ClimPACT2

https://github.com/ARCCSS-extremes/climpact2/

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Lisa Alexander and Nicholas Herold contributed significantly to development of this document, the indices and the ClimPACT2 software. The majority of indices in ClimPACT2 are calculated using code from the climdex.pcic R package which was developed by the Pacific Climate Impacts Consortium (PCIC). Input was also provided by James Hiebert of PCIC during development of ClimPACT2.

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The ClimPACT2 software updates ClimPACT which was based on the RClimDEX software developed by the WMO CCl/WCRP/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI). The CCl Co Chair for the CCl OPACE on Climate Monitoring and Assessment (Manola Brunet), ETCCDI members, Albert Klein Tank and Xuebin Zhang, along with Enric Aguilar, Juan Jose Nieto, Javier Sigro, Peter Domonkos, and Dimitrios Efthymiadis, contributed to development of the indices and software in the previous version of the technical manual.

ClimPACT2 is written in R, a language and environment for statistical computing and graphics and makes use of several R subroutines, including SPEI. R is available as Free Software under the terms of the Free Software Foundation's GNU General Public License in source code form.

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CREDITS

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Batch processing: Nicholas Herold.

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1. Background to the ET-SCI

This document was prepared on behalf of the World Meteorological Organization (WMO) Commission for Climatology (CCl) Expert Team on Sector-specific Climate Indices (ET-SCI). It outlines the background and goals of the ET-SCI and describes indices and software that were developed on their behalf.

The ET-SCI, formerly known as the Expert Team on Climate Risk and Sector-specific Indices (ET-CRSCI) was set up by the Fifteenth session of the WMO Technical Commission for Climatology (CCl-XV, Antalya, Turkey, February 2010), with terms of reference established to support eventual implementation of the Global Framework for Climate Services (GFCS). Following the sixteenth World Meteorological Congress in May 2011 where a decision was made by WMO members to implement the GFCS, the ET-SCI held their first meeting in Tarragona, Spain (13-15 July, 2011).

1.1 Role of ET-SCI in GFCS

The ET-SCI sits within CCl under the Open Panel of CCl Experts (OPACE) on Climate Information for Adaptation and Risk Management (OPACE-4). The objective of OPACE-4 is to improve decision-making for planning, operations, risk management and for adaptation to both climate change and variability (covering time scales from seasonal to centennial) and will be achieved through a higher level of climate knowledge, as well as by access to and use of actionable information and products, tailored to meet their needs. Activities primarily focus on the development of tailored climate information, products and services for user application in adaptation and risk management, and building interfaces with user groups to facilitate GFCS implementation.

The work of OPACE-4 is multidisciplinary, and requires close collaboration with experts from various socio-economic sectors. In keeping with the priorities agreed for initial implementation of the GFCS, the core priority sectors for consideration by the OPACE in this present intersessional period are agriculture/food security, water and health. This requires close collaboration with relevant experts in these sectors including seeking guidance and aid from the WMO Technical Commissions for Agricultural Meteorology (CAgM) and Hydrology (CHy) and with the World Health Organisation (WHO).

The ET-SCI Terms of Reference (ToR) and expected deliverables are shown in Appendix A. The deliverables include the collection and analysis of existing sector-relevant climate indices in addition to developing the tools required to produce them. At a meeting in Tarragona in 2011, members of the former ET-CRSCI invited sector and Commission representatives to help define a suite of indices that would represent a "core set" that would meet the ToR and deliverables. This manual outlines the rationale behind the creation of those indices and the ClimPACT2 software developed for their calculation.

1.2 The 'value' of climate indices

Monthly averages of climate data smooth over a lot of important information that is relevant for sectoral impacts. For this reason indices derived from daily data are an attempt to objectively extract information from daily weather observations to answer questions concerning aspects of the climate system that affect many human and natural systems with particular emphasis on extremes. Such indices might reflect the duration or amplitude of heat waves, extreme rainfall intensity and frequency or measures of extremely wet or dry/hot or cold periods that have socio-economic impacts. Climate indices provide valuable information contained in daily data, without the need to transmit the daily data itself.

Much progress has been made in recent decades through internationally agreed indices derived from daily temperature and precipitation that represent more extreme aspects of the climate, overseen by the CCl/WCRP/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI). Development and analyses of these indices has made a significant contribution to the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports.

1.3 Background to ETCCDI, Indices and Software

The ETCCDI started in 1999 and is co-sponsored by the World Climate Research Program (WCRP) and JCOMM. They developed an internationally coordinated set of core climate indices consisting of 27 descriptive indices for moderate extremes (Alexander et al. 2006; Zhang et al. 2011). These indices were developed with the 'detection and attribution' research community in mind. In order to detect changes in climate extremes, it was important to develop a set of indices that were statistically robust, covered a wide range of climates, and had a high signal-to-noise ratio. In addition, internationally agreed indices derived from daily temperature and precipitation allowed results to be compared consistently across different countries and also had the advantage of overcoming most of the restrictions on the dissemination of daily data that apply in many countries.

ETCCDI recognized that a two-pronged approach was needed to promote further work on the monitoring and analysis of daily climate records to identify trends in extreme climate events (Peterson and Manton, 2008). In addition to the formulation of indices described above, a second prong was to promote the analysis of extremes around the world, particularly in less developed countries, by organizing regional climate change workshops that provided training for the local experts and conducted data analysis. The goals of these workshops are to: contribute to worldwide indices database; build capacity to analyse observed changes in extremes; improve information services on extremes in the region; and publish peer-reviewed journal articles. Most of these articles were directly a result of the regional workshops and included all of the workshop participants as authors (e.g. Peterson et al. 2002; Vincent et al. 2005; Zhang et al. 2005; Haylock et al. 2006; Klein Tank et al. 2006; New et al. 2006; Aguilar et al, 2006, Aguilar et al. 2009; Caesar et al. 2011; Vincent et al. 2011).

As part of the workshop development, software called RClimDEX was also developed that could be used at the workshops (thus providing consistent definitions from each workshop and region). Environment Canada provides, maintains, and further develops the R-based software used for the workshops (freely available from http://etccdi.pacificclimate.org).

1.4 Background to Development of ET-SCI Indices

Most ETCCDI indices focus on counts of days crossing a threshold; either absolute/fixed thresholds or percentile/variable thresholds relative to local climate. Others focus on absolute extreme values such as the warmest, coldest or wettest day of the year. The indices are used for both observations and models, globally as well as regionally, and can be coupled with simple trend analysis techniques, and standard detection and attribution methods in addition to complementing the analysis of more rare extremes using Extreme Value Theory (EVT).

One current disadvantage of the ETCCDI indices is that few of them are specifically sector-relevant. While some of these indices may be useful for sector applications (e.g. number of days with frost for agricultural applications, heat waves for health applications) it was realised that it was important to get sectors involved in the development of the ET-SCI indices so that more application-relevant indices could be developed to better support adaptation.

The core set of indices agreed by the ET-SCI (as the ET-CRSCI) at their meeting in Tarragona, Spain in July 2011 were developed in part from the core set of indices that are developed and maintained by ETCCDI. The meeting included technical experts in climate and health and climate and agriculture from CCl and CAgM representing the health representatives from the health, water and agriculture sectors and it was agreed that the initial effort should consider requirements for climate indices relevant to heat waves and droughts. A core set of 34 indices was agreed at that meeting (Table B1). In some cases these indices are already part of the core set defined by the ETCCDI. All indices calculated by ClimPACT2 are shown in Appendix B and are separated into core and non-core ET-SCI indices. In addition, there is some scope in the ClimPACT2 software for the user to create their own index based on absolute thresholds.

It should be noted that indices development is an ongoing activity as additional sector-needs arise and other sectors are considered within the Terms of Reference and deliverables of the ET-SCI. This should therefore be seen only as the initial step in the continuing work of the ET-SCI.

1.5 Requirements for data quality when computing indices

Before indices can be computed, it is important that any daily input data are checked for quality and homogeneity. Homogeneity implies consistency of a series through time and is an obvious requirement for the robust analysis of climate time series. While many of the time series that are used for indices calculations have been adjusted to improve homogeneity, some aspects of these records may remain inhomogeneous, and this should be borne in mind when interpreting changes in indices. For example, most methods for assessing homogeneity do not consider changes in day-to-day variability or changes in how the series has been derived. It is possible for a change of variance to occur without a change in mean temperature. Two examples of ways in which this could occur are where a station moves from an exposed coastal location to a location further inland, increasing maximum temperatures and decreasing minimum temperatures, or where the number of stations contributing to a composite series changes.

Homogeneity adjustment of daily data is difficult because of high variability in the daily data when compared with monthly or annual data, and also because an inhomogeneity due to a change in station location or instrument may alter behaviour differently under different weather conditions.

Homogeneity adjustment of daily data is a very active field of research and there are many methods which could be used. Although many different methods exists, the ETCCDI promote the use of the RHTest software* because it is free and easy to use, making it ideal for demonstration in regional workshops. The software method is based on the penalized maximal t (PMT) or F test (PMF) and can identify, and adjust for, multiple change points in a time series (see Wang, 2008 and ETCCDI website for more details). PMT requires the use of reference stations for the homogeneity analysis but PMF can be used as an absolute method (i.e. in isolation or when there are no neighbouring stations to use for comparison). In ClimPACT2, apart from basic quality control, there is currently no means to homogenise data. We therefore assume that the required level of homogeneity testing and/or adjustment has already been applied.

*NB Daily adjustments, especially with absolute methods, must be applied with extreme care as – if incorrectly applied – they can damage the statistical distribution of the series. Therefore, data require careful post-workshop analysis in concert with metadata (where available) and as such ET-SCI recommend that any homogeneity software used at regional workshops is for demonstration purposes only.

1.6 Future prospects for the Indices

At present the core set of indices are defined using only daily maximum temperature (TX), daily minimum temperature (TN) and daily precipitation (PR). It is acknowledged that for sector applications, these variables (and the related indices) are all required, but users have also indicated a need for additional variables including: humidity (important for both agricultural and health indices); wind speed and direction (important for health indices, building design, energy, transportation, etc.); Sea Surface Temperatures (SSTs; useful for marine applications and in relation to the onset and variability of the El Niño-Southern Oscillation (ENSO)); onset and cessation dates for monsoon; rain periods, snow fall, snow depth, snow-water equivalent, days with snowfall and hydrological parameters (particularly important for mid-and high latitude applications). Some of these (e.g. onset dates) may require considerable study and available systematic long-term data. Furthermore, in a subsequent phase of the work of the Team, addition of 'event statistics' such as days with thunderstorms, hail, tornados, number of consecutive days with snowfall, etc., for expanded studies of hazards could be considered. The ET-SCI will consider (at a later date) whether to add these new variables to the dataset as a second level priority.

ET-SCI also feels that it is important to add several complex indices to this initial effort (for example heat waves), but recognized that more could be demanded by (or may be in current use by) sectors, once they are consulted on the process and through training. The development of indices to assess multi-day temperature extremes (e.g., prolonged heat waves) has been particularly challenging, as the occurrence of such events depends not just on the frequency distribution of daily temperatures, but also on their persistence from day to day. The existing ETCCDI indices measure the maximum number of consecutive days during events with six or more consecutive days above a specified percentile value or anomaly, vary widely in frequency across climates, describe events that occur rarely or not at all in many climates, and are poor discriminators of very extreme events. The ET-SCI are therefore recommending some new heat wave indices (see Appendix B; Perkins and Alexander, 2013 and Perkins et al. 2012) that have been added as a supplement to the core set in this initial phase of the software. This range of indices is defined for most climates and has a number of other desirable statistical properties, such as being approximately normally distributed in many climates.

Also drought indices have been included following ET-SCI recommendations. Since drought severity is difficult to quantify and is identified by its effects or impacts on different types of systems (e.g. agriculture, water resources, ecology, forestry, economy), different proxies have been developed based on climatic information. These are assumed to adequately quantify the degree of drought hazard exerted on sensitive systems. Recent studies have reviewed the development of drought indices and compared their advantages and disadvantages (Heim, 2002; Mishra and Singh, 2010; Sivakumar et al., 2010). Currently ClimPACT2 includes the Standardized Precipitation Index (SPI), proposed by McKee et al. (1993), and accepted by the WMO as the reference drought index for more effective drought monitoring and climate risk management (World Meteorological Organization, 2012), and the Standardized Precipitation Evapotranspiration Index (SPEI), proposed by Vicente-Serrano et al. (2010), which combines the sensitivity to changes in evaporative demand, caused by temperature fluctuations and trends, with the simplicity of calculation and the multi-temporal nature of the SPI.

In a subsequent phase, ET-SCI will investigate additional complex indices combining meteorological variables (e.g. temperature and humidity for physiological comfort), and could consider indices that combine meteorological/hydrological parameters with sector-based information including measures of vulnerability.

Much of the input for additional indices will come from regional workshops with participants from both National Meteorological and Hydrological Services (NMHSs) and sector groups. ET-SCI will work with sector-based agencies and experts, including those of relevant WMO Technical Commissions, particularly the Commission for Climatology for health, the Commission for

Hydrology (CHy) for water and the Commission for Agricultural Meteorology (CAgM) for agriculture and food security, to facilitate the use of climate information in users' decision-support systems for climate risk management and adaptation strategies. As part of this development, ET-SCI commissioned the development of ClimPACT2 with the aim of producing an easy and consistent way of calculating indices for each user, with regional workshop users particularly in mind. To date workshops have been held in Ecuador, Fiji and Barbados. An example of an ET-SCI workshop can be found here.

It is also acknowledged that updating indices is problematic for many regions and some regions would need specific indices to cope with their particular needs to provide climate services. As GFCS stresses the importance of the global, regional and local scales, ET-SCI acknowledges that support for this could come from Regional Climate Centers (RCCs) or Regional Climate Outlook Forums (RCOFs) etc. In addition, there are constraints on access to daily data. It is a considerable challenge to assemble worldwide datasets which are integrated, quality controlled, and openly and easily accessible. There is tension between traceability (access to the primary sources) and data completeness (use whatever available). Also a problem arises through the use of specified climatological periods which vary from group to group and which are used for base period calculations for percentile-based indices. In the first iteration of the software we use the base period of 1971-2000 but recognise that this will need to be amended for countries that do not have records covering this period. The software has been written in such a way that the user can specify the climatological base period which is most suitable for their data.

Users are invited to view ClimPACT2 as 'living software' in that it can and will be amended as additional user needs arise.

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2. Getting the software

2.1 Software requirements for ClimPACT2

To run ClimPACT2 the R software package, version 3.0.2 or later, needs to be installed on your operating system.
Note that the Graphical User Interface (GUI) for ClimPACT2 can be run in Windows, Linux and MacOS. However, the calculation of ClimPACT2 indices on netCDF data is only possible in Linux and MacOS. Furthermore, to calculate the ClimPACT2 indices on netCDF data the netcdf program also needs to be installed. This can be done through your operating system's package manager.

2.2 Getting ClimPACT2

The official ClimPACT2 github website is located at https://github.com/ARCCSS-extremes/climpact2/
To get the latest version of ClimPACT2 download and extract the following file to a new directory (https://github.com/ARCCSS-extremes/climpact2/archive/master.zip).
This will create a directory called climpact2-master. In this directory you will see the following files and sub-directories. You can now proceed to using ClimPACT2 in the one of 3 ways it has been designed for; using the GUI for processing single station files, calculating the indices on netCDF data or batch processing multiple station text files at once. These uses are covered in Sections 3, 4 and 5, respectively.

Table 1. List of ClimPACT2 files and directories

File/directory	Description
ancillary/	
climate.indices.csv	Index information used by ClimPACT2.
climpact2.etsci-functions.r	Index functions that augments those provided by the climdex.pcic R package.
climpact2.batch.stations.r	Script for calculating indices on multiple station text files. See Section 5.
climpact2.GUI.r	Script for calling the ClimPACT2 GUI. See Section 3.
climpact2.ncdf.thresholds.wrapper.r	Script for calculating index thresholds for netCDF data. See Section 4.
climpact2.ncdf.wrapper.r	Script for calculating indices for netCDF data. See Section 4.
installers/	
climpact2.batch.installer.r	Script to install R packages required to calculate indices on multiple station text files. See Section 5.
climpact2.ncdf.installer.r	Script to install R packages required to calculate indices on netCDF data. See Section 4.
LICENSE	License agreement.
pcic_packages/	
climdex.pcic.ncdf.climpact.tar.gz	Altered copy of climdex.pcic.ncdf (developed by PCIC). Required to calculate indices on netCDF data.
ncdf4.helpers_0.3-3.tar.gz	Additional netCDF functionality for R (developed by PCIC). Required to calculate indices on netCDF data.

QCedits_template.xls	A Microsoft Excel template provided for the user to record quality control changes made to their ClimPACT input file. See Appendix C.
README.md	Information and instructions for ClimPACT2.
sample_data/	
climpact2.sample.batch.metadata.txt	Sample metadata text file for use in calculating indices on multiple station text files. See Section 5.
climpact2.sampledata.1d.time-series.txt	Sample station text file for calculating the indices via the Graphical User Interface (GUI). See Section 3.
climpact2.sampledata.gridded.1991-2010.nc	Sample netCDF file for calculating indices on gridded data. See Section 4.
user_guide/	
ClimPACT2_user_guide.htm	This user guide.

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3. Using the Graphical User Interface

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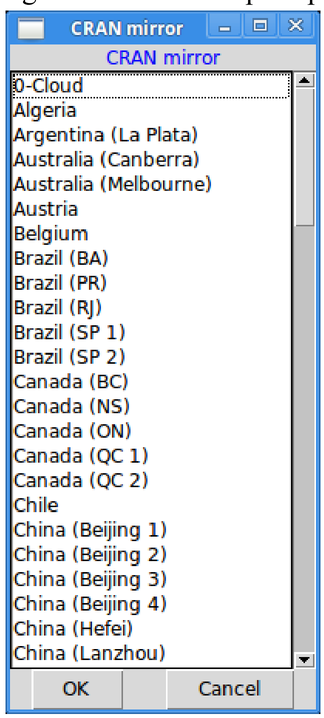
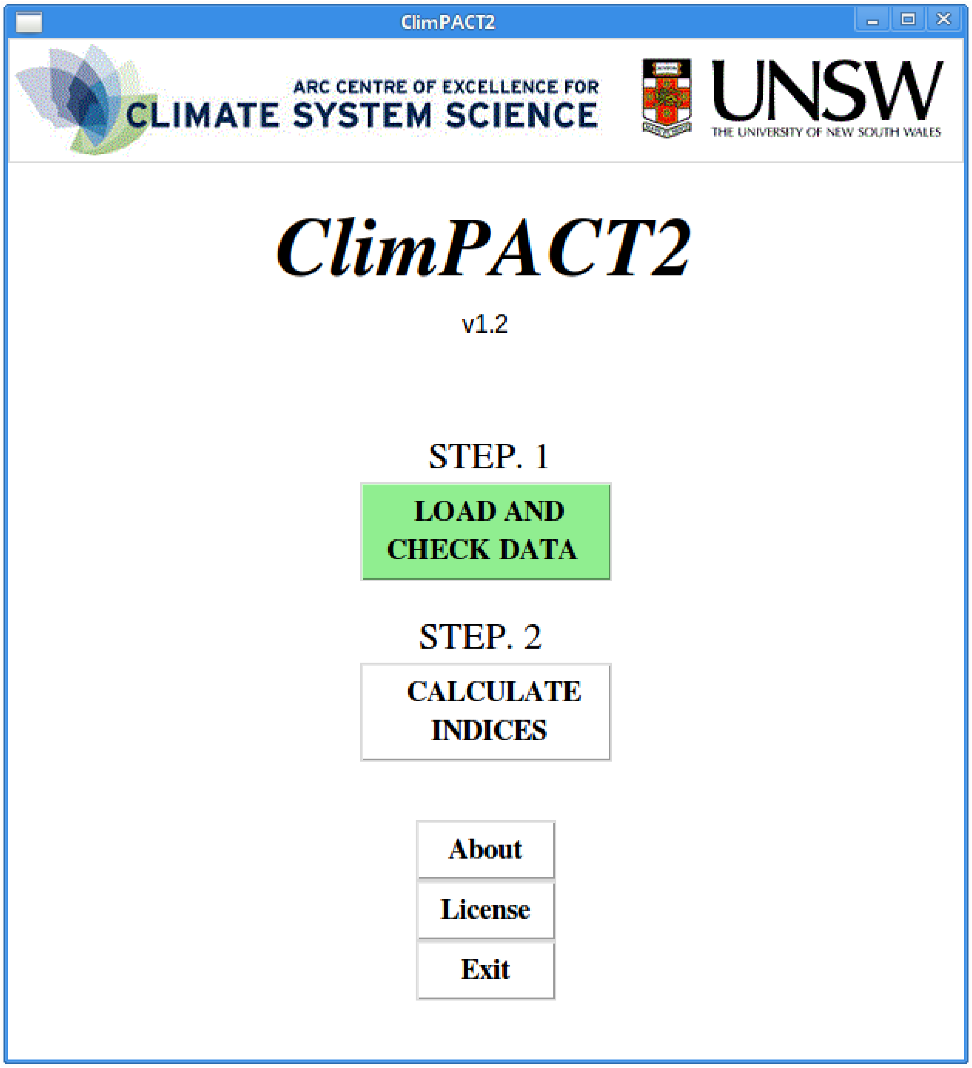
3.1 Starting the ClimPACT2 GUI

If you are using Windows, select the 'R' icon that was created during the installation of R (either on your Desktop or in the Start menu). Once in R, from the drop down menu click "File -> Change dir…" and choose the climpact2-master directory created when you downloaded ClimPACT2 (see Section 2 if you have not done this). Then, within the R console ">", type *source("climpact2.GUI.r")*.

In Linux or MacOS, open a terminal window, navigate to the directory where you have downloaded the ClimPACT2 software (see Section 2 if you have not done this). Enter R (by typing *R* at the terminal prompt) and type *source("climpact2.GUI.r")*.



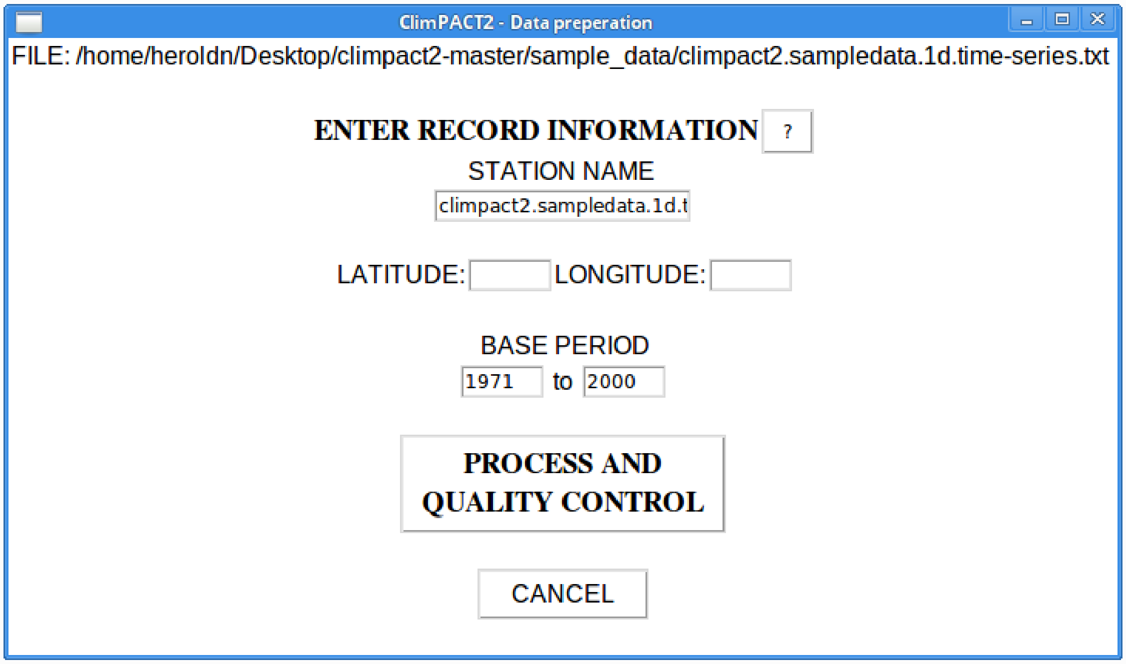
The first time climpact2.GUI.r is called, required R packages will be downloaded and installed. This may take a couple of minutes but will only occur once. During this process you may be asked to select the geographical location of the closest 'mirror' to download these packages from (see figure above). You may select any location, though the closest location will offer the fastest download speed.



3.2 Using the ClimPACT2 GUI

Once climpact2.GUI.r has installed the required packages, the ClimPACT2 GUI will open. The user will be presented with the ClimPACT2 home screen shown above. Here, two main options are presented, “STEP. 1” and “STEP. 2”, indicating the order in which the user should proceed to calculate the ClimPACT2 indices. The green highlighting of “STEP. 1” indicates which step the user currently needs to complete and thus which option they should select.

Selecting “STEP. 1” presents a prompt where the user can choose an ASCII file containing their climate data (refer to Appendix B for the required format of this file). The filename should be of the form “stationname.txt”. In this guide the sample file sydney_observatory_hill_1936-2015.txt will be used and the user is encouraged to use this sample file as a template for their own data. Once this file is selected a progress bar may briefly appear indicating progress in scanning for comma delimiters and replacing any with white space, checking that years are in the correct order, and substituting missing values of -99.9 with NA (the R nomenclature for a missing value). If any errors occur in reading the chosen file ClimPACT2 will display the error message and the user must check their file for the correct formatting.



3.3 Load and check data

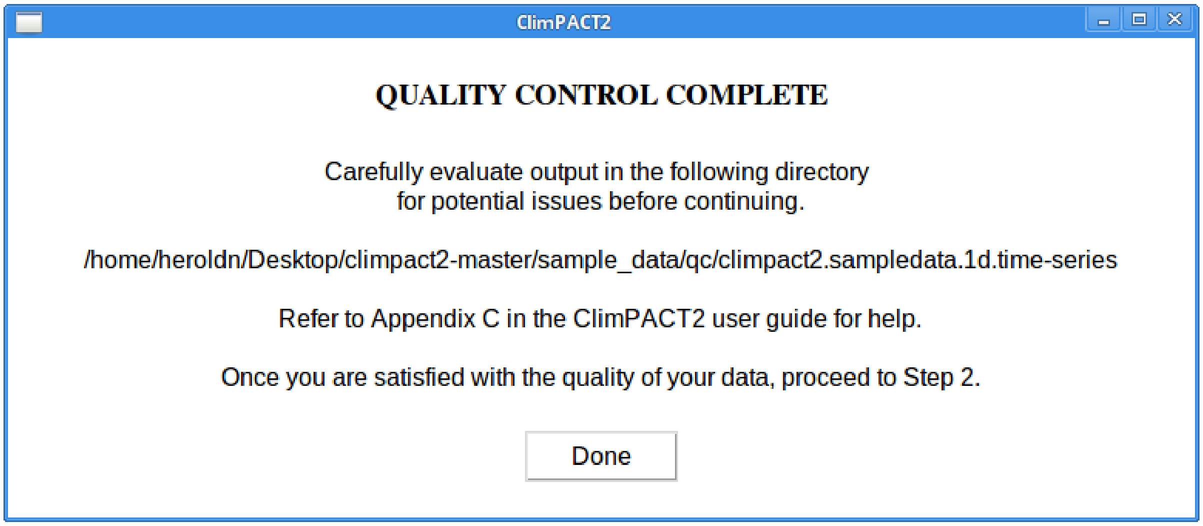
Once the chosen climate data file has been successfully read by ClimPACT2 the above window will appear, displaying the chosen file across the top (in this case sydney_observatory_hill_1936-2015.txt) and a series of input text boxes and buttons below. In this window metadata for the chosen ASCII file is input for the calculation of the indices. Selecting the '?' icon at the top of the screen will provide a summary of each input on this screen.

The first input text box allows the user to customise the station name of the data (the default being the filename). This should be informative and will be used to name files and directories produced by ClimPACT2 (these include output index .csv files, plots and diagnostic files).

Below this the user must specify the latitude and longitude of the station. This is required for some indices to approximate radiation balance for the site (latitude only). The valid latitude range is -90 to +90 and the valid longitude range is -180 to +180.

The base period input text boxes refer to the years that the user wishes percentile thresholds to be calculated over, this only effects percentile-based indices. For example, in a record from 1950 to 2010, the user may wish percentile thresholds to be calculated over the years 1961 to 1990. For a brief explanation of climate indices refer to Appendix F (Wait, what is a climate index?).

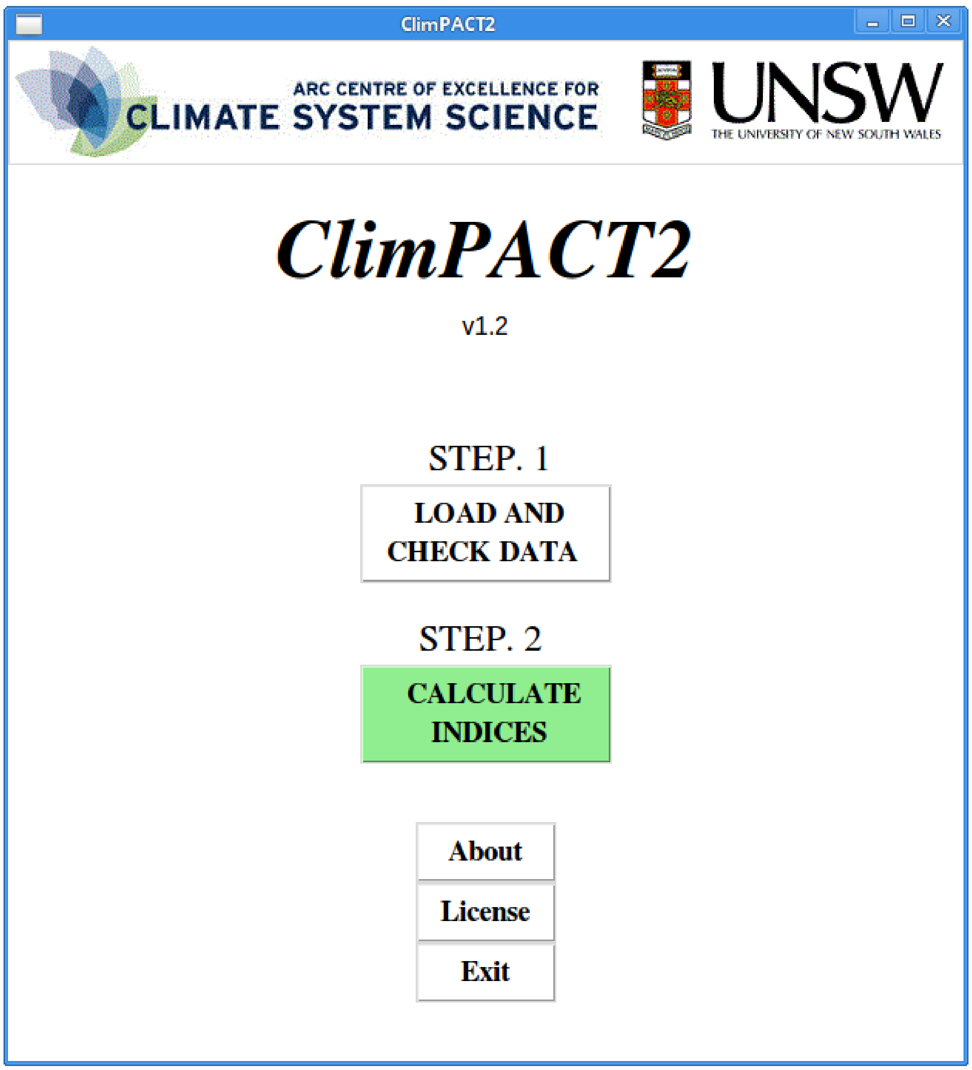
After the above text boxes have been entered, select 'PROCESS AND QUALITY CONTROL'. This step takes approximately a minute and a progress bar will appear. This step is mandatory to proceed to 'STEP. 2' of the ClimPACT2 process. During this step ClimPACT2 may stop if it detects errors in the data or the user's preferences. Specifically, ClimPACT2 will stop if the latitude and longitude values are not valid or if the base period years are not valid or compatible with the data. Upon completion, a message stating "QUALITY CONTROL COMPLETE" will be displayed (see figure below), along with a message asking the user to evaluate the quality control diagnostic files produced in the /qc subdirectory (this is located in the same directory as the station data file that the user selects, in this case sample_data/). The user should refer to Appendix C for guidance on interpreting the contents of the /qc directory. It is critical that the quality of the input data is verified before calculation of the ClimPACT2 indices.



By selecting 'Done' the user will be returned to the ClimPACT2 home screen.

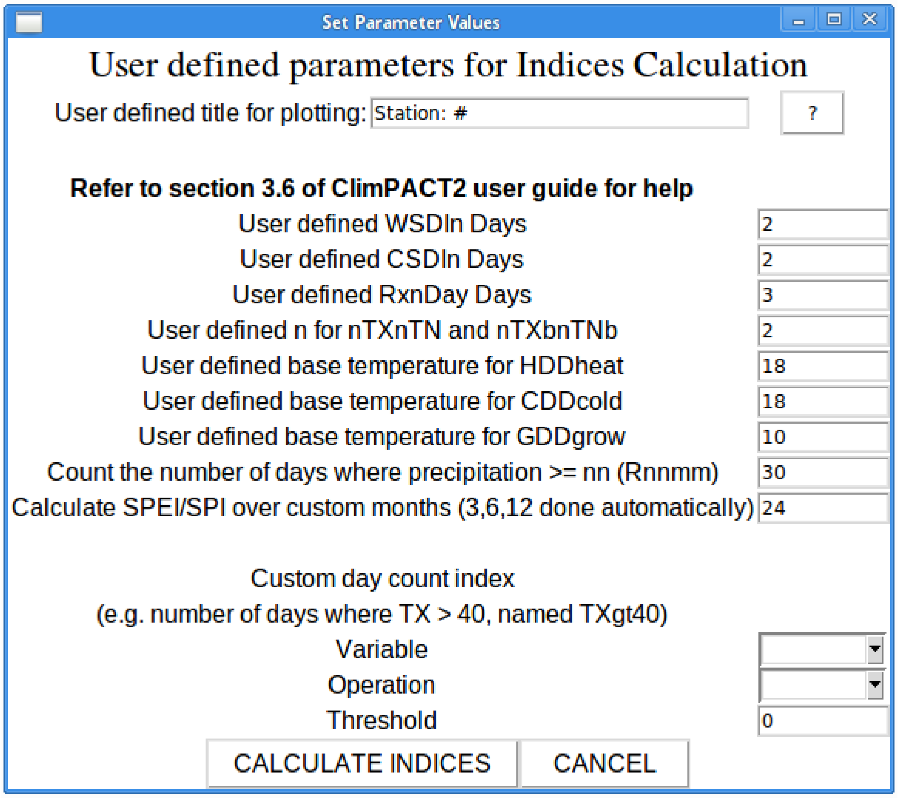
3.4 Calculating the indices

After STEP. 1 has been completed successfully, the "STEP. 2" button on the ClimPACT2 home screen will be highlighted green to indicate that the user is now able to calculate the indices, as shown below. Select the "CALCULATE INDICES" button.



3.5 Parameter values for index calculations

The below screen will appear allowing the user to set parameters relevant to several of the ClimPACT2 indices.



The “User defined WSDIn Days” sets the number of days which need to occur consecutively with a TX > 90th percentile to be counted in the WSDIn index.

The “User defined CSDIn Days” sets the number of days which need to occur consecutively with a TN < 10th percentile to be counted in the CSDIn index.

The “User defined RxnDay Days” sets the monthly maximum consecutive n-day precipitation to be recorded by the Rxnday index.

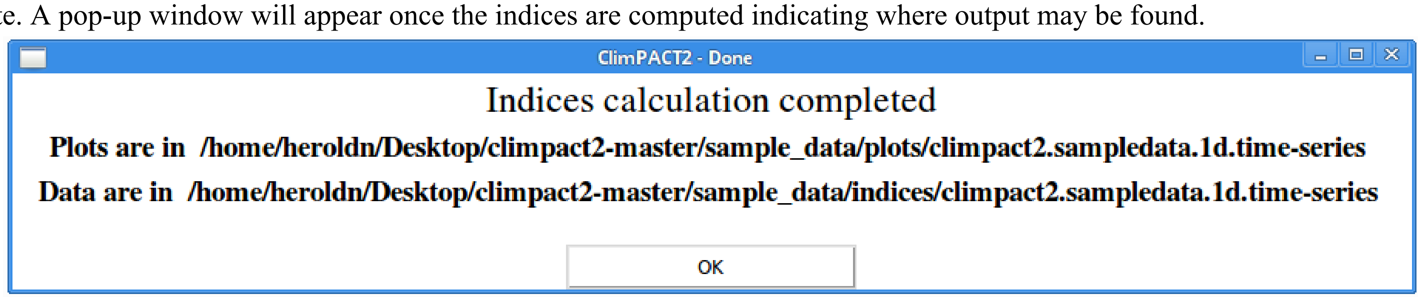
The “User defined n for nTXnTN and nTXbnTNb” sets the number of consecutive days required for the nTXnTN and nTXbnTNb indices.

The “User defined base temperature” for HDDheat, CDDcold and GDDgrow set the temperature to be used in the subtraction in these indices.

The “Count the number of days where precipitation >= nn (Rnnmm)” allows the user to calculate an index where the number of days with precipitation greater than or equal to a set amount is counted. This index will be called ‘rnnmm’, where ‘nn’ is the precipitation set by the user.

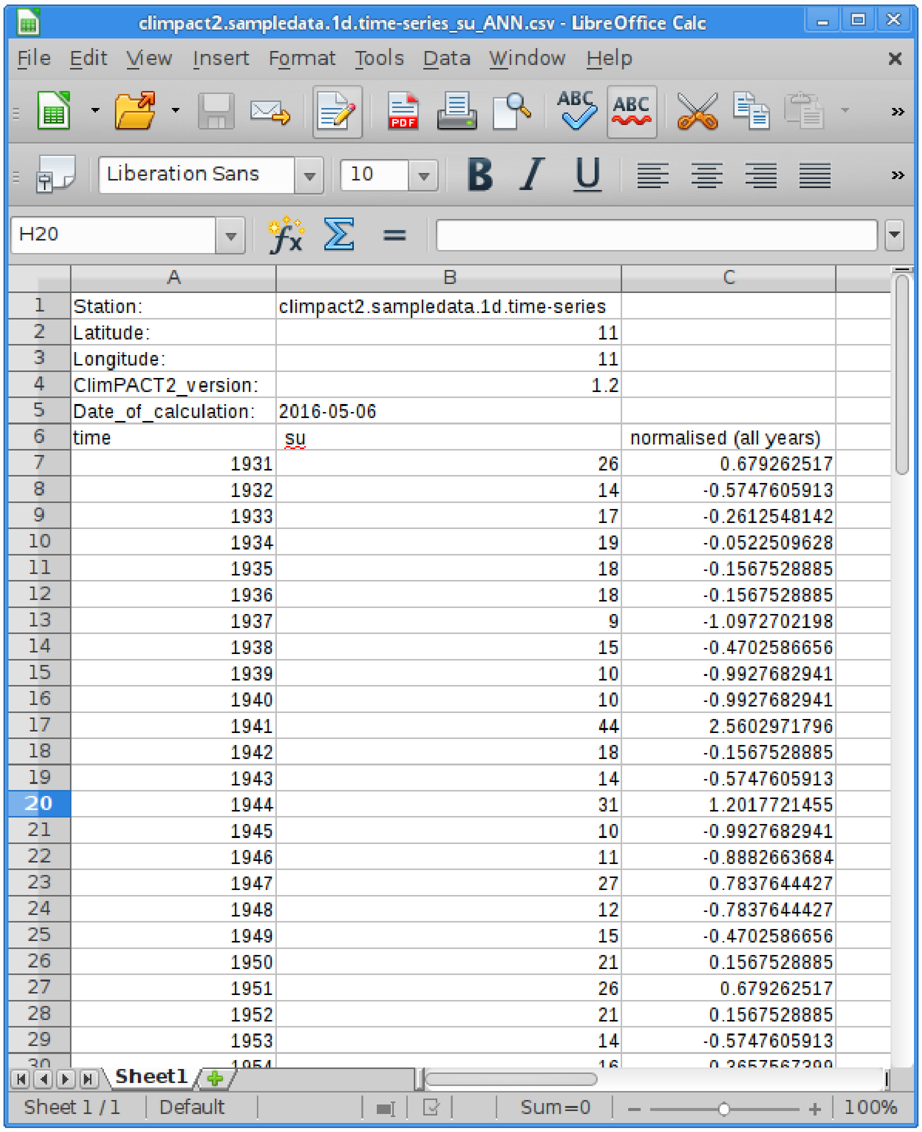
Lastly, under "Custom day count index" the user has the option to create their own index based on the number of days crossing a specified threshold for daily maximum temperature (TX), minimum temperature (TN), diurnal temperature range (DTR) or precipitation (PR). To calculate a custom index, the user must select one of these variables, an operator (<,<=,>,>=) and a constant. For example, selecting TX, the ‘>=’ operator and specifying ‘40’ as a constant will produce an index that counts the number of days where TX is greater than or equal to 40°C. ClimPACT2 output will refer to the index as TXge40. Operators are abbreviated in text with lt, le, gt and ge for <, <=, > and >=, respectively.

Once this step is completed, click “OK”. A progress bar will appear to indicate the time remaining. This should take less than a minute. A pop-up window will appear once the indices are computed indicating where output may be found.



3.6 Examining ClimPACT2 output

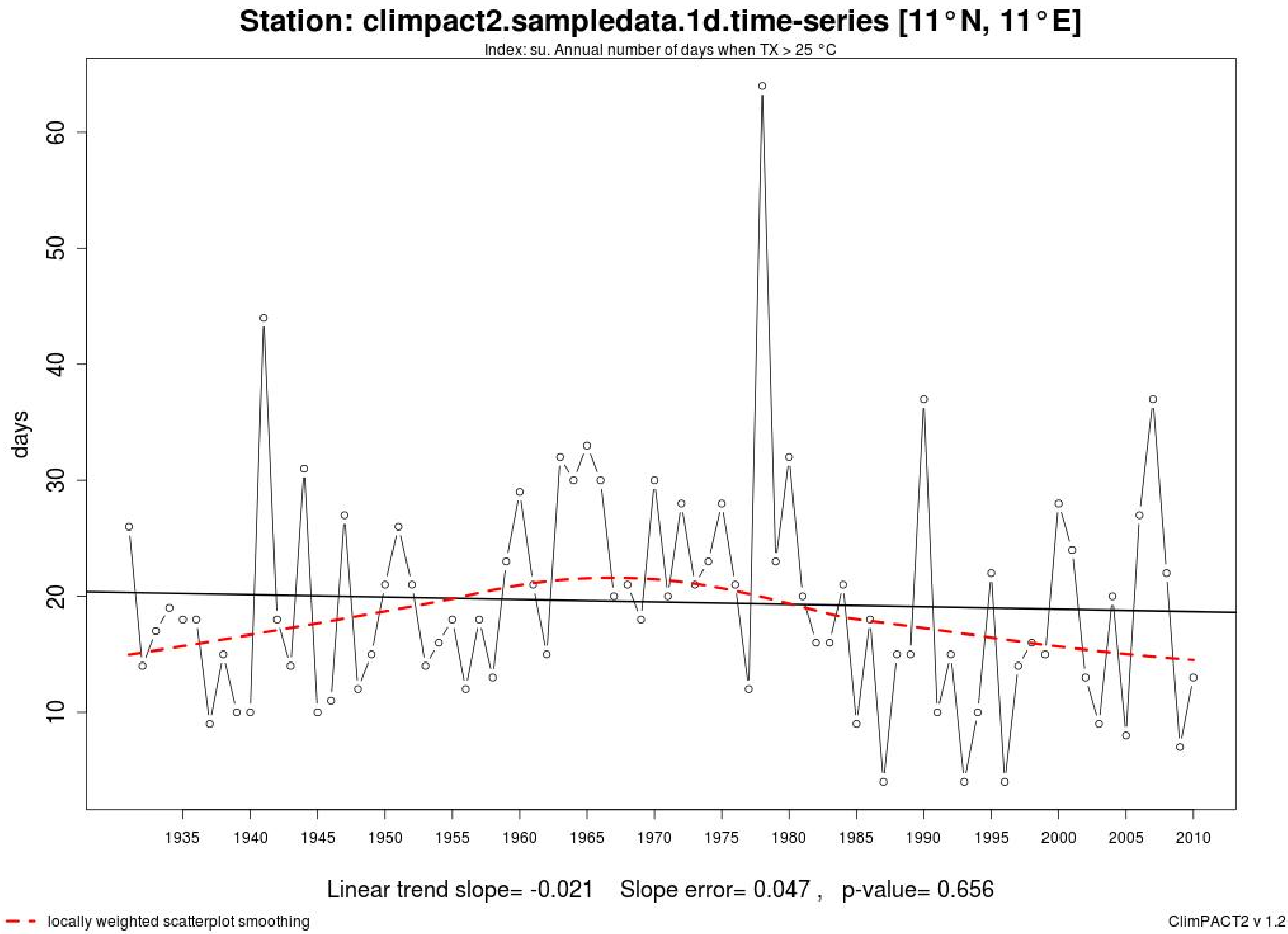
ClimPACT2 produces two sub-directories where the results of each index are stored. These sub-direcotires are in the folder where your input station file exists (in this example sample_data/). These directories are /plots and /indices. For each index one JPEG file (.jpg) containing a plot of the index and one comma-separated value (.csv) file containing the index values are created and put into the the plots/ and indices/ subdirectories, respectively. The .csv files can be opened in Microsoft Excel, Open Office Calc or a text editor. The index files have names “sydney_observatory_hill_1936-2015_XXX_YYY.csv” where XXX represents the name of the index (see Appendix A) and YYY is either ANN or MON depending on whether the index has been calculated annually or monthly, respectively. A sample .csv file for su is shown below. There is one value for each year the index is calculated. For indices calculated monthly there will be one value per month. A column containing normalised values is also written for most indices (these values are normalised using ALL available years/months).



	A	B	C
1	Station:	climpact2.sampledata.1d.time-series	
2	Latitude:	11	
3	Longitude:	11	
4	ClimPACT2_version:	1.2	
5	Date_of_calculation:	2016-05-06	
6	time	su	normalised (all years)
7	1931	26	0.679262517
8	1932	14	-0.5747605913
9	1933	17	-0.2612548142
10	1934	19	-0.0522509628
11	1935	18	-0.1567528885
12	1936	18	-0.1567528885
13	1937	9	-1.0972702198
14	1938	15	-0.4702586656
15	1939	10	-0.9927682941
16	1940	10	-0.9927682941
17	1941	44	2.5602971796
18	1942	18	-0.1567528885
19	1943	14	-0.5747605913
20	1944	31	1.2017721455
21	1945	10	-0.9927682941
22	1946	11	-0.8882663684
23	1947	27	0.7837644427
24	1948	12	-0.7837644427
25	1949	15	-0.4702586656
26	1950	21	0.1567528885
27	1951	26	0.679262517
28	1952	21	0.1567528885
29	1953	14	-0.5747605913
30	1954	16	[illegible]

An example of a plot for the index su is shown below. These files may be opened in any standard image viewing software. The plot of each index is shown with a locally weighted linear regression (red dashed line) to give an indication of longer-term variations. Statistics of the linear trend (solid black line) fitting are displayed at the bottom of the plot. In addition, one .pdf file ending in *_all_plots.pdf (climpact2.sampledata.1d.time-series_all_plots.pdf in our example), is produced in the subdirectory plots/. This file contains all plots in each .jpg file.

See Appendix A for definitions of each ClimPACT2 index.



Resulting trends for all indices are stored in the trend/ subdirectory in a single .csv file. There is one file for all indices with the name, in our example, "climpact2.sampledata.1d.time-series_trend.csv". Columns represent latitude, longitude, start year for trend calculation, end year for trend calculation, trend per year, standard error on trend calculation and the significance of the trend (< 0.05 indicates significance at the 5% level).

ClimPACT2

4. Calculating the indices from netCDF data

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Users who have three-dimensional netCDF datasets (time x latitude x longitude) of daily temperature and precipitation may utilise the climpact2.ncdf.wrapper.r and climpact2.ncdf.thresholds.wrapper.r scripts to calculate the ClimPACT2 indices. This functionality is intended for users familiar with R and the unix command line. This functionality is only available to users of Linux and MacOS operating systems. It utilises two packages developed by the Pacific Climate Impacts Consortium (PCIC): ncdf.helpers and climdex.pcic.ncdf. The latter package has been modified from it's original form in order to calculate all of the ClimPACT2 indices.

4.1 Installing required R packages

To calculate the ClimPACT2 indices on netCDF data your operating system will require the following software installed, in addition to R. All three products should be installable through your operating systems package manager. Select the versions of these packages that contain the development files. This process can be system dependent, please consult your technical support if you require help.

- netCDF
- PROJ4 (libproj-dev package on Linux)
- UDUNITS2 (libudunits2-dev package on Linux)

Once these products are installed on your operating system follow these steps:

1. cd to the climpact2-master directory created in Section 2
2. Enter R and run the following command *source('installers/climpact2.ncdf.installer.r')* to install the required R packages. This may take some time and you may be asked questions regarding the creation of a new library in which to install R packages to. You may also be asked to select the geographical location of the closest 'mirror' to download these packages from (see figure above). You may select any location, though the closest location will offer the fastest download speed. Lastly, you will also be asked whether you wish to install the modified climdex.pcic.ncdf package over any potentially existing package. This is necessary for calculating the indices on netCDF data. To do so, type "y" when asked.You will also be asked to confirm the installation of a modified version of climdex.pcic.ncdf. In order to proceed it is required that this modified R package be installed. It will overwrite any pre-existing copies of this package. The indices calculated in ClimPACT2 include those claculated by the original version of climdex.pcic.ncdf.

4.2 Calculating the indices on netCDF files

To calculate the ClimPACT2 indices on climate data contained inside one or more netCDF files, modify the climpact2.ncdf.wrapper.r script to point to these files and make necessary adjustments to the variable definitions in this script according to your data (the comments in this file will guide you in determining how to change these variables). *As a test, it is recommended to run the above script on the provided sample data BEFORE running on your own data.*

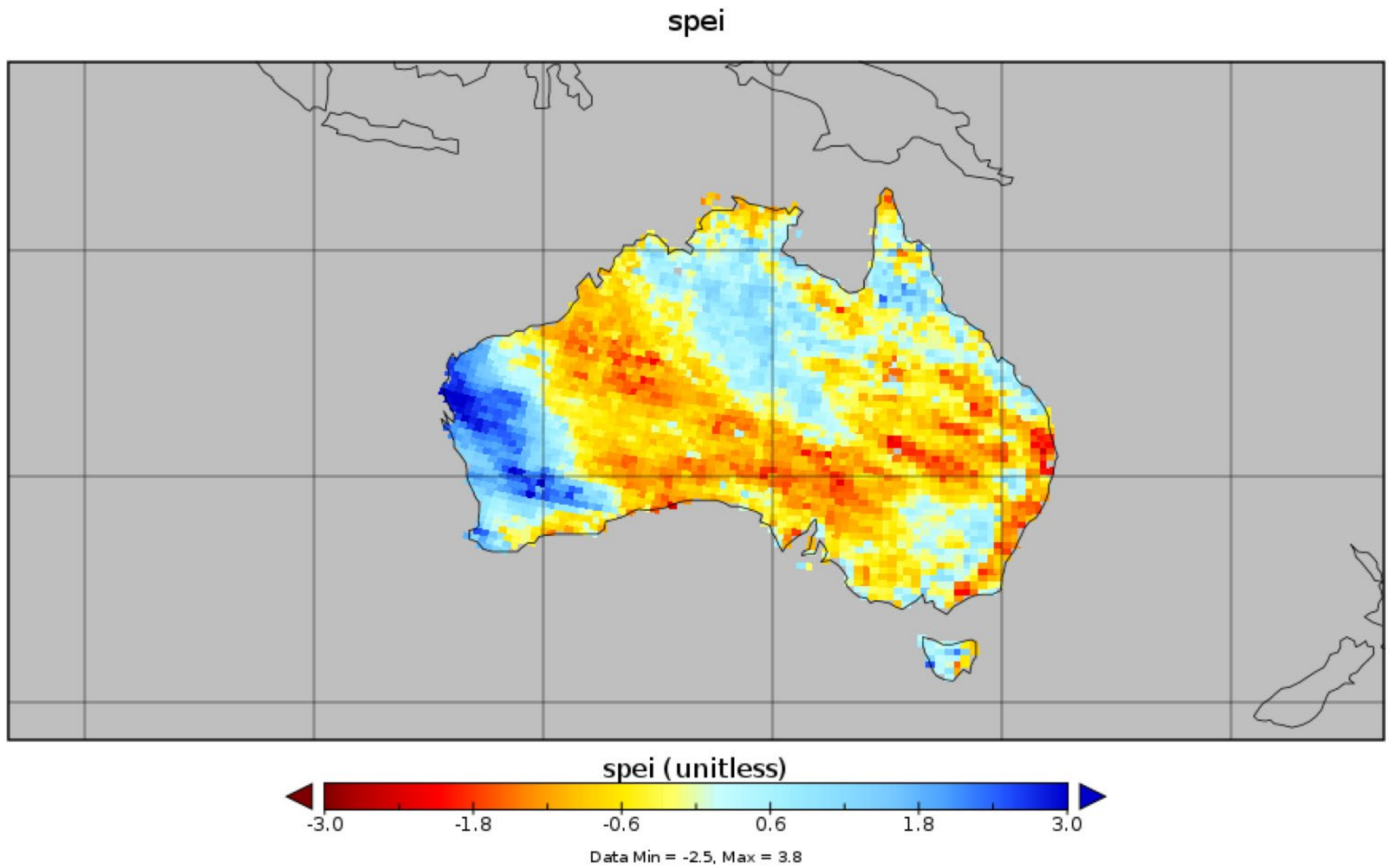
If you wish to calculate the indices for data contained in one set of netCDF files, however using percentile thresholds based on data in another set of netCDF files, then the climpact2.ncdf.thresholds.wrapper.r will need to be used. A typical example of this follows. The user has a netCDF file containing model simulated daily precipitation, maximum temperature and minimum temperature for the present day period of 1990 - 2010. The user also has a netCDF file containing climate model projections for the period 2050 - 2070. They wish to calculate the ClimPACT2 indices on both of these periods but want the percentile-based indices in both periods (present and future) to utilise thresholds calculated from the present day climate. For a brief explanation of climate indices refer to Appendix F (Wait, what is a climate index?).

This requires three steps:

1. Make a copy of climpact2.ncdf.wrapper.r and modify it to point to the present day netCDF files, specifying an appropriate base period. In the above example this might be 1990 - 2000 (your base period does NOT have to cover the entire range of your data). Run this script from the Linux command line using *Rscript climpact2.ncdf.wrapper.r*
2. Modify the climpact2.ncdf.thresholds.wrapper.r to point to the same present day netCDF files as specified in step 1. Here the user needs to specify the same base period, e.g. 1990 - 2000. Run this script from the Linux command line using *Rscript climpact2.ncdf.thresholds.wrapper.r*. Note step 1 and 2 can technically be done in any order, step 2 is only required in order to complete step 3.
3. Make a copy of climpact2.ncdf.wrapper.r and modify it to point to the future climate netCDF files, specifying a base period consistent with the above steps (e.g. 1990 - 2000) but this time specify the threshold file that was claculated in step 2 above. Run this script from the Linux command line using *Rscript climpact2.ncdf.wrapper.r*

These scripts typically take several hours to run (however, runtime varies strongly based on input file size and computer resources). Once you have run climpact2.ncdf.wrapper.r, numerous netCDF files will exist in the output directory specified. Where relevant, indices are calculated at both monthly and annual time scales. A typical output file name is *r20mm_ETCCDI_ANN_climpact.sample_historical_NA_1991-2010.nc*, where *r20mm* refers to the index calculated and *ANN* refers to the time scale this index was calculated on (*MON* for monthly). Output file names are dervied from the CMIP5 conventions and follow this format var_timeresolution_model_scenario_run_starttime-endtime.nc.

A visualisation of example output of the Standardised Precipitation-Evapotranspiration Index (SPEI) calculated over Australia is shown below. We recommend using Ncview or Panoply for easily viewing netCDF output.


spei
spei (unitless)
-3.0
-1.8
-0.6
0.6
1.8
3.0
Data Min = -2.5, Max = 3.8

ClimPACT2

5. Batch processing multiple station files

Occasionally users will have numerous station text files for which they would like to calculate the ClimPACT2 indices. For this purpose using the GUI part of ClimPACT2 (Section 3) would be impractical. In this case the data may be processed using the climpact2.batch.stations.r script. In this case all station files must be in the same format as specified for the GUI and is detailed in Appendix B.

5.1 Installing the required R packages

Prior to calculating the indices on multiple station files several R packages need to be installed. Follow these steps:

1. Open a terminal window and cd to the climpact2-master directory created in Section 2.
2. Open R, and type *source("installers/climpact2.batch.installer.r")*. This process can take a couple of minutes but only needs to be completed once. During this process you may be asked to select the geographical location of the closest 'mirror' to download these packages from. You may select any location, though the closest location will offer the fastest download speed.

5.2 Calculating the indices on multiple station files

The script that provides this functionality is climpact2.batch.stations.r. This script requires command line arguments to be passed to it at run time. Execution of this script takes the following form, from the Linux command line:

Rscript climpact2.batch.stations.r /full/path/to/station/files/ /full/path/to/metadata.txt base_period_begin base_period_end cores_to_use

The 5 command line arguments above are defined in the following table.

Table 2. Command line arguments to pass to climpact2.batch.stations.r

/full/path/to/station/files/	Directory where individual station files are kept. An example can be found in sample_data/XXXX
/full/path/to/metadata.txt	Text file that contains information about each station file to process.
base_period_begin	Beginning year for the base period. To be used on all stations.
base_period_end	Ending year for the base period. To be used on all stations.
cores_to_use	Number of processor cores to use. When processing hundreds or thousands of files, this is useful.

An example of executing the climpact2.batch.stations.r file would be:

Rscript climpact2.batch.stations.r ./sample_data/Renovados_hasta_2010 ./sample_data/climpact2.sample.batch.metadata.txt 1971 2000 4

The metadata.txt file contains 12 columns defined in the following table. A sample metadata.txt file can be found at ./sample_data/climpact2.sample.batch.metadata.txt in the ClimPACT2 directory.

Table 3. Column definitions for metadata.txt file. See ./sample_data/climpact2.sample.batch.metadata.txt for an example.

station_file	Station file name to process. This column lists all of the individual station text files that you wish to process and that are stored in the directory passed to climpact2.batch.stations.r (as argument 1 in table 2).
latitude	Latitude of station
longitude	Longitude of station
wsdin	Number of days to calculate WSDI on. See Appendix A.
csdin	Number of days to calculate CSDI on. See Appendix A.
Tb_HDD	Base temperature to use in the calculation of HDDHEAT. See Appendix A.
Tb_CDD	Base temperature to use in the calculation of CDDCOLD. See Appendix A.
Tb_GDD	Base temperature to use in the calculation of GDD. See Appendix A.
rxnday	Number of days across which to calculate Rxnday. See Appendix A.
rnnmm	Precipitation threshold used to calculate Rnnmm. See Appendix A.

txtn	Number of days across which to calculate both nTXnTN and nTXbnTNb. See Appendix A.
SPEI	Custom time scale over which to calculate SPEI and SPI. 3, 6 and 12 months are calculated by default. This could be set to 24 months, for example.

As the climpact2.batch.stations.r is executed, 5 folders will appear in your directory where your station text files are stored. These are indices/, plots/, thres/, trend/ and qc/. Under each of these folders subdirectories will exist for each station file that has been processed containing the files relevant to each of the above 5 directories. The table below details the contents of each sub directory. Additionally, if calculating the indices on numerous files, errors are bound to occur (typically due to insufficient data to calculate the indices on). When ClimPACT2 encounters an error with an input file during batch processing the error will be recorded in a text file that has the same name as the corresponding input file, with ".error.txt" appended. A summary of all errors will be printed to screen when batch processing finishes.

Table 4. Sub directories created once climpact2.batch.stations.r has run.

indices/	Contains separate .csv files containing the data for each index calculated.
plots/	Contains separate .jpg files containing plots for each index calculated.
thres/	Contains a .csv file containing threshold information used for calculating percentile based indices.
trend/	Contains a .csv file containing linear trend information for each index calculated.
qc/	Contains quality control information for each station file processed. See Appendix C for information on how to interpret these files. Ensuring the quality of each station meets your satisfaction is critical prior to analysing the resulting indices. This may be an iterative process.

ClimPACT2

Appendix A: Tables of ClimPACT2 indices

To calculate all of the ClimPACT2 indices time-series of **daily minimum temperature (TN)**, **daily maximum temperature (TX)** and **daily precipitation (PR)** are required. **Daily mean temperature (TM)** is calculated from TM = (TX + TN)/2. **Diurnal temperature range (DTR)** is calculated from DTR = TX – TN. Many indices are calculated at both annual and monthly time scales. In the following two tables of core and non-core ET-SCI indices, the sector(s) of relevance to each index are indicated as determined by the ET-SCI in consultation with sector representatives, where **H=Health**, **AFS=Agriculture and Food Security** and **WRH=Water Resources and Hydrology**. Some indices have not been evaluated against specific sectors.

Note also that the ClimPACT2 GUI allows users to create their own absolute day count index as detailed in Section 3.

TABLE A1: Core ET-SCI indices (As agreed July 2011. Updated index names and definitions May 2016). Bold indicates also ETCCDI index.

Short name	Long name	Definition	Plain language description	Units	Time scale	Sector(s)
FD	Frost Days	Number of days when TN < 0 °C	Days when minimum temperature is below 0°C	days	Mon/Ann	H, AFS
TNlt2	TN below 2°C	Number of days when TN < 2 °C	Days when minimum temperature is below 2°C	days	Mon/Ann	AFS
TNltm2	TN below -2°C	Number of days when TN < -2 °C	Days when minimum temperature is below -2°C	days	Mon/Ann	AFS
TNltm20	TN below -20°C	Number of days when TN < -20 °C	Days when minimum temperature is below -20°C	days	Mon/Ann	H, AFS
ID	Ice Days	Number of days when TX < 0 °C	Days when maximum temperature is below 0°C	days	Mon/Ann	H, AFS
SU	Summer days	Number of days when TX > 25 °C	Days when maximum temperature exceeds 25°C	days	Mon/Ann	H

TR	Tropical nights	Number of days when TN > 20 °C	Days when minimum temperature exceeds 20°C	days	Mon/Ann	H,AFS
GSL	Growing Season Length	Annual number of days between the first occurrence of 6 consecutive days with TM > 5 °C and the first occurrence of 6 consecutive days with TM < 5 °C	Length of time in which plants can grow	days	Ann	AFS
TXx	Max TX	Warmest daily TX	Hottest day	°C	Mon/Ann	AFS
TNn	Min TN	Coldest daily TN	Coldest night	°C	Mon/Ann	AFS
WSDI	Warm spell duration indicator	Annual number of days contributing to events where 6 or more consecutive days experience TX > 90th percentile	Number of days contributing to a warm period (where the period has to be at least 6 days long)	days	Ann	H, AFS, WRH
WSDId	User-defined WSDI	Annual number of days contributing to events where *d* or more consecutive days experience TX > 90th percentile	Number of days contributing to a warm period (where the minimum length is user-specified)	days	Ann	H, AFS, WRH
CSDI	Cold spell duration indicator	Annual number of days contributing to events where 6 or more consecutive days experience TN < 10th percentile	Number of days contributing to a cold period (where the period has to be at least 6 days long)	days	Ann	H, AFS
CSDId	User-defined CSDI	Annual number of days contributing to events where *d* or more consecutive days experience TN < 10th percentile	Number of days contributing to a cold period (where the minimum length is user-specified)	days	Ann	H, AFS, WRH
TXgt50p	Fraction of days with above average temperature	Percentage of days where TX > 50th percentile	Fraction of days with above average temperature	%	Mon/Ann	H, AFS, WRH
TX95t	Very warm day threshold	Value of 95th percentile of TX	A threshold where days above this temperature would be classified as very warm	°C	Daily	H, AFS
TMge5	TM of at least 5°C	Number of days when TM >= 5 °C	Days when average temperature is at least 5°C	days	Mon/Ann	AFS
TMlt5	TM below 5°C	Number of days when TM < 5 °C	Days when average temperature is below 5°C	days	Mon/Ann	AFS
TMge10	TM of at least 10°C	Number of days when TM >= 10 °C	Days when average temperature is at least 10°C	days	Mon/Ann	AFS
TMlt10	TM below 10°C	Number of days when TM < 10 °C	Days when average temperature is below 10°C	days	Mon/Ann	AFS
TXge30	TX of at least 30°C	Number of days when TX >= 30 °C	Days when maximum	days	Mon/Ann	H, AFS

			temperature is at least 30°C			
TXge35	TX of at least 35°C	Number of days when TX >= 35 °C	Days when maximum temperature is at least 35°C	days	Mon/Ann	H, AFS
TXdTNd	User-defined consecutive number of hot days and nights	Annual count of *d* consecutive days where both TX > 95th percentile and TN > 95th percentile, where 10 >= *d* >= 2	Total consecutive hot days and hot nights (where consecutive periods are user-specified)	events	Ann	H, AFS, WRH
HDDheatn	Heating Degree Days	Annual sum of *n* - TM (where *n* is a user-defined location-specific base temperature and TM < *n*)	A measure of the energy demand needed to heat a building	degree-days	Ann	H
CDDcoldn	Cooling Degree Days	Annual sum of TM - *n* (where *n* is a user-defined location-specific base temperature and TM > *n*)	A measure of the energy demand needed to cool a building	degree-days	Ann	H
GDDgrown	Growing Degree Days	Annual sum of TM - *n* (where *n* is a user-defined location-specific base temperature and TM > *n*)	A measure of heat accumulation to predict plant and animal developmental rates	degree-days	Ann	H, AFS
CDD	Consecutive Dry Days	Maximum number of consecutive dry days (when PR < 1.0 mm)	Longest dry spell	days	Mon/Ann	H, AFS, WRH
R20mm	Number of very heavy rain days	Number of days when PR >= 20 mm	Days when rainfall is at least 20mm	days	Mon/Ann	AFS, WRH
PRCPTOT	Annual total wet-day PR	Sum of daily PR >= 1.0 mm	Total wet-day rainfall	mm	Mon/Ann	AFS, WRH
R95pTOT	Contribution from very wet days	100*r95p / PRCPTOT	Fraction of total wet-day rainfall that comes from very wet days	%	Ann	AFS, WRH
R99pTOT	Contribution from extremely wet days	100*r99p / PRCPTOT	Fraction of total wet-day rainfall that comes from extremely wet days	%	Ann	AFS, WRH
RXdday	User-defined consecutive days PR amount	Maximum *d*-day PR total	Maximum amount of rain that falls in a user-specified period	mm	Mon/Ann	H, AFS, WRH
SPI	Standardised Precipitation Index	Measure of "drought" using the Standardised Precipitation Index on time scales of 3, 6 and 12 months. See McKee et al. (1993) and the WMO SPI User guide (World Meteorological Organization, 2012)for details. Calculated using the SPEI R	A drought measure specified as a precipitation deficit	unitless	Custom	H, AFS, WRH

		package.				
SPEI	Standardised Precipitation Evapotranspiration Index	Measure of "drought" using the Standardised Precipitation Evapotranspiration Index on time scales of 3, 6 and 12 months. See Vicente-Serrano et al. (2010) for details. Calculated using the SPEI R package.	A drought measure specified using precipitation and evaporation	unitless	Custom	H, AFS, WRH

TABLE A2: Non-core ET-SCI indices also calculated by ClimPACT2. Bold indicates also ETCCDI index.

Short name	Long name	Definition	Plain language description	Units	Time scale	Sector(s)
TXbdTNbd	User-defined consecutive number of cold days and nights	Annual number of *d* consecutive days where both TX < 5th percentile and TN < 5th percentile, where 10 >= *d* >=2	Total consecutive cold days and cold nights (where consecutive periods are user-specified)	events	Ann	H, AFS, WRH
DTR	Daily Temperature Range	Mean difference between daily TX and daily TN	Average range of maximum and minimum temperature	°C	Mon/Ann	
TNx	Max TN	Warmest daily TN	Hottest night	°C	Mon/Ann	
TXn	Min TX	Coldest daily TX	Coldest day	°C	Mon/Ann	
TMm	Mean TM	Mean daily mean temperature	Average daily temperature	°C	Mon/Ann	
TXm	Mean TX	Mean daily maximum temperature	Average daily maximum temperature	°C	Mon/Ann	
TNm	Mean TN	Mean daily minimum temperature	Average daily minimum temperature	°C	Mon/Ann	
TX10p	Amount of cool days	Percentage of days when TX < 10th percentile	Fraction of days with cool day time temperatures	%	Ann	
TX90p	Amount of hot days	Percentage of days when TX > 90th percentile	Fraction of days with hot day time temperatures	%	Ann	
TN10p	Amount of cold nights	Percentage of days when TN < 10th percentile	Fraction of days with cold night time temperatures	%	Ann	
TN90p	Amount of warm nights	Percentage of days when TN > 90th percentile	Fraction of days with warm night time temperatures	%	Ann	
CWD	Consecutive Wet Days	Maximum annual number of consecutive wet days (when PR >= 1.0 mm)	The longest wet spell	days	Ann	

R10mm	Number of heavy rain days	Number of days when PR >= 10 mm	Days when rainfall is at least 10mm	days	Mon/Ann	
Rnnmm	Number of customised rain days	Number of days when PR >= *nn*	Days when rainfall is at least a user-specified number of mm	days	Mon/Ann	
SDII	Daily PR intensity	Annual total PR divided by the number of wet days (when total PR >= 1.0 mm)	Average daily wet-day rainfall intensity	mm/day	Ann	
R95p	Total annual PR from heavy rain days	Annual sum of daily PR > 95th percentile	Amount of rainfall from very wet days	mm	Ann	
R99p	Total annual PR from very heavy rain days	Annual sum of daily PR > 99th percentile	Amount of rainfall from extremely wet days	mm	Ann	
Rx1day	Max 1-day PR	Maximum 1-day PR total	Maximum amount of rain that falls in one day	mm	Mon/Ann	
Rx5day	Max 5-day PR	Maximum 5-day PR total	Maximum amount of rain that falls in five consecutive days	mm	Mon/Ann	
HWN(EHF/Tx90/Tn90)	Heatwave number (HWN) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the 90th percentile of TN	The number of individual heatwaves that occur each summer (Nov – Mar in southern hemisphere and May – Sep in northern hemisphere). A heatwave is defined as 3 or more days where either the EHF is positive, TX > 90th percentile of TX or where TN > 90th percentile of TN. Where percentiles are calculated from base period specified by user. See Appendix D and Perkins and Alexander (2013) for more details.	Number of individual heatwaves	events	Ann	H, AFS, WRH
HWF(EHF/Tx90/Tn90)	Heatwave frequency (HWF) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the 90th percentile of TN	The number of days that contribute to heatwaves as identified by HWN. See Appendix D and Perkins and Alexander (2013) for more details.	Total number of days that contribute to individual heatwaves	days	Ann	H, AFS, WRH
HWD(EHF/Tx90/Tn90)	Heatwave duration (HWD) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the	The length of the longest heatwave identified by HWN. See Appendix D and Perkins and Alexander (2013) for more details.	Length of the longest heatwave	days	Ann	H, AFS, WRH

	90th percentile of TN					
HWM(EHF/Tx90/Tn90)	Heatwave magnitude (HWM) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the 90th percentile of TN	The mean temperature of all heatwaves identified by HWN. See Appendix D and Perkins and Alexander (2013) for more details.	Average temperature across all individual heatwaves	°C (°C^2 for EHF)	Ann	H, AFS, WRH
HWA(EHF/Tx90/Tn90)	Heatwave amplitude (HWA) as defined by either the Excess Heat Factor (EHF), 90th percentile of TX or the 90th percentile of TN	The peak daily value in the hottest heatwave (defined as the heatwave with highest HWM). See Appendix D and Perkins and Alexander (2013) for more details.	Hottest day of the hottest heatwave	°C (°C^2 for EHF)	Ann	H, AFS, WRH
CWN_ECF	Coldwave number (CWN) as defined by the Excess Cold Factor (ECF).	The number of individual ‘coldwaves’ that occur each year. See Appendix D and Nairn and Fawcett (2013) for more information.	Number of individual coldwaves	events	Ann	H, AFS, WRH
CWF_ECF	Coldwave frequency (CWF) as defined by the Excess Cold Factor (ECF).	The number of days that contribute to ‘coldwaves’ as identified by ECF_HWN. See Appendix D and Nairn and Fawcett (2013) for more information.	Total number of days that contribute to individual coldwaves	days	Ann	H, AFS, WRH
CWD_ECF	Coldwave duration (CWD) as defined by the Excess Cold Factor (ECF).	The length of the longest ‘coldwave’ identified by ECF_HWN. See Appendix D and Nairn and Fawcett (2013) for more information.	Length of the longest coldwave	days	Ann	H, AFS, WRH
CWM_ECF	Coldwave magnitude (CWM) as defined by the Excess Cold Factor (ECF).	The mean temperature of all ‘coldwaves’ identified by ECF_HWN. See Appendix D and Nairn and Fawcett (2013) for more information.	Average temperature across all individual coldwaves	°C^2	Ann	H, AFS, WRH
CWA_ECF	Coldwave amplitude	The minimum daily value in the	Coldest day of the coldest	°C^2	Ann	H, AFS,

	(CWA) as defined by the Excess Cold Factor (ECF).	coldest 'coldwave' (defined as the coldwave with lowest ECF_HWM). See Appendix D and Nairn and Fawcett (2013) for more information.	coldwave			WRH

References

McKee T B, Doesken N J and Kleist J 1993 The relationship of drought frequency and duration to time scales Proceedings of the 8th Conference on Applied Climatology vol 17 (American Meteorological Society Boston, MA, USA) pp 179–83

Nairn J R and Fawcett R G 2013 Defining heatwaves: heatwave defined as a heat-impact event servicing all community and business sectors in Australia (Centre for Australian Weather and Climate Research) Online: http://www.cawcr.gov.au/technical-reports/CTR_060.pdf

Perkins S E and Alexander L V 2013 On the Measurement of heatwaves J. Clim. 26 4500–17 Online: http://dx.doi.org/10.1175/JCLI-D-12-00383.1

Vicente-Serrano S M, Beguería S and López-Moreno J I 2010 A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index J. Clim. 23 1696–718 Online: http://dx.doi.org/10.1175/2009JCLI2909.1

WMO 2012 Standardized Precipitation Index User Guide (7 bis, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland) Online: http://www.wamis.org/agm/pubs/SPI/WMO_1090_EN.pdf

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Appendix B: Input data format

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B.1 Station text files

The station text files input into the GUI or batch processing has several requirements which are listed below. We recommend that users use the sample input file provided with ClimPACT2 as a template for their own data (climpact2.sampledata.1d.time-series.txt).

1. ASCII text file
2. Columns as following sequences: Year, Month, Day, PR, TX, TN (NOTE: PR units = millimeters and Temperature units = degrees Celsius)
3. The format as described above must be space delimited (e.g. each element separated by one or more spaces).
4. For data records, missing data must be coded as -99.9; data records must be in calendar date order. Missing dates are allowed.
5. Decimal places must be denoted by the period character, not a comma (i.e. "." not ",").

Example lines for a station text file.

1901	1	1	-99.9	-3.1	-6.8
1901	1	2	-99.9	-1.3	-3.6
1901	1	3	-99.9	-0.5	-7.9
1901	1	4	-99.9	-1	-9.1
1901	1	7	-99.9	-1.8	-8.4

B.2 netCDF files

The netCDF files processed by ClimPACT2 must be CF-compliant. See the sample input file for a template for your data (climpact2.sampledata.gridded.1991-2010.nc).

Specific issues that have been found with incorrect input data include:

- There must be no 'bounds' attributes in your latitude or longitude variables.

- Your precipitation variable must have units of "kg m-2 d-1", not "mm/day". These are numerically equivalent.
- Your minimum and maximum temperature variables must be uniquely named and have units of "degrees_C", "C" or "K".
- ncrename, ncatted and ncks from the NCO toolset will help you modify your netCDF files accordingly.

An ncdump of climpact2.sampledata.gridded.1991-2010.nc is provided below.

```
 > ncdump -h climpact2.sampledata.gridded.1991-2010.nc
netcdf climpact2.sampledata.gridded.1991-2010 {
dimensions:
        lon = 24 ;
        lat = 19 ;
        time = UNLIMITED ; // (7305 currently)
        nb2 = 2 ;
variables:
        float lon(lon) ;
                lon:standard_name = "longitude" ;
                lon:long_name = "Longitude" ;
                lon:units = "degrees_east" ;
                lon:axis = "X" ;
        float lat(lat) ;
                lat:standard_name = "latitude" ;
                lat:long_name = "Latitude" ;
                lat:units = "degrees_north" ;
                lat:axis = "Y" ;
        double time(time) ;
                time:standard_name = "time" ;
                time:long_name = "Time" ;
                time:bounds = "time_bnds" ;
                time:units = "hours since 1800-01-01 00:00:00" ;
                time:calendar = "standard" ;
        double time_bnds(time, nb2) ;
        float tmax(time, lat, lon) ;
                tmax:units = "K" ;
        float tmin(time, lat, lon) ;
                tmin:units = "K" ;
        float precip(time, lat, lon) ;
                precip:units = "kg m-2 d-1" ;

// global attributes:
                :history = "Fri Feb 26 10:25:00 2016: ncatted -O -a units,precip,o,c,kg m-2 d-1
climpact2.sampledata.gridded.1991-2010.nc" ;
}
```

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Appendix C: Quality Control (QC) diagnostics

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Preface

This appendix describes the output of the QC functionality present in ClimPACT2. While the QC checks performed by ClimPACT2 are reasonably extensive they do not guarantee that all errors will be detected. Furthermore, a separate category of quality issues, that of *homogeneity*, often occurs in station data and ClimPACT2 does no checking for this. Thus it is advised that, if the user is analysing observations (as opposed to model data) that they be sure of the quality of their data before using ClimPACT2, or, that they utilise additional checks for homogeneity in addition to the QC checks performed by ClimPACT2 (and described in this appendix). RHtests is one program that performs homogeneity tests. It is freely available, easy to use and is also built on the R programming language.

The text in this appendix is adapted from text written by Enric Aguilar and Marc Prohom for the R functions they created to perform quality control, which have been integrated into the ClimPACT2 software with their permission.

C.1 Overview

Once the user selects 'PROCESS AND QUALITY CONTROL' ClimPACT2 will take a minute or two to calculate thresholds and perform quality control checks. At the end of this process a dialogue box will appear telling the user to check the /qc subdirectory created in the directory where their station text file is stored.

The /qc folder contains the following files (where "mystation" refers to the name of the user's station file):

7 .pdf files, with graphical information on data quality:

- mystation_tminPLOT.pdf
- mystation_tmaxPLOT.pdf
- mystation_dtrPLOT.pdf
- mystation_prcpPLOT.pdf
- mystation_boxes.pdf
- mystation_boxseries.pdf
- mystation_rounding.pdf

9 .csv files with numerical information on data quality

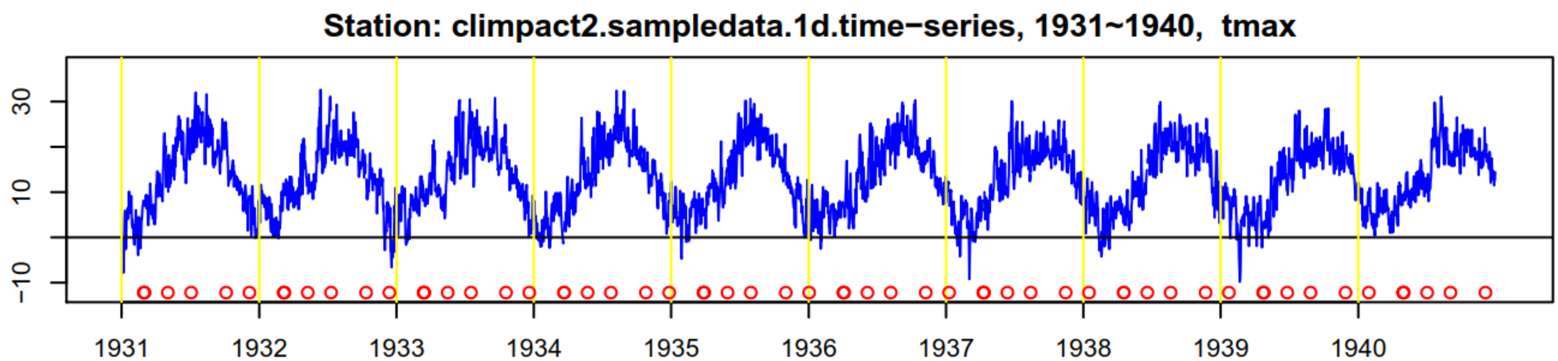
- mystation_duplicates.csv
- mystation_outliers.csv
- mystation_tmaxmin.csv

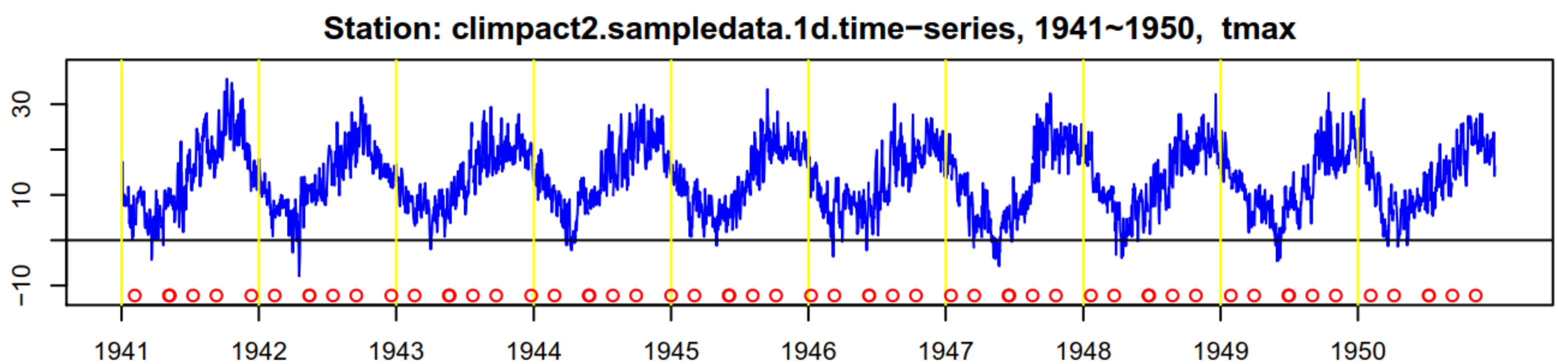
- mystation_tx_flatline.csv
- mystation_tn_flatline.csv
- mystation_toolarge.csv
- mystation_tx_jumps.csv
- mystation_tn_jumps.csv
- mystation_temp_nastatistics.csv

C.2 File descriptions

mystation_tminPLOT.pdf
mystation_tmaxPLOT.pdf
mystation_dtrPLOT.pdf
mystation_prcpPLOT.pdf

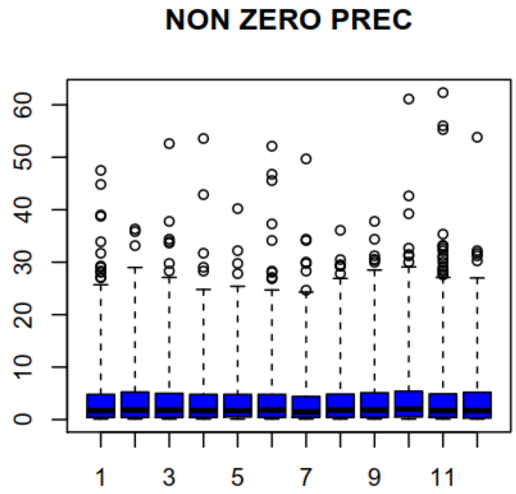
These files contain simple plots of the daily time-series of minimum temperature, maximum temperature, diurnal temperature range and precipitation, respectively. This allows the user to view the data and identify obvious problems by eye such as missing data (indicated by red circles) or unrealistic values.
Below is an example for tmax.

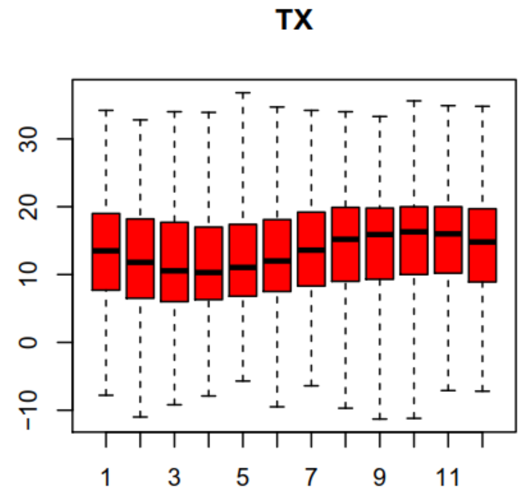


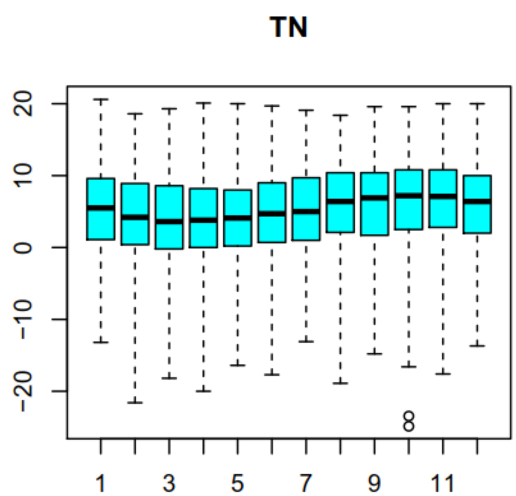


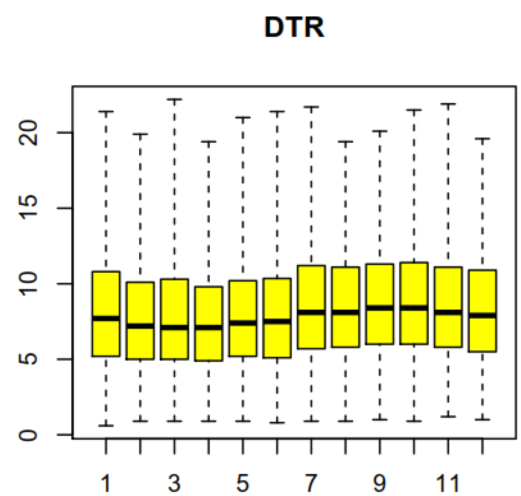
mystation_boxes.pdf

This file identifies potential outliers based on the interquartilic (IQR). The IQR is defined as the difference between the 75th (p75) and the 25th (p25) percentiles. As can be seen in the example below, the mystation_boxes.pdf file contains boxplots of temperature and precipitation data flagging as outliers (round circles) all those temperature values falling outside a range defined by p25 – 3 interquartilic ranges (lower bound) and p75 + 3 interquartilic ranges (upper bound). For precipitation, 5 IQR are used.









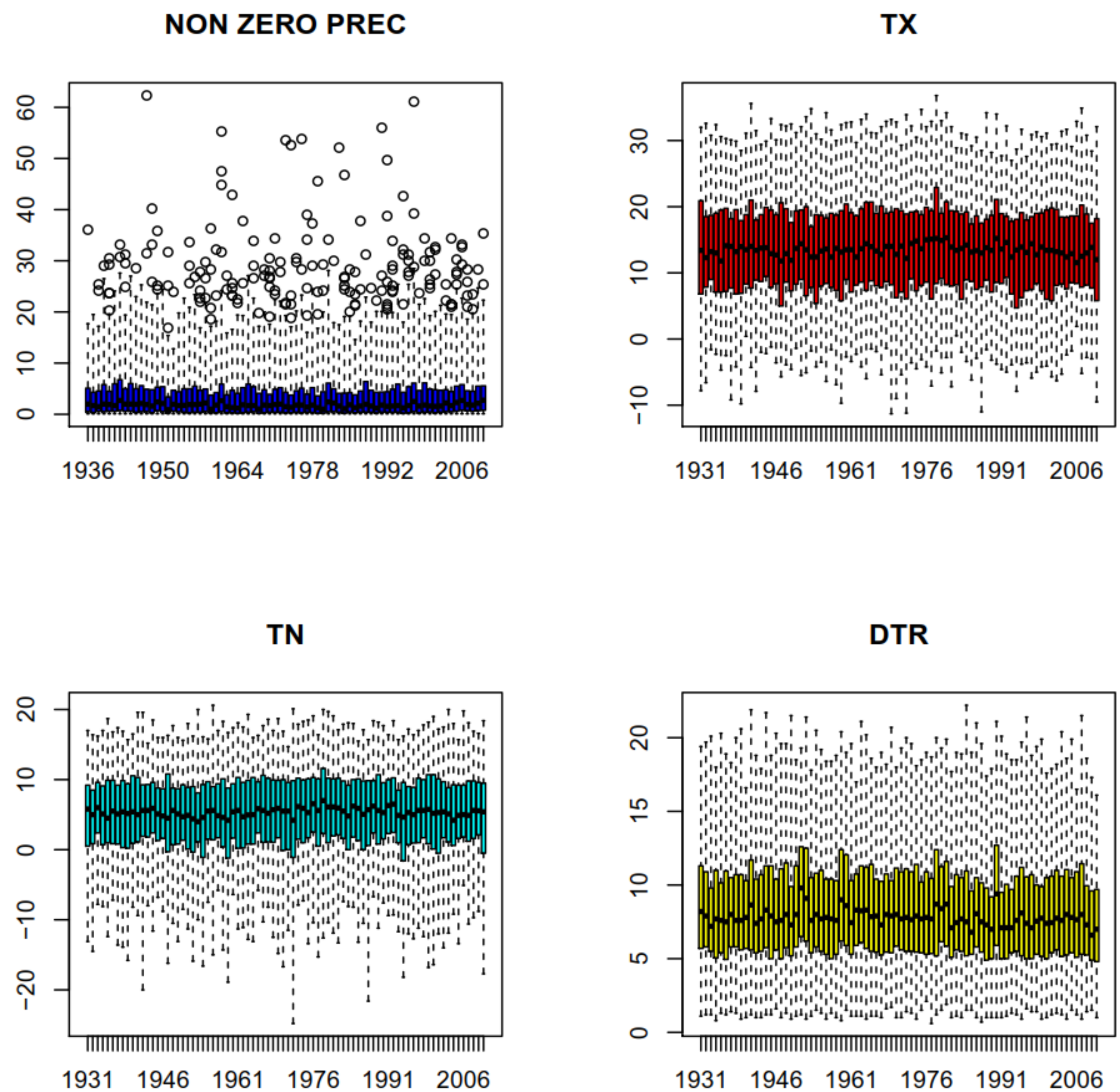
The values identified by this graphical quality control, are sent to a .csv file, mystation_outliers.csv. This file lists the outliers grouped under the variable that produced the inclusion of the record in the file and specifying the margin (upper bound or lower bound) that is surpassed. So, under 'Prec up' appear those values that represent a precipitation outlier; under 'TX up' are those that represent a maximum temperature higher than p75+3*IQR; under 'TX low' are outliers that represent an observation lower than p25-3*IQR. The explanation given for TX, also applies to TN and DTR. The advantage of this approach is that the detection of this percentile based outliers is not affected by the presence of larger outliers, so ONE RUN OF THE PROCESS IS ENOUGH!

Date	Prec	TX	TN	DTR
Prec up				
2/01/1951	31.8	14.3	10.2	4.1
12/01/1961	47.5	23.4	11.4	12
5/04/1963	42.8	19.2	13.6	5.6
18/04/1967	29.1	20.2	11.8	8.4
19/04/1969	28.2	27.7	17.9	9.8
19/04/1973	53.6	14.8	11.1	3.7
21/11/1991	55.9	11.4	7.8	3.6

11/11/1995	32.1	18.4	13.5	4.9
1/12/2000	31.6	18.6	12.6	6
31/12/2001	32.1	16	9.4	6.6
15/12/2005	30.2	22.1	13.3	8.8
TX up				
TX low				
TN up				
TN low				
30/10/1972	2.5	-11.2	-23.4	12.2
31/10/1972	4.3	-4.8	-24.8	20
DTR up				
DTR low				

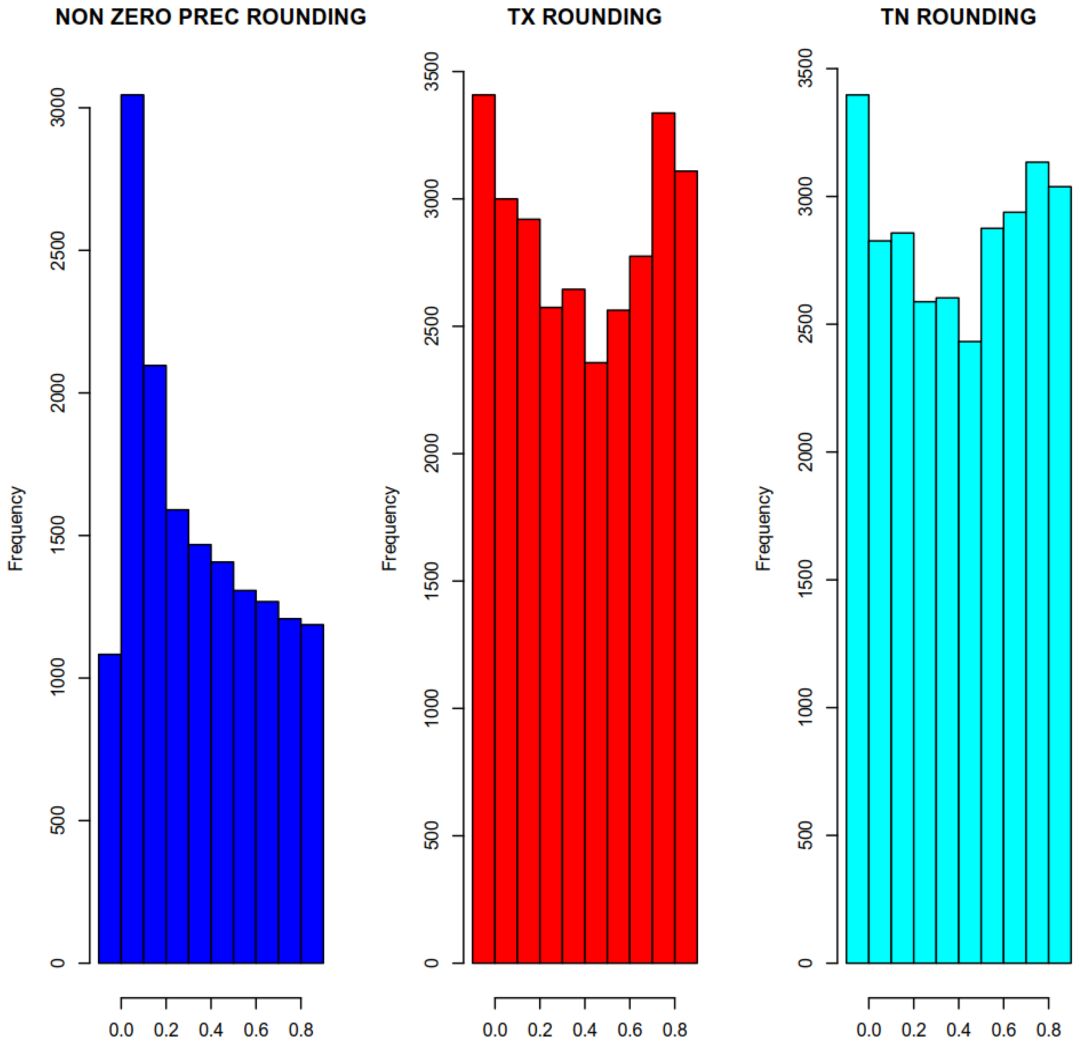
mystation_boxseries.pdf

The graphic file boxseries.pdf (which does not have a numerical counterpart) produces annual boxplots. This file is useful to have a panoramic view of the series and be alerted of parts of the series which can be problematic (see values around 1984 in the example figure below).



mystation_rounding.pdf

This file looks at rounding problems by plotting the frequency of values after each decimal point. It shows how frequently each of the 10 possible values (.0 to .9) appears. It is expected that .0 and .5 will be more frequent (although there is no statistical reason for this!).



mystation_tn_flatline.csv
mystation_tx_flatline.csv

The mystation_tn_flatline.csv and mystation_tx_flatline.csv files report occurrences of 4 or more equal consecutive values in, respectively, TX and TN. A line for each sequence of 4 or more consecutive equal values is generated. In the example below all sequences are 4 values long (i.e. each corresponding value has been repeated 3 extra times). The date specified belongs to the end of the sequence.

Date	TX	Number of duplicates
4/09/1937	18	3
28/11/1937	16.9	3

Looking at the data, the first sequence identified by the QC test is shown below.

1937	9	1	0	16.4	11.6
1937	9	2	0	18	10.2
1937	9	3	0	18	8.6
1937	9	4	0	18	7

mystation_duplicates.csv

The file mystation_duplicates.csv includes all dates which appear more than once in a datafile. In the listing below, one can see that 1958/08/26 occurs twice, and thus will be reported in mystation_duplicates.csv.

1951 8 24
1951 8 25
1951 8 26
1951 8 26
1951 8 28
1951 8 29
1951 8 30
1951 8 31

mystation_toolarge.csv

The file mystation_toolarge.csv reports precipitation values exceeding 200 mm (this and any other threshold can be easily reconfigured before execution) and temperature values exceeding 50 ºC.

mystation_tx_jumps.csv
mystation_tn_jumps.csv

The files mystation_tx_jumps.csv and mystation_tn_jumps.csv will list those records where the temperature difference with the previous day is greater or equal than 20 ºC.

mystation_tmaxmin.csv

The mystation_tmaxmin.csv file, records all those dates where maximum temperature is lower than minimum temperature.

mystation_temp_nastatistics.csv

This file lists the number of missing values that exists for each variable (TX, TN, PR) for each year.

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Appendix D: Heatwave and coldwave calculations

D.1 Heatwave (HW) definitions and aspects

The HW calculations used in ClimPACT2 are based off Perkins and Alexander (2013), hereafter PA13, with some slight modifications to the Excess Heat Factor (EHF; Perkins personal comms 2015). See PA13 for background information.

Corresponding to the framework of PA13, three HW definitions are used in ClimPACT2. Neither is more 'correct' than the other, and all are provided for the user to interpret with the appropriate discretion. These definitions are based on the 90th percentile of TN (minimum daily temperature) designated Tn90, the 90th percentile of TX (maximum daily temperature) designated Tx90, and the EHF (see D.3 below).

According to the above **three HW definitions (Tn90, Tx90 and EHF)** a HW event is defined as any length of three or more days where one of the following conditions is met.

1. TN > 90th percentile of TN.
2. TX > 90th percentile of TX.
3. the EHF is positive.

The percentiles for Tn90 and Tx90 are calculated within a user-specified base period and for each calendar day using a 15 day running window.

All HW definitions in ClimPACT2 are calculated over the extended summer period (with the exceptions of the Excess Heat Factor (EHF) and Excess Cold Factor (ECF) as defined by Nairn and Fawcett (2013), see below). In the southern hemisphere the extended summer season includes November to March, in the northern hemisphere it includes May to September.

For each of the above three HW definitions there are **five HW Aspects** that are calculated for each year or summer.

1. HW Number (HWN): The number of HW events (>= 3 HW days) that begin in the period of

interest in addition to those that start prior to but continue into the period of interest.

2. HW Frequency (HWF): The number of days that contribute to HWs defined by HWN (these are termed 'HW days'). For HW's that begin prior to the period of interest, only the HW days within the period of interest are counted. For HW's that extend beyond the period of interest, a maximum of 14 days beyond the period of interest is counted.
3. HW Duration (HWD): Length in days of the longest heatwave defined by HWN.
4. HW Magnitude (HWM): The mean of the mean HW days of each HW defined by HWN.
5. HW AMplitude (HWA): The peak daily value in the hottest HW (defined as the HW with the highest HWM).

D.2 Notes regarding calculations

- When calculating HWs, leap days are ignored and deleted from data.
- The year of a HW season refers to the year it commences in. e.g. the summer season of 2009 for Sydney, Australia, begins in November 2009.
- If there are no HWs in a given year, then HWN and HWF = 0. All other HW aspects = NA.
- For netCDF data, values calculated over ocean grid cells should be ignored.

D.3 Excess Heat Factor

The EHF is a combination of two excess heat indices (EHI) representing the *acclimitisation* to heat and the climatological *significance*;

$$EHI(accl.) = [(TM_i + TM_{i-1} + TM_{i-2})/3] – [(TM_{i-3} + \ldots + TM_{i-32})/30]$$

$$EHI(sig.) = [(TM_i + TM_{i-1} + TM_{i-2})/3] – TM90_i$$

Where TM_i represents the average daily temperature for day i and $TM90_i$ is the 90th percentile of TM over all calendar day i within the user-specified base period, using a 15 day running window. TM is calculated via TM = (TX + TN)/2. The EHF is defined from the above two defintions:

$$EHF = EHI(sig.) \times \max(1,EHI(accl.))$$

The above definition of the EHF differs to that in PA13 in several key areas. In PA13 the EHF was defined as in Nairn and Fawcett (2013), using the climatological 95th percentile of TM over the base period (i.e. one percentile for the entire base period, not a unique percentile for each calendar day). In

ClimPACT2, the EHF has been updated (Perkins personal comms 2015) and uses the 90th percentile of TM for each calendar day using a 15 day running window. For users calculating the indices on netCDF data, an option exists to change the definition of the EHF calculation to that of Nairn and Fawcett (2013). To do this, simply change the "EHF_DEF" variable in *climpact2.ncdf.wrapper.r* to "NF13", instead of the default "PA13". In the GUI (see Section 3) the EHF is calculated using the modified "PA13" method.

D.4 Excess Cold Factor

Coldwaves (periods of uncharacteristically cold temperatures) are calculated in ClimPACT2 via the ECF that was developed by Nairn and Fawcett (2013) and is directly analagous to the EHF as defined by those authors.

The ECF is a combination of two excess cold indices (ECI) representing the *acclimitisation* to cold and the climatological *significance*;

$$ECI(accl.) = [(TM_i + TM_{i-1} + TM_{i-2})/3] – [(TM_{i-3} + \ldots + TM_{i-32})/30]$$

$$ECI(sig.) = [(TM_i + TM_{i-1} + TM_{i-2})/3] – TM05$$

Where

$$ECF = -ECI(sig.) \times \min(-1, ECI(accl.))$$

Where TM_i represents the average daily temperature for day i and TM05 is the 5th percentile of TM which is calculated within a user-specified base period. TM is calculated via TM = (TX + TN)/2. See Nairn and Fawcett (2013) for more details.

D.6 References

Nairn J R and Fawcett R G 2013 Defining heatwaves: heatwave defined as a heat-impact event servicing all community and business sectors in Australia (Centre for Australian Weather and Climate Research)

Perkins S E and Alexander L V 2013 On the Measurement of heatwaves J. Clim. 26 4500–17 Online: http://dx.doi.org/10.1175/JCLI-D-12-00383.1

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Appendix E: Threshold estimation and base period temperature indices calculation

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Empirical quantile estimation:
The quantile of a distribution is defined as

, $1<p<1$,

where F(x) is the distribution function. Let denote the order statistics of (i.e. sorted values of {X}), and let denote the ith sample quantile definition. The sample quantiles can be generally written as:

Hyndman and Fan (1996) suggest a formula to obtain medium un-biased estimate of the quantile by letting and letting , where int(u) is the largest integer not greater than u. The empirical quantile is set to the smallest or largest value in the sample when $j<1$ or $j>n$ respectively. That is, quantile estimates corresponding to $p<1/(n+1)$ are set to the smallest value in the sample, and those corresponding to $p>n/(n+1)$ are set to the largest value in the sample.

Bootstrap procedure for the estimation of exceedance rate for the base period:
It is not possible to make an exact estimate of the thresholds due to sampling uncertainty. To provide temporally consistent estimate of exceedance rate throughout the base period and out-of-base period, we adapt the following procedure (Zhang et al. 2005) to estimate exceedance rate for the base period. This method is used to calculate percentile thresholds inside the base period for all indices except WSDI, WSDId, CSDI, CSDId and the HW indices.

a. The 30-year base period is divided into one “out-of-base” year, the year for which exceedance is to be estimated, and a “base-period” consisting the remaining of 29 years from which the thresholds would be estimated.
b. A 30-year block of data is constructed by using the 29 year “base-period” data set and adding an additional year of data from the “base-period" (i.e., one of the years in the “base-period” is repeated). This constructed 30-year block is used to estimate thresholds.

c. The “out-of-base” year is then compared with these thresholds and the exceedance rate for the “out-of-base” year is obtained.
d. Steps (b) and (c) are repeated for an additional 28 times, by repeating each of the remaining 28 in-base years in turn to construct the 30-year block.
e. The final index for the “out-of-base” year is obtained by averaging the 29 estimates obtained from steps (b), (c) and (d).

References

Zhang X, Hegerl G, Zwiers F W and Kenyon J 2005 Avoiding Inhomogeneity in Percentile-Based Indices of Temperature Extremes *J. Clim.* **18** 1641–51 Online: http://dx.doi.org/10.1175/JCLI3366.1

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Appendix F: Frequently Asked Questions

1. Wait, what is a climate index?
In the broadest sense an index is a representation of a particular aspect of some data. In the context of climate science an index is a calculation that reflects a certain aspect of the climate record. For example, there are indices that measure different aspects of the El-Nino Southern Oscillation (ENSO) as well as indices that measure drought such as the Palmer Drought Severity Index (PDSI). A *climate extremes index* is one that characterises some extreme aspect of the climate record (as opposed to a mean aspect). For example, and of direct relevance to the indices calculated by ClimPACT2, if someone possesses 30 years of daily maximum temperatures then they have essentially a list of approximately 10,950 daily values. One climate index that could be applied to this data is the calculation of the maximum of daily maximum temperatures for each year. This would show whether the peaks of maximum temperatures are changing over time and would return 30 values, one for each year. The application of this index reduces the 10,950 values to 30 values and provides insight into how the positive extremes of a particular climate record are changing. The purpose of any index is to extract some useful information from a larger dataset.

Types of climate inidices in ClimPACT2

ClimPACT2 reads in daily precipitation, maximum temperature and minimum temperature data and calculates numerous climate indices, most of which relate to extreme aspects of the climate. Substantial literature exists describing a large portion of these indices and also contain excellent introductions to climate indices in general (e.g. Zhang et al. 2011, Zwiers et al. 2013). Most of these indices (not all) fall under one of several categories, including min/max indices, threshold indices and duration indices.

Min/max indices indicate the minimum or maximum of some variable. For example, the maximum daily maximum temperature each year (see example above). Or conversely the minimum daily minimum temperature each year. These are both ClimPACT2 indices designated txx and tnn, respectively (see Appendix A).

Threshold indices count the number or proportion of days above or below a certain threshold. For example, the number of days each year where precipitation is greater than 10 mm (R10mm). The threshold in use may be *absolute* (like the previous example), or *percentile-based*. For example, the number of days where precipitation is higher than the 95th percentile of daily precipitation. Percentile-based indices provide a measure of how extremes are changing relative to the climatology of the site in question, as opposed to an arbitrary fixed value. This provides easier spatial interpretation of trends as each location is being measured according to the local climatology. For example, if counting the number of days where maximum temperature exceeds 30 degrees Celcius, this value will be much closer to 365 days per year in the tropics compared to the middle latitudes, and the temporal trend may be drastically different between the two climate zones. Instead, counting the number of days where maximum temperature exceeds the 90th percentile provides a substantially more robust measure of change. The percentiles used in calculating percentile-based indices are calculated over a user-specified base period (recommended by the World Meteorological Organisation to be 1961 - 1990).

Duration indices measure the length of time of or between certain events, or the aggregate number of days meeting a certain criteria. For example, the growing season length (GSL) measures the number of days between the first instance in the year when daily mean temperatures exceed that needed for growth and the first instance subsequently when daily mean temperature falls below that needed for growth.

2. What should be the length of the baseline/reference period?

The World Meteorological Organisation (WMO) defines the current state of 'normal' climate to be the average between 1961 and 1990. Thus, ideally these will be the years of your base period when calculating the ClimPACT2 indices. However, it is recognised that many stations do not have this length of record (or discontinuous records throughout this period), thus a period as close to the above years as possible is desired, as well as a length of base period as close to 30 yeras as possible.

3. How are missing data handled by ClimPACT2?

In the ClimPACT2 GUI, missing data need to be stored as -99.9 in the input data files (see APPENDIX B) but are converted to an internal format that R recognises (NA, not available).
For netCDF files, missing data can be any valid real value, so long as the missing_value attribute is defined accordingly.

4. Why do the SPI/SPEI output produce so much missing data when my input files do not contain missing data?

If you observe numerous missing data in your SPI or SPEI output when calculated on gridded indices, despite your input not having a corresponding amount of missing data, it is likely that you have specified a base period that is too short. Try and specify a base period of at least 30 years when possible. The R package used to calculate SPI and SPEI has been known to produce numerous missing data when a base period of ~10 years or less is specified.

5. Are the SPI/SPEI the best or only form of drought indices?

The SPI and SPEI are certainly not the only drought indices available, and they are both relative newcomers compared to indices such as the Palmer Drought Deverity Index (PDSI). Whether the SPI/SPEI are the best is subjective and dependent upon many factors, however, they are commonly used drought indices hence their inclusion in ClimPACT2. We encourage you to read the original SPI and SPEI documentation, as well as this excellent online resource by Vicente-Serrano and Begueria on the SPEI, its history and its application. An excellent example of the responsible use of the SPI/SPEI can be seen in work by the Global Precipitation Climatology Centre.

6. How can ClimPACT2 results be analysed further or used to produce customised graphics using other popular packages?

The ClimPACT2 GUI produces its own plots of each index (in the "plots" folder) once the software has completed running (see Section 3). However, all of the indices output data are stored in the "indices" directory in .csv format. Many graphics packages are able to handle this file format so you can produce your own customised plots easily with your favourite software package.

For output netCDF files, any netCDF viewer can be used to view these. We recommend using Ncview or Panoply for viewing netCDF output. Numerous programming language are available which allow you to manipulate and plot netCDF files (e.g. R, Python, NCL, Ferret).

7. Can I add additional indices to ClimPACT2 myself?

Section 3.5 details how a custom day count index can be created via the GUI. Besides this process, there is no easy method to add indices but if you are familiar with the R programming language you can amend the code to add additional indices if you require. This is a good solution if you have very specific sector requirements that are not covered by the current suite of indices. However, it is critical that the added indices and any changes made to an existing index is documented.

8. Why does ClimPACT2 require so many R packages to be installed?

ClimPACT2 depends on code written by many other individuals and institutions. These bodies have released their code as R packages and to save "re-inventing the wheel" ClimPACT2 incorporates these R packages into itself. This is typically considered best practice though does lead to "dependency hell" where requiring a package may further require more packages to be installed. Thus, currently there are approximately 15 R packages that need to be installed to use ClimPACT2's full functionality. However, this process only has to occur once.

9. Can I recommend additional indices to be added to the ET-SCI core set?

Yes, but any indices added to the core set have to be agreed by the members of the ET-SCI.

References

McKee T B, Doesken N J and Kleist J 1993 The relationship of drought frequency and duration to time scales Proceedings of the 8th Conference on Applied Climatology vol 17 (American Meteorological Society Boston, MA, USA) pp 179–83

Vicente-Serrano S M, Beguería S and López-Moreno J I 2010 A Multiscalar Drought Index Sensitive to Global Warming: The Standardized Precipitation Evapotranspiration Index J. Clim. 23 1696–718 Online: http://dx.doi.org/10.1175/2009JCLI2909.1

Zhang X, Alexander L, Hegerl G C, Jones P, Tank A K, Peterson T C, Trewin B and Zwiers F W 2011 Indices for monitoring changes in extremes based on daily temperature and precipitation data Wiley Interdiscip. Rev. Clim. Chang. 2 851–70 Online: http://dx.doi.org/10.1002/wcc.147

Zwiers F W, Alexander L V, Hegerl G C, Knutson T R, Kossin J P, Naveau P, Nicholls N, Schär C, Seneviratne S I and Zhang X 2013 Climate Extremes: Challenges in Estimating and Understanding Recent Changes in the Frequency and Intensity of Extreme Climate and Weather Events BT - Climate Science for Serving Society: Research, Modeling and Prediction Priorities ed R G Asrar and W J Hurrell (Dordrecht: Springer Netherlands) pp 339–89 Online: http://dx.doi.org/10.1007/978-94-007-6692-1_13

ClimPACT2

Appendix H: Goals and terms of reference of the ET-SCI

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At the first meeting of the ET-SCI in Tarragona, Spain in July 2011, the following Terms of Reference (ToR) and deliverables were agreed as follows are:

- Develop methods and tools including standardized software for, and to generate, sector-specific climate indices, including their time series based on historical data, and methodologies to define simple and complex climate risks;
- Promote the use of sector-specific climate indices to bring out variability and trends in climate of particular interest to socio-economic sectors (e.g., droughts), with global consistency and to help characterize the susceptibility of various sectors to climate;
- Develop the training materials needed to raise capacity and promote uniform approaches around the world in applying these techniques;
- Work with sector-based agencies and experts, including those of relevant WMO Technical Commissions, particularly the Commission for Hydrology (CHy) and the Commission for Agricultural Meteorology (CAgM), to facilitate the use of climate information in users' decision-support systems for climate risk management and adaptation strategies;

Submit reports in accordance with timetables established by the OPACE 4 co-chairs.

- In addition various deliverables were proposed for consideration by the Team. These included:
- A collection and analysis of existing climate indices with particular specific sectoral (agriculture, water, health and Disaster Risk Reduction (DRR)) applications at national and regional scales;
- Technical publication on climate indices for sectoral application in risk assessment and adaptation;
- Methods and tools, standardized software and associated training materials required to produce sector-specific climate indices for systematic assessment of the impact of climate variability and change and to facilitate climate risk management and adaptation (to be done in collaboration

with WMO Technical Commissions, particularly CCl OPACE-2 and with relevant agencies and organizations if required;

- Pilot training workshop (at least one region) on development of the indices;
- Workshop Report/Publication.