244/216/88 -O -K >> $out

# add scale
psscale $C $D $B1 -O -K >> $out

# add text
# format: X Y size angle font justification(CB/LB/RB/LT/RT) text
cat << EOF | pstext -R0/20/0/15 -Jx1c -O -N >> $out
0 15.6 14 0.0 1 LB 2008-06-14 [0m] srednia dobowa / daily mean
0.2 0.2 11 0.0 13 LB Bogusz Piliczewski
7.0 0.8 14 0.0 1 CB temperatura wody
7.0 0.2 14 0.0 1 CB sea temperature
12.6 0.7 14 0.0 1 RB EUMETSAT
12.6 0.2 14 0.0 1 RB IMGW
EOFEOF
```

The example above creates a plot of sea surface temperature (SST) in the Baltic Sea using the `grdimage` command. Then the script adds the land, a colour scale and custom annotations. The output can be seen in Figure 1. An example of plotting vector fields combining `grdvector` and `grdimage` tools is shown in Figure 2.

Graphical output

The GMT output saved in PostScript format can be exported to PNG format, which is readable by an internet browser, using the `ps2png` script (http://www.mat.univie.ac.at/~groch/tth_linux/ps2png), which requires the `ghostscript` and `netpbm` utilities.

```
# export to PNG format using ps2png script by Ian Hutchinson 1999
ps2png $out output.png > /dev/null 2>&1
```

Other examples

The GMT is fast so can also be used for dynamic online mapping. There are many examples of such a kind of use, e.g.: Jules Verne Voyager, an interactive map tool for virtual exploration of Earth and other worlds (<http://jules.unavco.org/>); an Interactive Global Map of Sea Floor Topography Based on Satellite Altimetry & Ship Depth Soundings (Smith and Sandwell, 1997; <http://ibis.grdl.noaa.gov/cgi-bin/bathy/bathD.pl>) and the World Ocean Database Search and Select at the National Oceanographic Data Center (<http://www.nodc.noaa.gov/cgi-bin/OC5/SELECT/builder.pl>). The GMT is designed to produce high quality printable maps and for that purpose can be combined with other software, such as GRASS (Beaudette, 2007).

Limitations

The unix shell approach to interfacing GMT is well suited for scripting purposes, but may be time consuming at the development phase. There are two additional software packages, which are intended to make working with GMT easier: Mirone (Luis, 2007; <http://w3.ualg.pt/~jluis/mirone/>) and iGMT (Becker and Braun 1998; <http://www.seismology.harvard.edu/~becker/igmt/>).

In order to plot maps in GMT the geographical co-ordinates have to be stored as dimensions in the netCDF file. Some datasets contain this information in variables or even in additional files: in such a case the user must create a grid suitable for GMT. The author solved this problem using ncks (NCO), paste and nearneighbor (GMT) tools.

```
# clear temporary files
> sst.z
> sst.xyz

# define a file with geographical coordinates
xy='coord.xy'

# create an output.nc grid
ncks -H -s %.2f\n -v sea_surface_temperature input.nc > sst.z
paste $xy sst.z > sst.xyz
nearneighbor sst.xyz -I0.02|0.01 -R9.37/30.25/53.65/65.89 -S0.05 -Goutput.nc
```

Conclusions

This article describes the application of the Generic Mapping Tools in operational marine data products. The scripting-ready interface, stability and fast processing make GMT an adequate tool for automated visualisation. The high quality of the output allows its use in professional publishing. An important advantage of this package over commercial software is its' free open source license. There are also some limitations of GMT mentioned above and users used to "the mouse" may find it difficult to use command line tools with many options.

References

- Becker T.W. and Braun A., 1998: New program maps geoscience data sets interactively, *EOS Transactions AGU*, 79: 505.
- Beaudette D., 2007: Producing Press-Ready Maps with GRASS and GMT. *OSGeo Journal*, 1: 29-35.
- Luis J.F., 2007: Mirone: A multi-purpose tool for exploring grid data. *Computers & Geosciences*, 33: 31-41.
- Piliczewski B., 2003: Application of the Golden Software Surfer mapping software for automation of visualization of meteorological and oceanographic data in IMGW Maritime Branch. [In:] EGS-AGU-EUG Join Assembly, Nicea, 6-11.04.2003, *Geophysical Research Abstracts*, vol. 5, European Geophysical Society.
- Smith WHF and Sandwell D.T., 1997: Global Sea Floor Topography from Satellite Altimetry and Ship Depth Soundings. *Science*, 277: 1956-1962.
- Wessel P. and Smith W.H.F., 1998: New, improved version of Generic Mapping Tools released. *EOS Transactions AGU*, 79 (47): 579.
- Zender C.S., 2008: Analysis of Self-describing Gridded Geoscience Data with netCDF Operators (NCO). *Environmental Modelling & Software* 23(10): 1338–1342.

Abstract

The aim of this article is to describe the application of the Generic Mapping Tools and other freely available open source packages for operational graphical presentation of environmental data. A general approach to development of such data products is outlined. NetCDF Operators and Climate Data Operators are employed for pre-processing of data. Scripts for map image creation make use of the Generic Mapping Tools, followed by conversion of the GMT-created PostScript to PNG for raster image export and display on a client browser. GMT programs take their parameters from command line parameters, so it can be easily called from shell scripts or pipes. The example scripts were written in Bash on Linux, but can also be developed in any other programming language. The processing in GMT is fast and reliable, so it may also be used for dynamic creation of products.

Streszczenie

Celem niniejszego artykułu jest opisanie zastosowania pakietu Generic Mapping Tools oraz innego otwartego programowania do operacyjnej prezentacji danych środowiskowych. Przedstawiono sposób podejścia do opracowania tego typu produktów. Do wstępnego przetwarzania danych zastosowano pakiety NetCDF Operators oraz Climate Data Operators. Skrypty tworzące mapy wykorzystują pakiet Generic Mapping Tools, a następnie dokonują konwersji z formatu PostScript do formatu PNG w celu wyświetlenia mapy w przeglądarce internetowej. Programy pakietu GMT przyjmują wszystkie parametry z wiersza poleceń, toteż mogą być wywoływane przez skrypty i potoki. Przykładowe skrypty zostały napisane w języku skryptowym Bash w środowisku Linux, lecz można wykorzystać do tego celu każdy inny język programowania. Przetwarzanie w GMT jest szybkie i niezawodne, toteż może być także użyte do dynamicznego generowania produktów.

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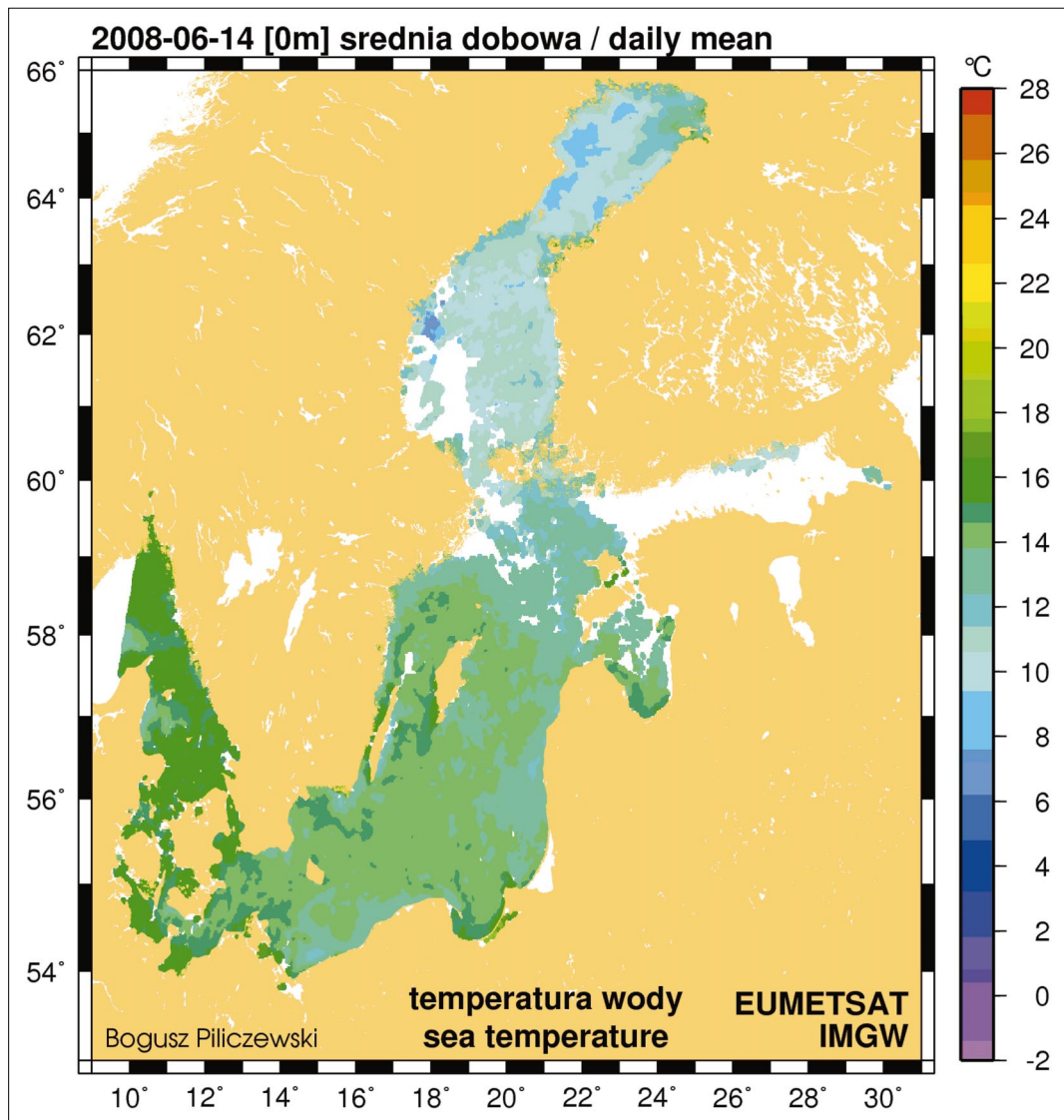


Figure 1. A sample SST map produced with GMT

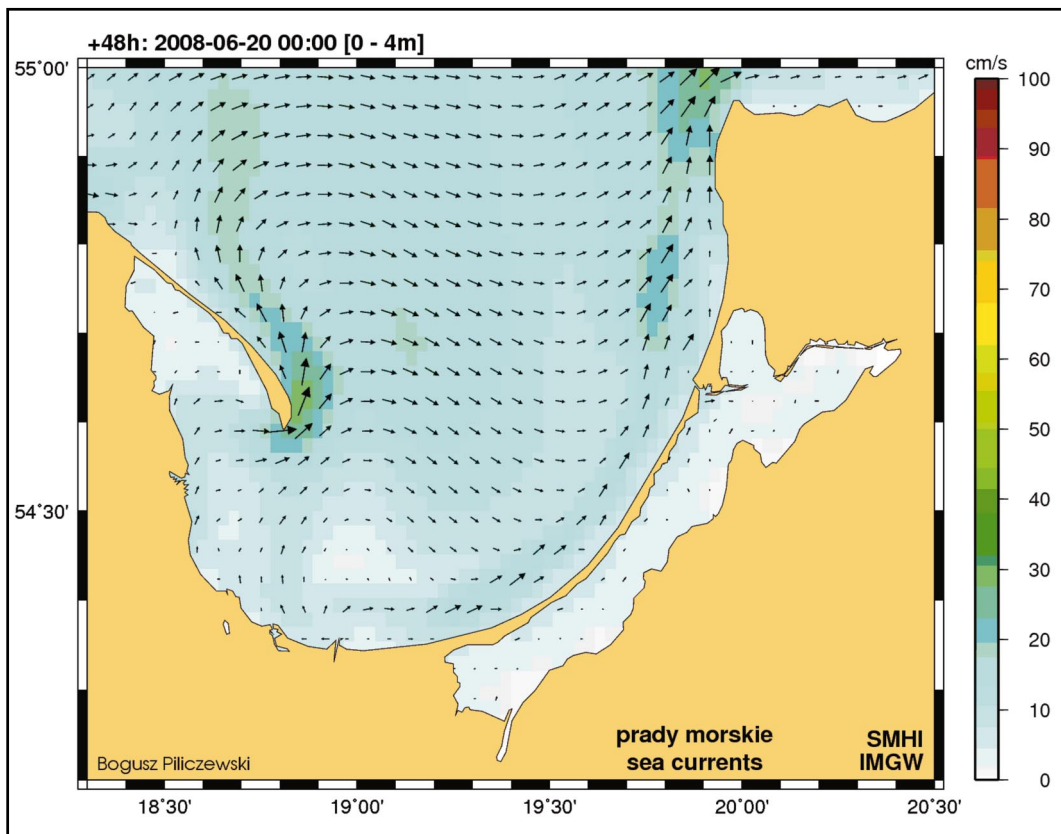


Figure 2. A sample map of sea currents produced with GMT