DATA VISUALIZATION WITH GNUPLOT IN CLIMATE CHANGE EDUCATION

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Abstract

Although scientific research on global climate change has significantly improved human understanding of the Earth system, integration of the topic into school education remains a challenge. Climate science deals with enormous amount of data measured by satellites, meteorological stations etc. Some of the data are freely available on-line (global temperature, CO_2 concentration, sea ice extent etc.) and can also be used in the classrooms in order to enhance ICT and climate literacy of the students. In this paper we present sample school activities based on data visualization with "gnuplot", which is a command-line driven graphing utility for Linux, MS Windows and many other platforms.

Keywords

ICT education, climate literacy, visualization, Gnuplot

Introduction

Our present civilisation is ever more dependent on using computers. All published texts and images are computer-based in our times. Most young people in rich countries are creating some. However, but a tiny proportion of them is able to use anything outside the scope of various clicking software. The skill of writing algorithms is not at all widespread. This is in spite of the fact most of you have experienced probably – writing and using algorithms is fun: "wow, it works!"

In the old times, producing graphics from recorded data was tedious, so publishing long tables instead was common. But an image is worth thousands of numbers, if we paraphrase an old saying. Making a graph from data contained in a spreadsheet file handled by some *office suite is often the climax of what is taught at schools in this respect.

A much more powerful tool to produce graphs is a standalone software gnuplot (1), http://www.gnuplot.info/. It is easy to install on any platform, starting to use it is as simple as possible. Apart from on-screen outputs, files in all useful graphics formats can be made, versatility of their appearance is immense. Learning to perform complex tasks is facilitated by taking examples from the gnuplot site and adapting them to the user's needs. Another source of good advice is (2). Gnuplot is "the" tool to generate graphs for wikipedia (3), a set of graphs for which the source scripts are shown is (4). Example scripts for climate data are, e.g, (5).

For the extremely broad scope of climate change, or just its core part, climate science, floods of data are freely available. Visualising them using gnuplot can help education and, in the same time, become a motivation for students to start using a simple scripting language – gnuplot can be their entrance to the art of programming. We have created a set of gnuplot scripts for our textbook (6), and further ones are being added. Data sources are fully documented within them, so that anybody can produce updated graphs in the following years.

Some scripts have English versions too, so it is easy to edit them to have titles in another language. Our students are asked to plot further data in a similar way, or in novel ways.

Example 1

The usual way of showing spectra is by using either wavelength, frequency or wavenumber on the horizontal axis. All of them are misleading as far as energy flux is concerned, the proper way is using a natural logarithm of their numeric value (7). An example for 3 solar spectra is at Fig. 1 – a task difficult to express in the grayscale domain. It is shown here just to demonstrate that tuning the shades of gray and thickness of lines enables to visualize even such data. For a nicer colour graph, the source data and gnuplot scripts referencing the data and producing both variants see http://amper.ped.muni.cz/gw/activities/graphs and its "sources" subdirectory.
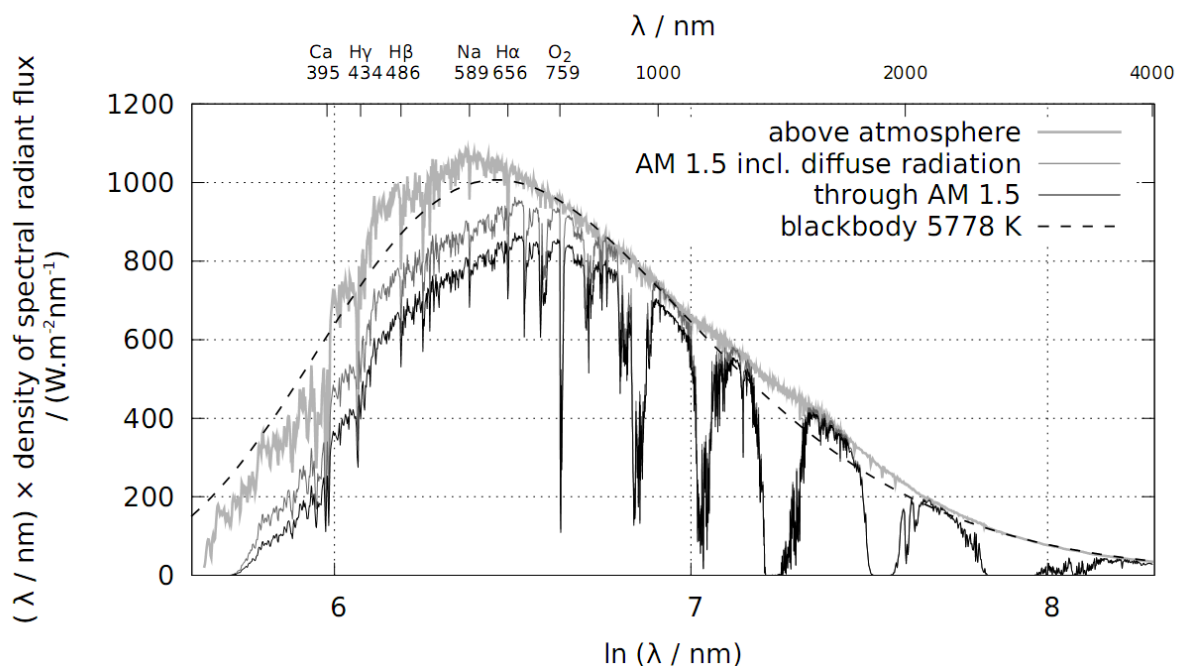

Fig. 1: Logarithmic scale of horizontal axis gives spectra of bodies emitting radiation due to their temperature the most reasonable shape; having the argument of the natural logarithm as a multiplier of the quantity on the vertical axis makes the area below the curve equal to the radiant flux. Sun does not shine as a blackbody due to the fact that in some wavelengths its radiation comes from deeper layers of the photosphere which are more hot, this concerns most of the visible range with exception of the strongest spectral lines, in which the photosphere is least transparent. A set of lines denoted by Fraunhofer as A, B (Hα), C, D, G' (Hγ) and H, K (these being very close together, both produced by calcium) is marked at the top axis from right to left. Line A is not produced in the photosphere, but by molecular oxygen in our atmosphere. The dashed curve represents so-called effective temperature, at which the total radiant flux of a Sun-sized blackbody would be the same as the solar one. The radiation at the bottom of the Earth atmosphere, at the sea level, is shown by the two lower-lying curves. It is fainter especially in several infrared bands due to absorption by water vapour. In the shortest wavelengths, direct sunshine (thin black line) is up to one third fainter than direct+diffuse radiation, as the air disperses such radiation much more than infrared – this is why the sky is deep blue if the air is very clear. Plotted values for "incl. diffuse radiation" concern a direction pointing to the Sun being at 42° of angular height, with its rays going through 1.5 more air than the vertical direction would imply, this is denoted as AM 1.5; they include radiation coming from the terrain ("light soil") as well. See details of air+ground conditions at the source of data, http://rredc.nrel.gov/solar/spectra/am1.5/. It is interesting to note, that for "amount of light", just the region between Hγ and Hα is what really matters – some one third of solar radiation around us.

Example 2

Much simpler spectra can help people understand why the old-time bulbs are rather inefficient sources of light, unlike Sun, see Fig. 2. For such smooth spectra, black dashed lines are OK, as available in the monochrome version of pdf terminal. As the previous figure, the bitmap version has been produced simply by marking the graph in pdf viewer by a mouse. The source script is bulbs.gnp at http://amper.ped.muni.cz/gw/activities/graphs/sources/.
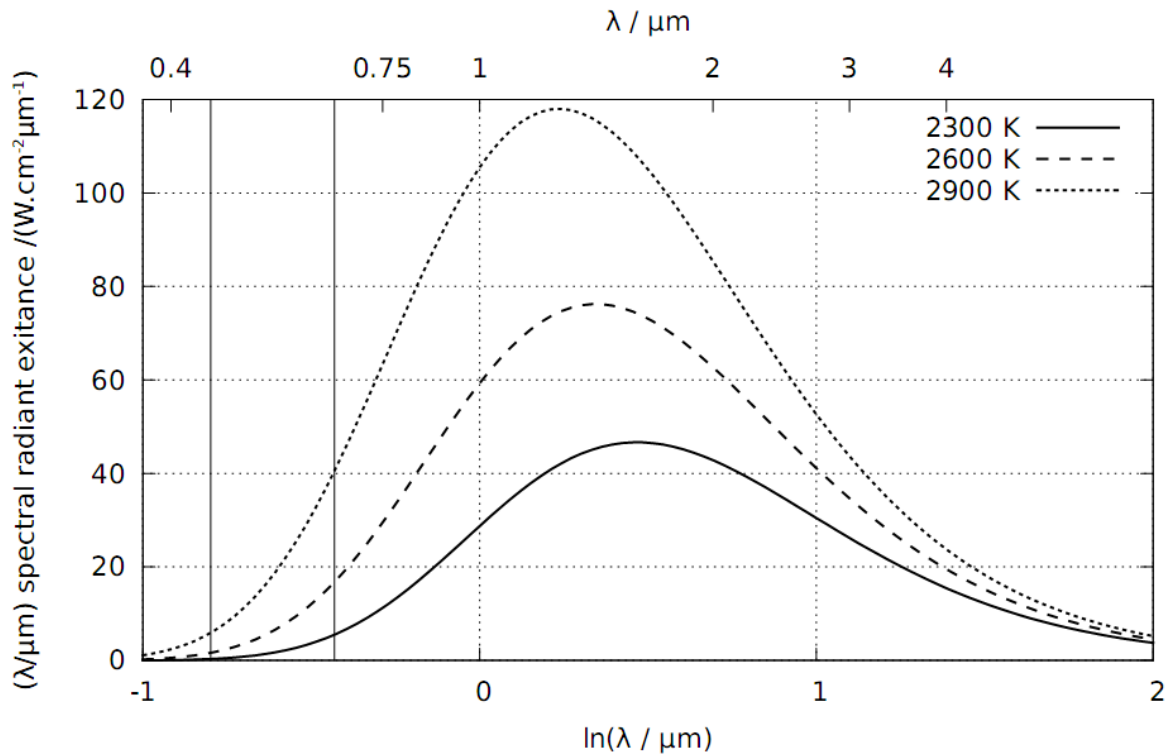

Fig. 2: Tungsten (wolfram) emits almost as a gray body, with emittance about 0.4, at temperatures common for shining wires in bulbs. Even at the highest temperatures which can be sustained for tungsten, just a tiny part of emitted radiation contributes to lighting. Vast majority belongs to the infrared domain.

Example 3

One of the most common misconceptions people have is confusion of climate with weather. Layman's judgement of climatic changes is often based on observation of a single weather event (unusually cold/hot day). Climate of a particular region can be defined as weather statistics over a long period. Climatologists prefer to use period of 30 years for averaging data obtained from weather stations. Most important variables for climate classification are air temperature and precipitation. Monthly averaged temperature and total precipitation over long period can be shown in a single graph called "climograph". Climographs of different regions are ordinarily shown in geography textbooks and atlases of the world. One quick look at the climograph can give you quite good idea about climatic conditions of a given location.

Climograph puts together weather and climate. To enhance student's understanding of connection of weather and climate, they should practice reading and interpreting climographs. There are many ways how to teach climographs at schools. Following activity is suitable for

ICT lessons. The goal is to plot a climograph with gnuplot. First of all students will choose any weather station and download its data (24-hr average temperature and precipitation) from the websites http://www.worldclimate.com/. If students are not yet familiar with gnuplot they might not be able to write the whole script from scratch. In this case they can be provided with a script and their task is to modify data file and adjust graph's vertical axes for their data. Additionally the can be asked to change type of output file, size picture, type of font, colours, etc. The source script for climograph Brno-Tuřany (see Fig. 4) climograph.gnp and data file turany.txt is available at http://amper.ped.muni.cz/gw/activities/graphs/sources/.
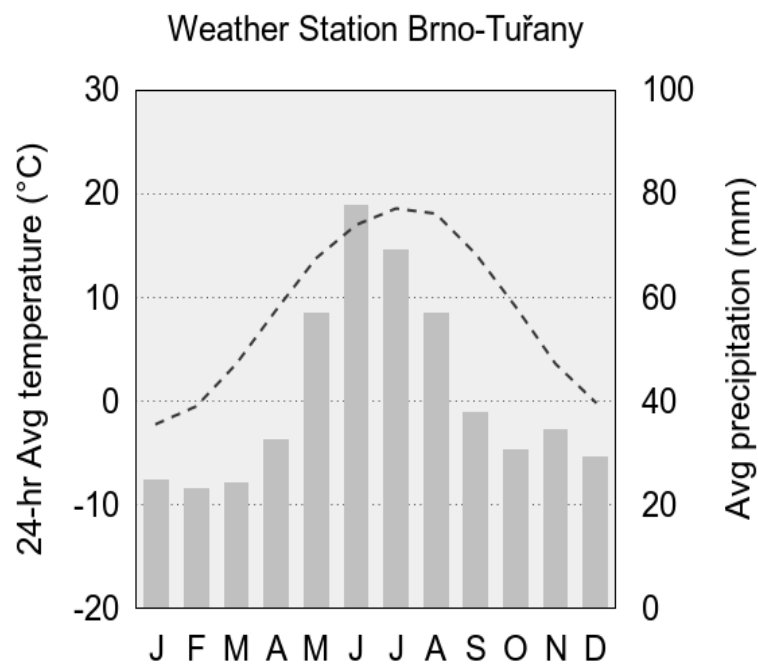

Fig. 4: Climograph for weather station Brno-Tuřany (Czech Republic) showing 24-hr average temperature (dashed line) and precipitation (grey columns) for period 1951–1990. Horizontal axis represents 12 months of the year.

Example 4

Global warming is most usually expressed in terms of change of temperature of air at 2 m and of open sea surface. The global temperature anomaly from such data is much influenced by the ENSO – in its positive phase El Niño, less heat goes to the oceans, whereas in the negative phase, La Niña, deep ocean warms and surface cools. The strongest El Niño ever observed caused the 1998 temperature anomaly. Cool anomalies in the mid-80's and in the beginning of 90's were caused by SO_2 emissions from El Chichón and Pinatubo huge volcanic eruptions. Trends of the global temperature anomaly expressed in kelvins per decade is often discussed; in short timespans, less than 15 years, it can be due to such influences even negative. It is an easy exercise to compute such trend using linear regression. Our gnuplot script does this task (see http://amper.ped.muni.cz/gw/activities/graphs/GISStemp/) and produces a graph saying two trends: over the whole selected timespan, and over some shorter one. An example is at Fig. 5. In this case, monochrome mode of a png terminal was enough, using differing line widths.
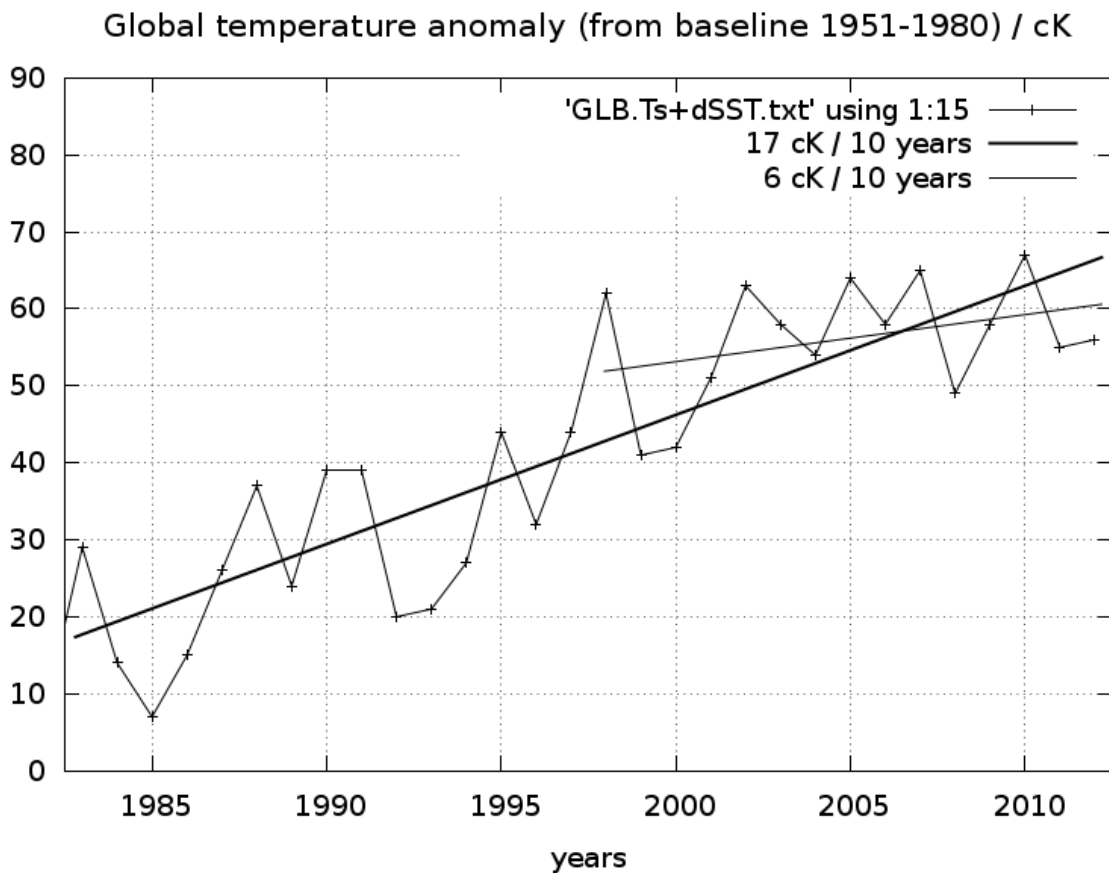
Global temperature anomaly (from baseline 1951-1980) / cK

Fig. 5: Linear fits of GISS land+sea temperature anomalies, as plotted by a gnuplot script. The temperature trend over the last 15 years is smaller due to the super-strong El Niño at its beginning and prevailing La Niña at its end.

Conclusion

Much more complicated tasks may be solved by gnuplot. The above examples are graphs from our textbook (7), just changed from Czech to English and tuned to some tolerable non-colour versions. Hundreds of excellently documented examples of graphs are available at the homepage of gnuplot, http://www.gnuplot.info/ and the links from there. Studying them can be a way how to learn the art of making graphs. Or even maps, as the example at (2) shows. From another conference participants, we would welcome any advice how to attract pupils and students to master computer-production of graphs and maps, and we are curious about their experience in visualization of science-based data.

From our past experience, we can offer an almost continuous series of graphs of light data and mostly of meteo data as well, from summers 2006 to 2012. An overview of them is, e.g., http://amper.ped.muni.cz/weather/allnew10.htm and the comments on their making and the employed scripts (also in bash, to modify gnuplot scripts for each day) are at http://amper.ped.muni.cz/weather/.

Acknowledgements

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