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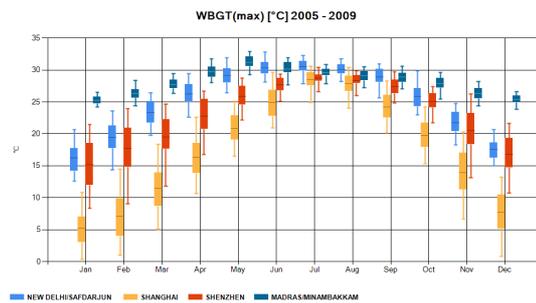
What Hothaps-Soft can do

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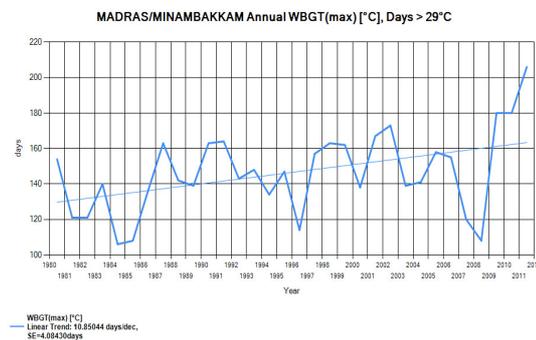
This is Section 1 of the Hothaps-Soft manual and serves as an introduction and provides an overview of the software's features.

- Section 2 contains step by step descriptions of the actual operation of Hothaps-Soft
- Section 3 contains more detailed technical specifications.

Monthly heat exposure patterns



Number of super-hot days



Comparisons of different locations

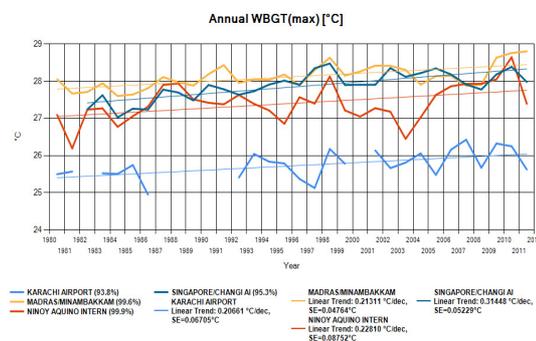


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Aims and applications of Hothaps-Soft

This software was developed to conveniently describe the local climate conditions in different parts of the world, based on routine weather station data and local grid cell estimates. There is a special focus on the seasonal variations of heat exposure and how these are changing and how they may develop in the future with climate change. The software uses daily weather station data freely available on the Internet..

The Hothaps-Soft facilitates the presentations of long term time trends of local climate data for local heat exposure and climate change analysis. A number of different data presentation outputs are available, including threshold analysis which shows the numbers of days above a selected level of any of the climate variables. This makes it possible to describe occurrence of “extreme events”.

Data and calculations can be exported from Hothaps-Soft for use in Excel spreadsheets. Further user-friendly applications are under development.

While not limited to it, our special interest is in workplace heat exposures, estimated from the geographically based climate data, and relations between local heat exposures and impacts on occupational health risks and heat related reductions of work productivity. The software calculates specific heat stress indicators used in workplace assessments. The results for particular time periods and the time trends can be used for other local climate descriptive analyses, with any particular aim (e.g. analysis of climate situation for agricultural production).

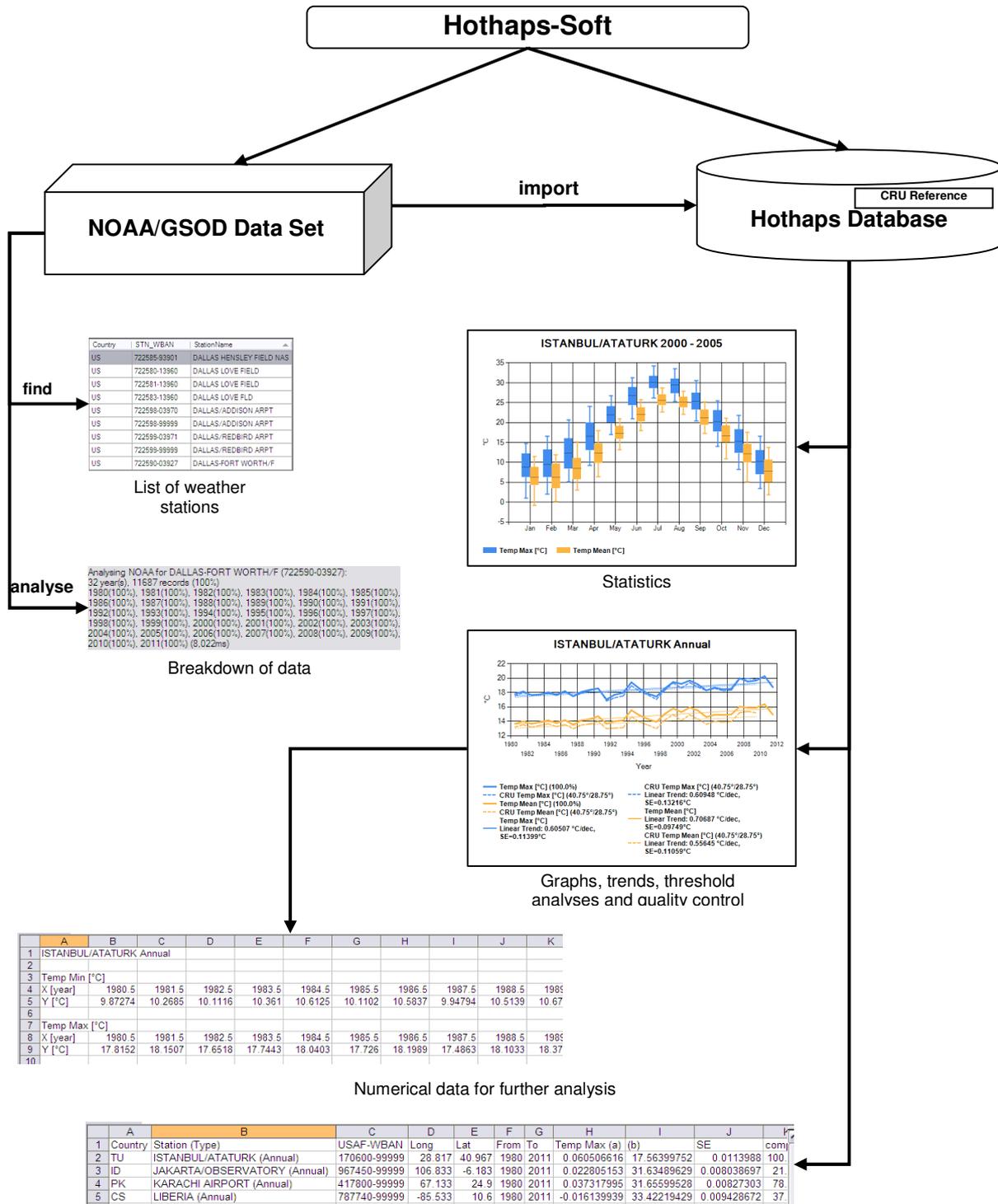
The ultimate aim is to provide information that can be used to

- assess the importance of climate change mitigation
- assess the need for better programs for occupational heat stress prevention, and
- assess the need for improved urban planning and building design to reduce future heat stress inside the buildings, whether they are workplaces, commercial centres or residences.

Potential users of the software

The outputs of this software are of particular value for occupational health professionals and administrators, but it also produces important heat exposure data for any other application. The climate descriptions and trend analyses can be of importance for agricultural services, building code analysts, planners, architects and the construction industry, air conditioning and refrigeration as well as general engineering and manufacture, global corporations and, of course, climate change researchers.

Overview of software components, processes and outputs



Inputs

Weather station data:

Daily data from NOAA/GSOD (US National Oceanographic and Atmospheric Administration/ Global Summary of the Day); includes every day from 1980 to the present. The dataset includes: Daily maximum, mean and minimum temperature (Tmax, Tmean and Tmin); dew point (Td); rainfall; average wind speed; maximum wind speed.

Data availability and reliability is a major concern. NOAA aggregates data from thousands of stations around the world. Depending on local conditions (e.g. stations being moved, renamed, equipment being replaced, upheavals like wars and strikes, etc.) climate data over the 30 year period considered for this study is patchy in a number of the larger cities. Our software only includes data into the database when at least 90% of daily data are available for a month.

The GSOD data set contains humidity data, which is fundamental to heat stress calculations. The more limited, but more closely quality controlled, GHCN data set (Global Historical Climatology Network) has no humidity data. One study that used an automatic quality assurance system (Durre et al., 2010) identified less than 1% errors in 1.5 billion climate data recordings. We expect the percentage errors in the GSOD data set to be small as well, but, when possible, any outputs should be compared with data from different data sets. This is one reason why we have included the CRU grid cell data in the software.

Grid cell averaged climate data:

Global data, 0.5° x 0.5° grid cells (50km square at the equator), monthly estimates from CRU-3 (University of East Anglia, UK, Climate Research Unit) (Goodess and Harris, 2010) includes every month 1980 – 2011. The dataset includes: Tmax, Tmean, Tmin, water vapor pressure/dew point, wind speed, (other variables may be added, e.g. monthly rainfall). The data set is described in publications from CRU (CRU, 2004; Mitchell & Jones 2005).

Site selection

Before importing and producing graphical or tabular outputs, Hothaps-Soft allows location and the assessment of available weather station data.

- Stations can be located by a text search of any part of a station's name
- Stations searches can be narrowed to a particular country
- Stations can be located using latitude and longitude
- Stations can be analysed and their *data density* displayed

Finding specific weather stations

When the name of a weather station is known, one can search for that specific station. Many weather stations in GSOD may have unexpected names. For instance, looking for weather stations in Bangkok, the previous major airport is included in the GSOD data set as “Don Muang”, the local name for that airport. Thus, it is sometimes necessary to carry out a bit of searching for the station of interest.

Finding country-specific stations

A search for weather stations in a specific country is easy. One can either show all stations in the downloaded GSOD data set, or search for a particular name or fraction of a name, and then narrow the search by selecting a country.

Finding near-by stations

The *Find Nearby* feature allows searching available stations within a specified area around the entered coordinates. A square or a circle around a specific weather station can be defined by size and a simple search immediately shows which station lie within the square or the circle. Because the coordinates of a selected station are automatically filled into the search criteria, one can effectively search for sites around any given station.

Analysing weather station data

The graphics and tabular output options for each month and year are only available for weather stations where at least 90% of the days have recorded data. The *Analyse* feature scans the available data and calculates the *data density* for selected stations: Data density = proportion (%) of daily data available at this location during the selected time period; if all daily data is available, the density is 100%. Analysing the data density and can lead to an importing choice.

Outputs

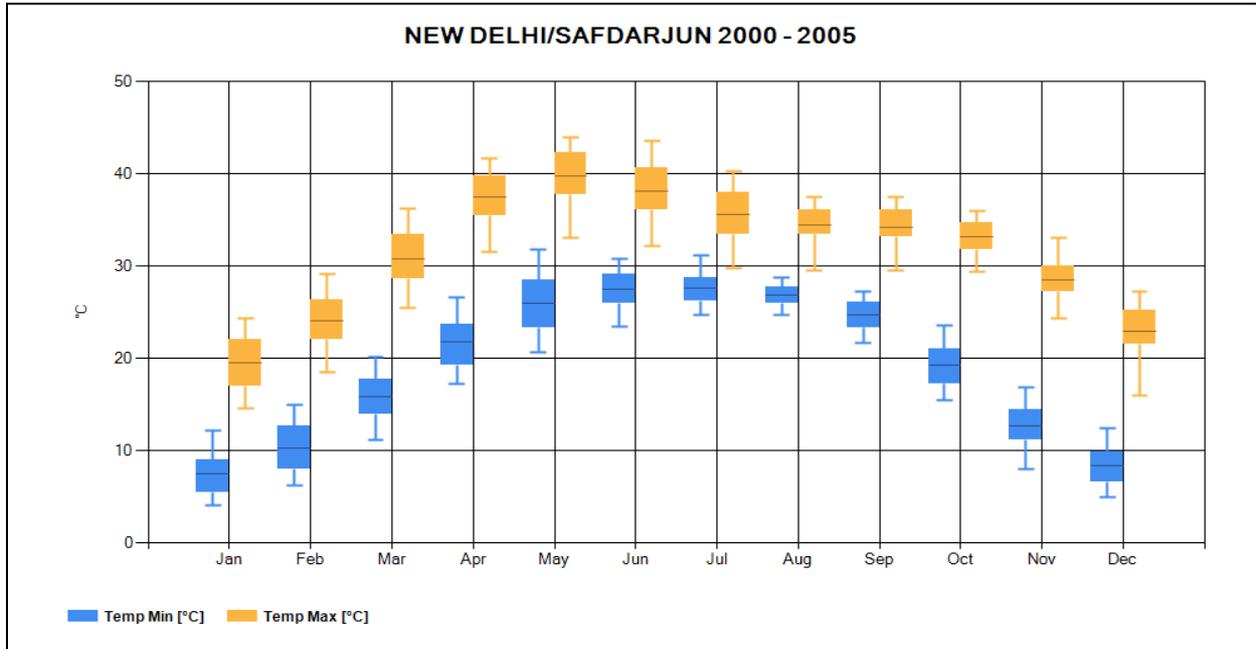
Hothaps-Soft produces graphic or tabular outputs for selected locations in a few seconds.

Derived from daily data, basic climate variables and calculated indicators can be displayed, like WBGT (Wet Bulb Globe Temperature; a widely used occupational heat exposure indicator), UTCI (Universal Thermal Climate Index; a new World Meteorological Organization recommended indicator of perceived heat stress). WBGT and UTCI are calculated based on humidity, Tmax and Tmean. WBGTmax and UTCImax would describe typical mid-afternoon highest heat exposure levels. Heat indexes based on Tmean denote the average exposure over a day. A respective mid-point calculation is also available.

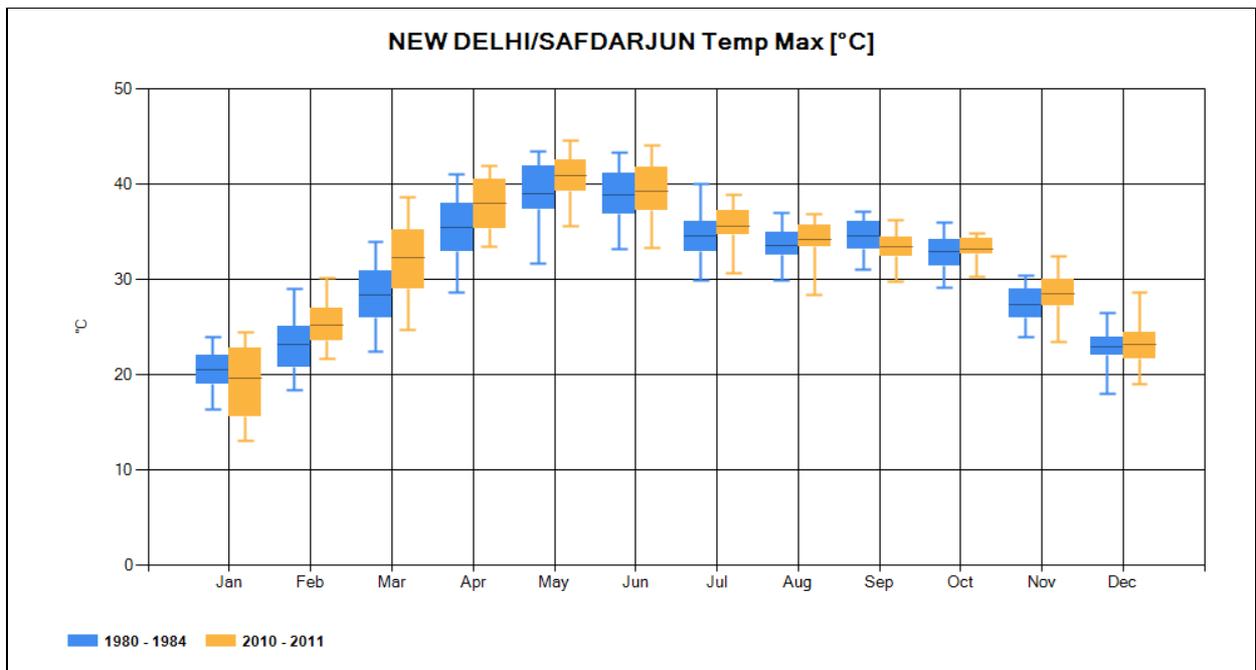
Graphics showing monthly variations in climate variables or time trends, 1980 until the last full calendar year can easily be produced and exported as .jpg or .png files to any folder. All graphical outputs can be customised by setting axis-values, markers, headings, legend positions, choosing font sizes and colours, or choosing black and white only mode. Some examples are shown below.

Monthly climate status at specific sites

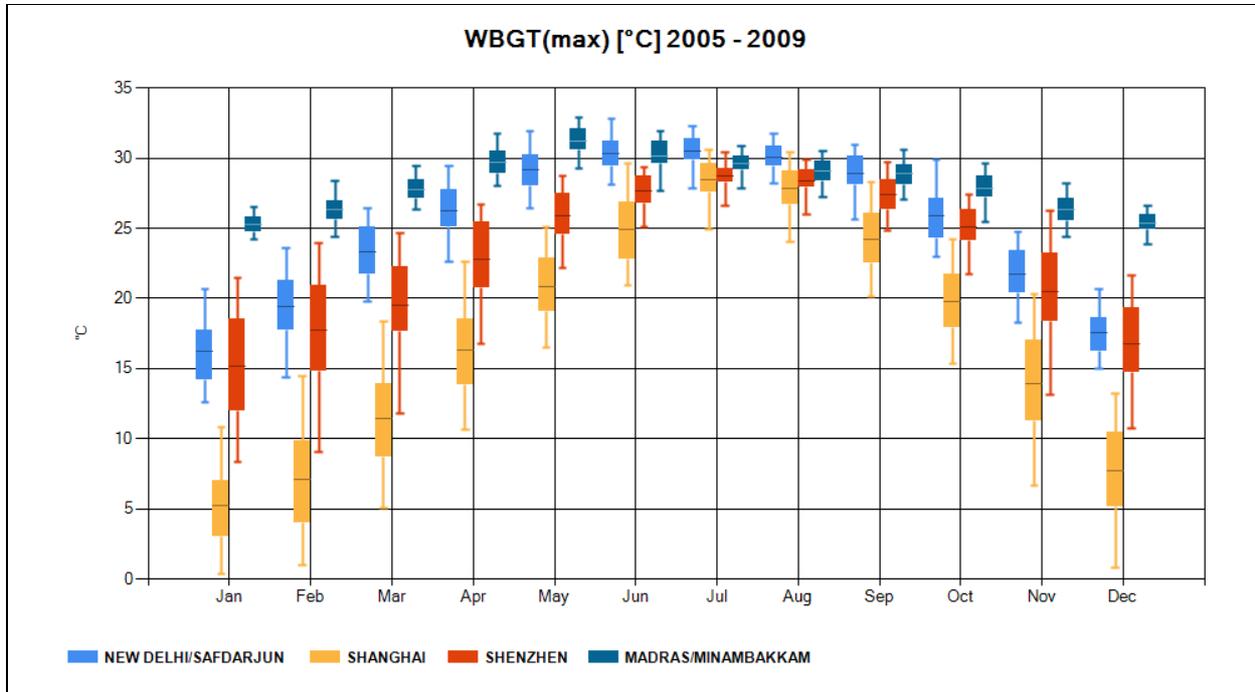
The figure below shows the Tmax and Tmin for Safdarjun airport in central New Delhi: monthly averages (means) as line, box with 25-percentile, and bars (whiskers) out to 5-percentile in each direction. The box and whiskers percentiles can be customised. The graphic can be customised to show means and/or medians for each month, as well as extreme values (i.e. outliers outside the whisker percentile).



These graphics can be produced for any time range, and can include more than one time period in the same graph, as shown below. The average Tmax has increased during most months:

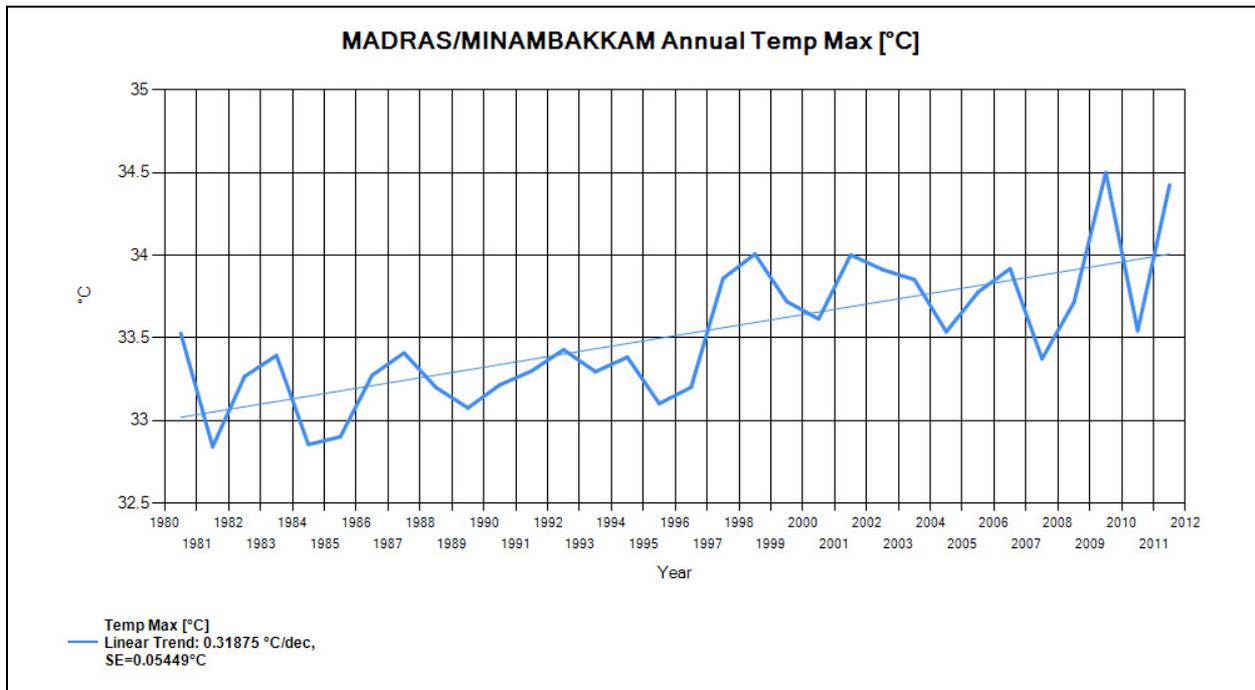


The graphs can also compare monthly averages of heat exposures at several sites. The following graph shows that the summer months are very hot (average WBGTmax > 25 °C), while winter months in Shenzhen, Shanghai and New Delhi are cool. Chennai (Madras) is hot all year round.

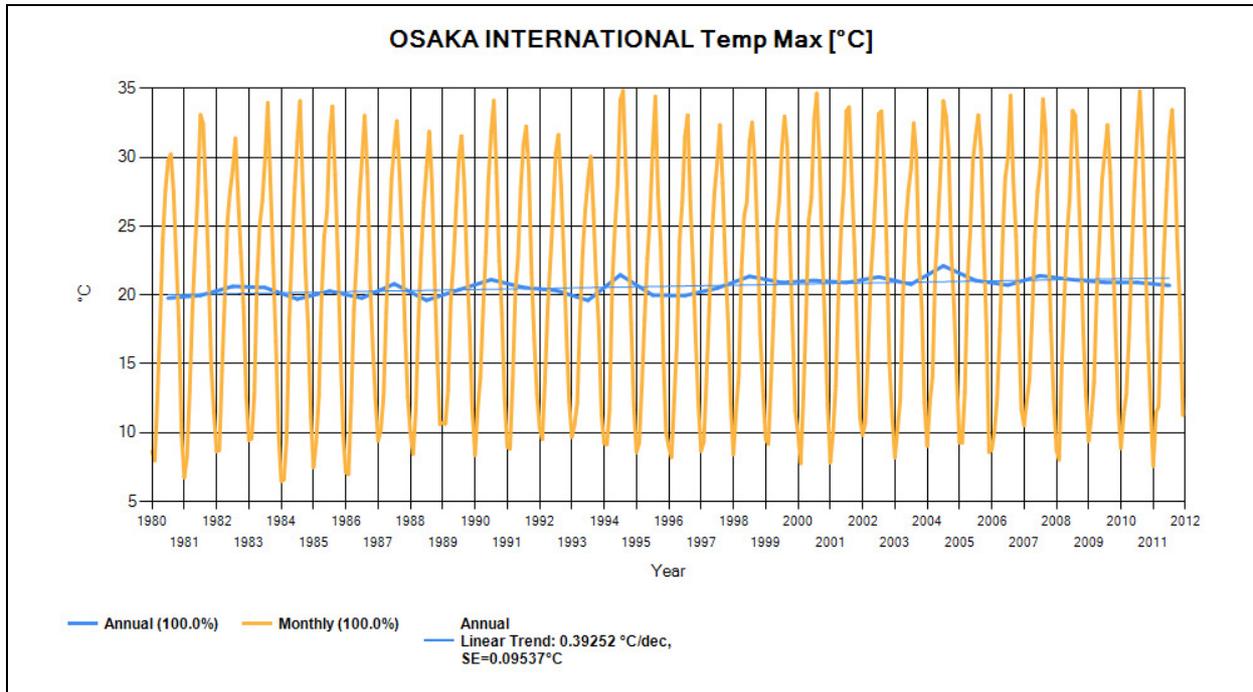


Time trends at specific sites

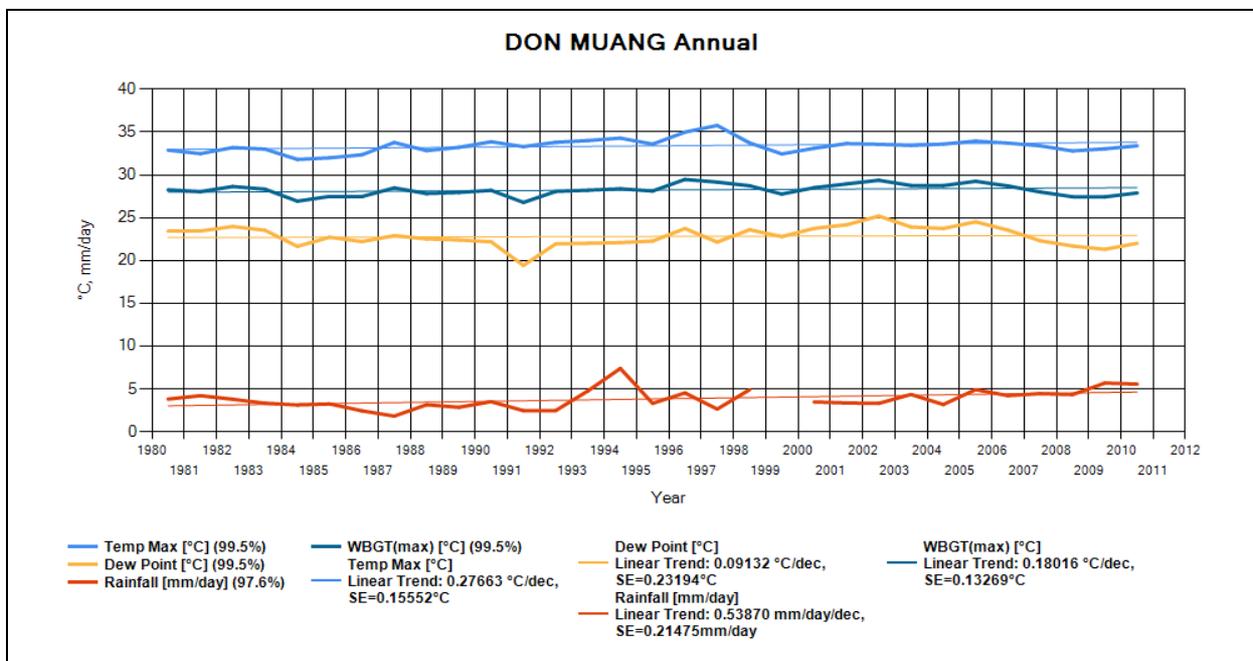
Monthly or yearly time trends can easily be shown. The graph below shows the annual trend from 1980 to 2011 of Tmax in Madras with a fitted line increasing 0.32 °C per decade.



Time trends can be displayed as monthly and/or annual averages. In Osaka the trends go upwards by 0.4 °C per decade. The legend shows the trend's slope as well as the Standard Error (SE).



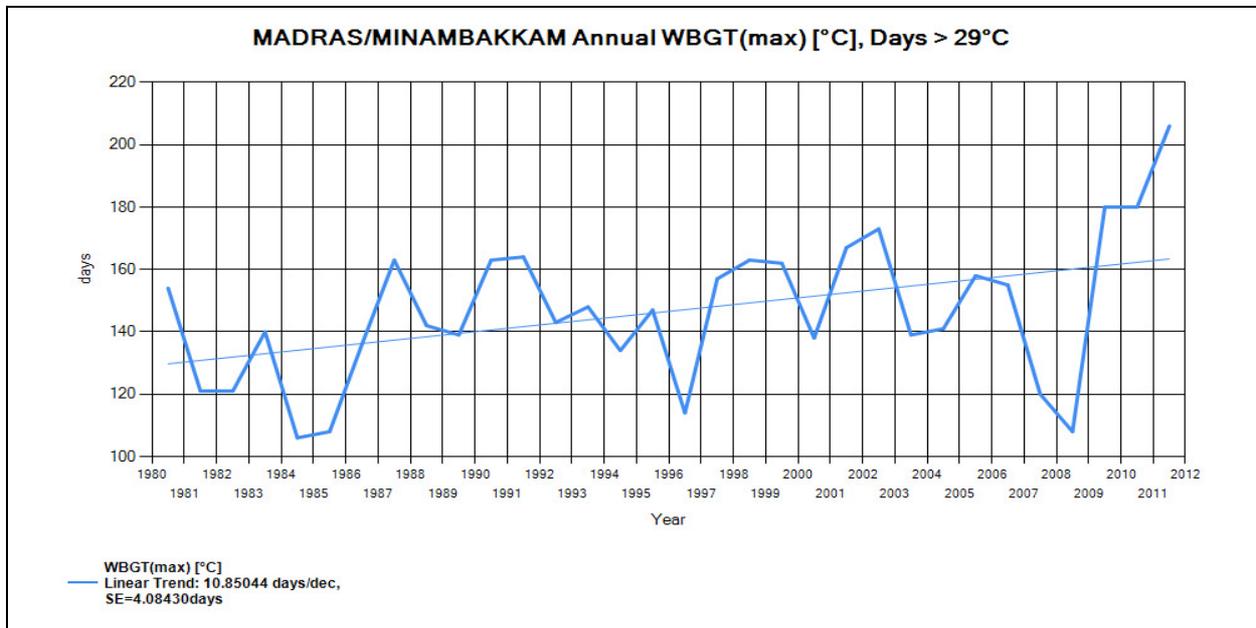
By including several climate variables, one can judge the links between the variables. At Don Muang airport in Bangkok, annual Tmax and rainfall are going up, Td (dew point) is also going up, and the combination of Tmax and Td creates an increase in the calculated WBGTmax.



The time trends may look rather flat, but the global climate change trend that is of concern is as low as 0.2 °C per decade. Hothaps-Soft can also calculate the number of days above a threshold:

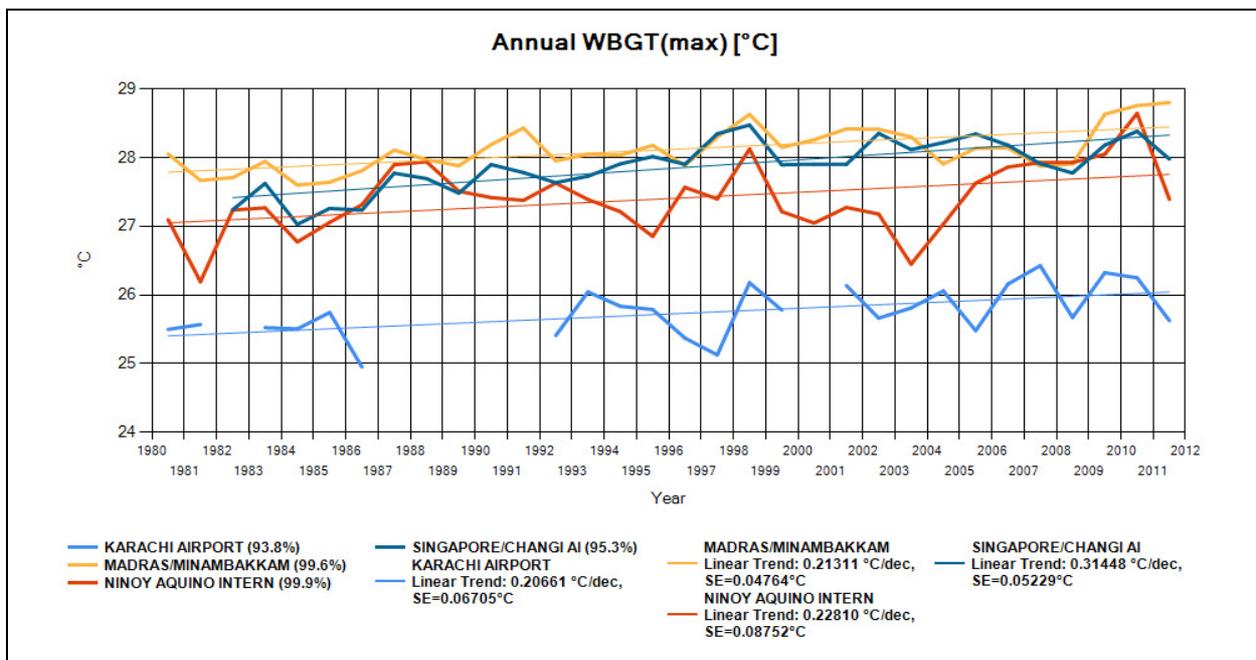
Number of days above a set threshold

Such numbers can be presented for any of the climate variables and heat stress indexes. For instance, the number of days that WBGTmax exceeds 29 °C each year in Chennai (Madras) is increasing by 10.9 days per decade. This means that during the 32 years plotted the period with such extreme afternoon WBGT values has lengthened by more than a month:



Comparisons between sites

WBGTmax in four Asian cities are compared. Gaps occur when full annual data (at least 90% daily data in each month or year) is not available:



Comparison between GSOD and CRU-3 data

To validate time trends of climate variables for a specific weather station, CRU-3 grid cell data containing this weather station can be overplayed. The CRU-3 data represents a $0.5^\circ \times 0.5^\circ$ square, and the levels sometimes differ from the levels at the weather station. But when the time trends are similar (see below) it is likely that the rate of change is reasonably accurate (in this case approx. 0.3°C per decade increase of Tmax at Bangkok's Don Muang airport):

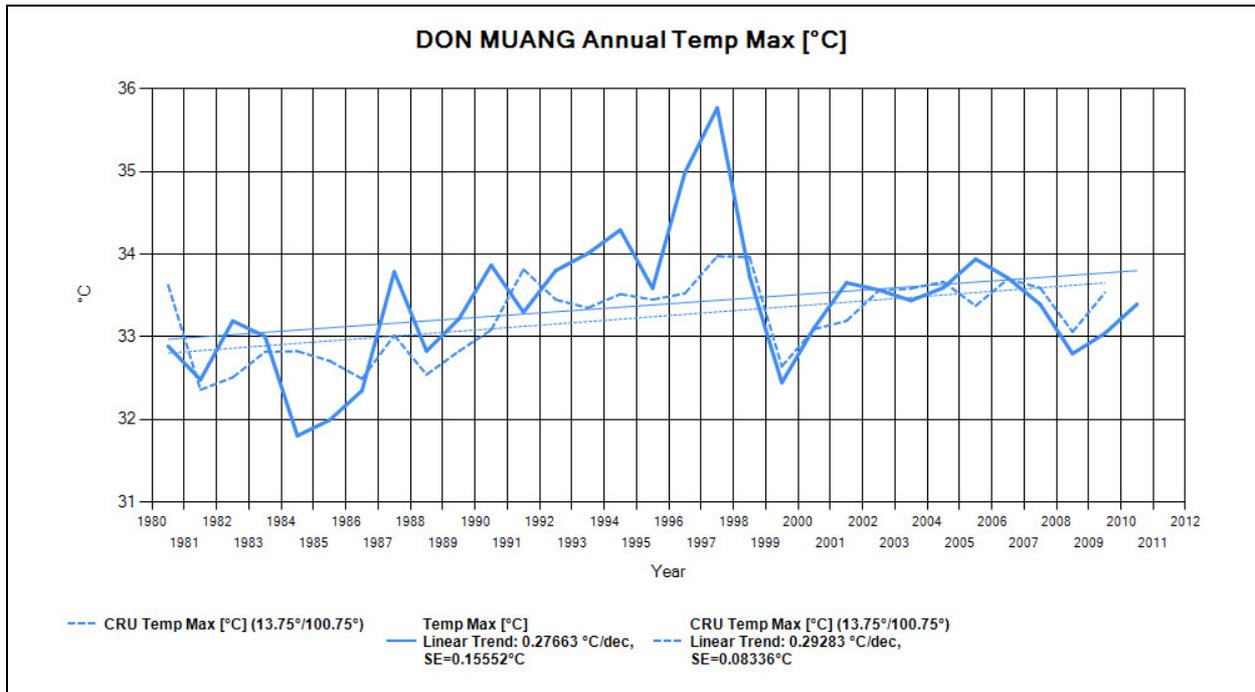
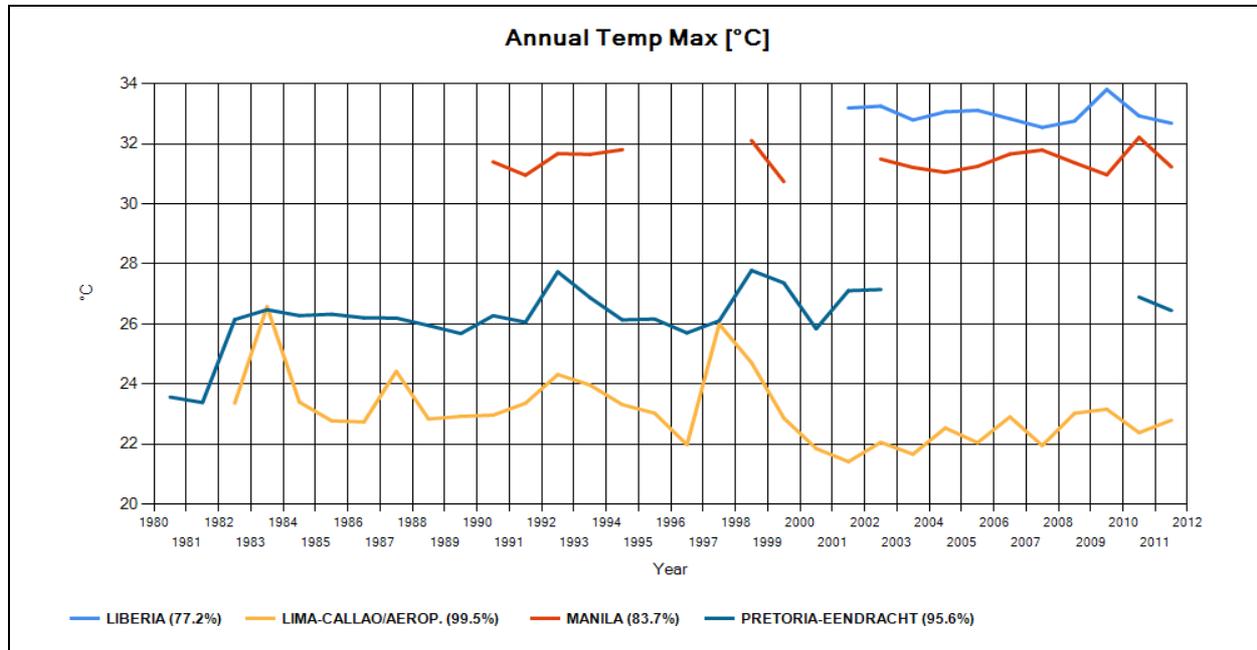
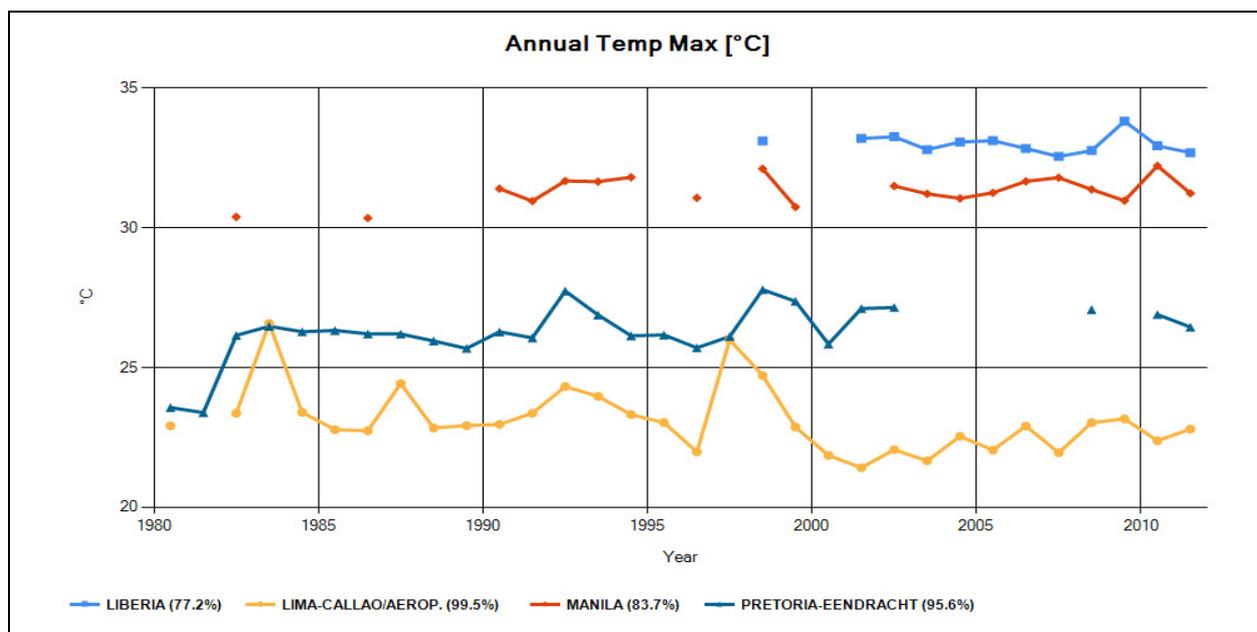


Chart customisation

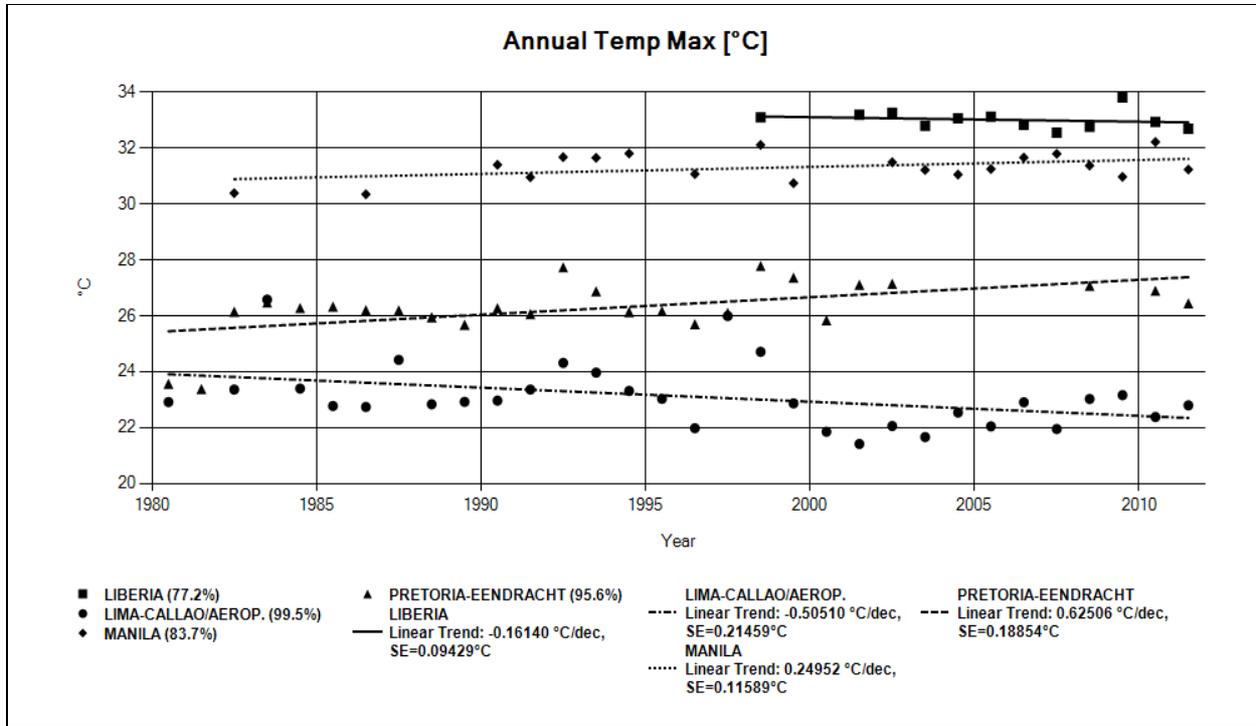
Display details can be changed to suit individual requirements. The following chart is a starting point, which is redrawn below after modifying a few parameters:



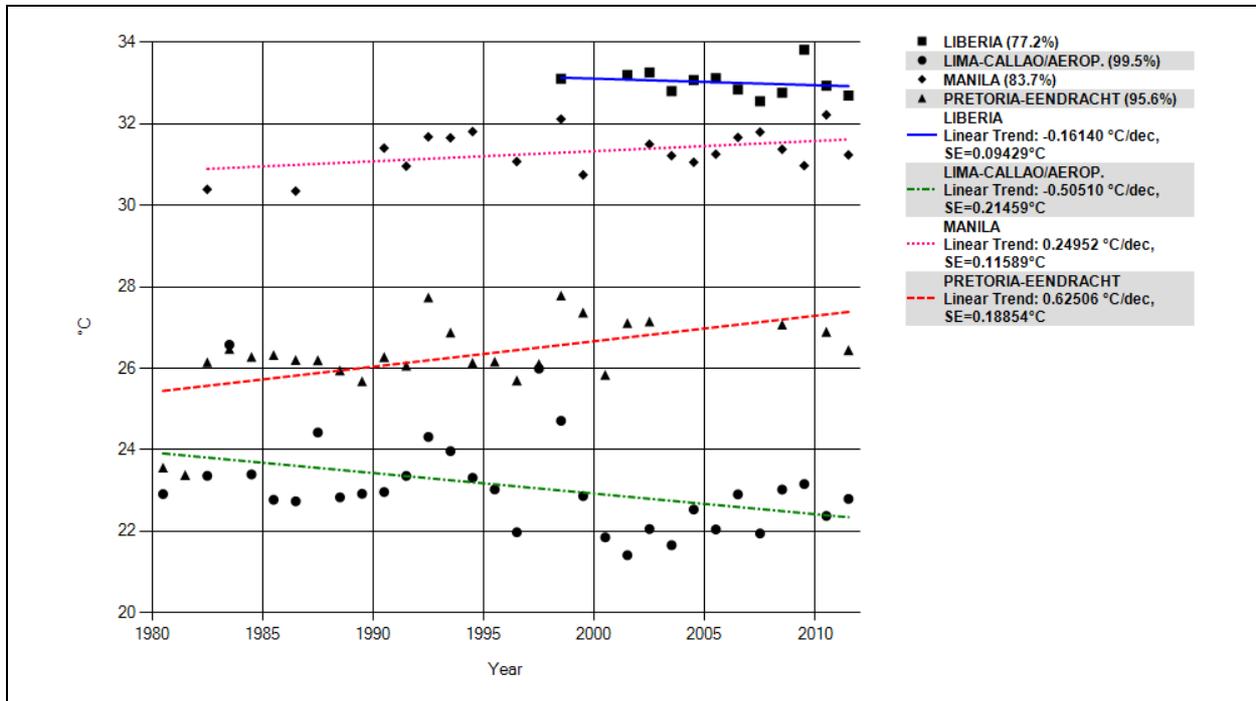
For the chart below the X and Y axis divisions have been changed (both set to 5) and the Y-axis maximum fixed to 35. In addition *Markers* have been turned on to reveal additional data-points (as *lines* are only drawn between 2 adjacent data-points):



For this graph *Lines* have been turned off (i.e. only markers are visible) which makes the trend lines stand out. In addition colours have been turned off, as many publications are black & white only:



You can also change the axes' font size, modify the position and font size of legends, turn legends and/or headings off altogether, and assign custom colours to each graph:



Exporting numeric data

When a weather station dataset is ready for analysis and graphic presentations, one can choose to produce statistical analysis outputs in numeric form, which can then be opened as a file or directly exported into an Excel spreadsheet for example. For the selected (highlighted) values the following outputs are supported:

- Average: A single average value as well as the standard deviation (SD) based on daily readings or monthly/annual averages
- Regression (Average): Slope (a) in unit/year, intersect (b) and standard error (SE)
- Regression (Thresholds): After entering a threshold value slope (a) unit/year, intersect (b) and standard error (SE) are produced
- Slope Residuals: Sums the differences between the data values of the last 10, 8, 6 and 4 years and the trend line/slope of the series
- Average Residuals: Sums the differences between the data values of the last 10, 8, 6 and 4 years and the series' average
- Raw Daily Data: Creates one comma-delimited text file containing daily records for each selected station
- Raw Data from Graphic Windows: Any data plotted in the chart windows

Here are some examples: The following exports are all preceded by the station(s) details and the time period. E.g. for **Dallas Forth Worth Airport** between **1980** and **2011** you get:

| | | | | | | |
|---------|-----------------------------|--------------|---------|--------|------|------|
| Country | Station (Type) | USAF-WBAN | Long | Lat | From | To |
| US | DALLAS-FORT WORTH/F Annual) | 722590-03927 | -97.041 | 32.896 | 1980 | 2011 |

Most outputs also quote the degree of completeness (compl) as a percentage. The output for **Regression (Averages)** appends the following fields:

| | | | |
|--------------|----------|----------|---------|
| Temp Max (a) | (b) | SE | compl |
| 0.041061209 | 25.23947 | 0.018307 | 100.00% |

The output for **Regression (Thresholds) for > 35 °C** appends the following fields:

| | | | |
|-------------------|----------|----------|---------|
| Temp Max > 35 (a) | (b) | SE | compl |
| 0.472690616 | 49.64205 | 0.448188 | 100.00% |

The output of **Raw Daily Data** shows the station's details, a recording date column plus one column for each chosen value. For the selections above the table would appear like this when opened in Excel (only the first few values are shown here):

DALLAS-FORT WORTH/F (722590-03927)

| | |
|-----------|----------|
| Rec Date | Temp Max |
| 1/01/2011 | 9.38889 |
| 2/01/2011 | 9.38889 |
| 3/01/2011 | 15.6111 |
| etc. | |

Future software developments

The following inputs and outputs are potential additions being explored, but the impact on analysis speed etc. will need to be considered before further modifications are made.

Climate data

Data for additional intra-software analysis: Average hourly distributions of T_{air} , T_d , expressed as T_{max}/T_{mean} and T_{dmax}/T_{dmean} for each month weather station, based on hourly data from GSOD, available from 1992 – 2006

(work is in progress to see in which practical and valid manner such hourly distributions could be produced and entered into Hothaps-Soft).

Special quality assurance analysis data: Comparisons with quality controlled weather station data, e.g. daily from NOAA/GHCN

Solar radiation inflow data to calculate outdoor heat exposures in the sun: from NASA, same grid cells as CRU (could be added; currently explored)

Modelled future climate data: from CRU or other modelling sources (this will require decisions about which models to include, etc.). We have access to CRU-models and other models for grid cells for each month in 2030 and 2050. Our website www.ClimateCHIP.org already displays current climate models based on RCPs.

Making maps of monthly climate and heat stress variables based on grid cell data: Such maps have already been made for selected areas, and these maps can become a powerful tool in communicating heat stress issues in different parts of the world.

Health, productivity and economic impact estimates

Health and productivity risk estimates: Exposure-effect and exposure-response relationships for workplace heat exposure have been described in publications based on field study evidence and experimental studies. Hothaps-Soft could include choices for calculations of health and productivity risks (as well as confidence interval estimates) as the software is further developed.

A major report for WHO already contains such risk estimates, and they show that in the most affected parts of the world, e.g. South Asia and West Africa, people in heavy labour jobs outdoors are going to need to take longer and longer midday/afternoon rest breaks to avoid heat stroke. This reduces their work productivity at least during daylight hours. As much as 10% of annual daylight hours is already lost due to heat, and this will increase to 20% or more in 2050, based on the climate models available.

Population data: These data can make it possible to calculate the heat impacts in terms of number of affected persons. We already have data from IIASA, gender and age distributed (ages 0-4, 5-14, 15-64, 65+); same grid cells as CRU, for 1975, 2000, 2030 and 2050.

Economic impact analysis: When the numbers of affected people has been calculated, the results can also be put into an economic context for that particular country or region. The economic losses due to heat can be both as a result of actual health impacts, but more importantly it will be a result of reduced work ability during excessively hot parts of each day. The methods for this analysis is still under development, but one can foresee that for some countries or parts of countries the annual GDP may be reduced by several percent due to current and future increasing heat.

The software and this documentation are subject to regular revision.

Please contact the team at info@climatechip.org for further information as well as applying for a copy of the software.