STARDEX Diagnostic Extremes Indices Software

User Information

Version 3.3.1, June 2004

Introduction

The STARDEX extremes indices software comprises two elements: a Fortran subroutine *extremes_indices* that calculates all the indices for a single location; and a program *station_indices* that uses the above subroutine to process station data in a standard input format.

The software was developed from the program *ClimateIndices* originally written at the US National Climatic Data Centre (NCDC) by Tom Peterson and Byron Gleason in 1999. The first version included about 20 climate indices. A further 20 indices were added by Malcolm Haylock from the Australian Bureau of Meteorology in 2000 on a visit to NCDC. Work for STARDEX was then undertaken by Colin Harpham of King's College London, after receiving the code from the European Climate Assessment (ECA). A further dozen indices were added relating to wet and dry spells. The code was tidied and converted to a subroutine by Malcolm Haylock, now with the Climatic Research Unit. Finally, two further indices were added relating to cold-wave duration and no-defrost days.

Configuring the code

The Fortran 90 source code includes the program file *station_indices.f90*, which calls the subroutine *extremes_indices* in *indices.f90* to calculate the indices. The file *indices.f90* need never be changed if adapting the program for other data input formats. The program *station_indices.f90* can be used as a model for users wishing to write their own program.

There is an include file *indices.inc* which needs to be resident in the same directory. Data and parameters are passed to the subroutine using a Fortran *common block*.

There are several user-defined parameters that need to be set in the program before compiling. The default values are given below:

In the file *indices.inc* set the start and end years for the analysis. Data outside of this period are ignored and do not have to exist over the entire period:

    parameter(minyr=1950, maxyr=2002)

In the file *station_indices.f90* (or your own program) set the following:

bm_minyr=1961	start year of base period for normals
bm_maxyr=1990	end year of base period for normals
miss=-999.9	missing value of input data
wd_cutoff=1.0	minimum rain for wet day classification
frac_thresh=0.8	minimum fraction of non-missing data allowed
DegDays_Thresh=5.0	threshold for degree day and growing season calculations
minPercentileDays=10	minimum no. of days for which a percentile can be calculated
newnames=.true.	use new (clearer) names for indices
top10=.false.	output STARDEX top 10 indices only

Compiling the code

The code has been tested on a Unix system using the following compiler:

```
f90 station_indices.f90 indices.f90
```

The code has been developed in a UNIX environment, so ensure the files are ftp transferred as ASCII when using Windows to convert the line ending/carriage returns.

Alternatively the program can be compiled in a Windows environment using the Fortran 90 compatible compiler of your choice.

Running the program

Each station should appear in its own file. The first line of the station data file should contain the latitude and longitude separated by a comma or space. The latitude is in degrees north (-ve for southern hemisphere). The format of the longitude does not matter. The latitude is used to determine which month the growing season and frost seasons are centred on. The station data are formatted one line per day in the order: year, mth, day, tmin, tmax, tmean, precip. Values need to be separated by a comma or space. If only precipitation data are to be analysed then set the temperature fields to missing, or vice versa if only temperature data are to be analysed.

There are two options for running the program:

```
station_indices station1 station2 station3 …
station_indices (no arguments)
```

In the second case, station file names are placed in a file called *station_list.dat*

The results are written to a file of the same name as the station with the file extension *.ind.csv*. A *.csv* (comma-separated file) can be loaded directly into Excel (usually just by double-clicking the file) in order to view the time series of the indices. The output file contains one column for each index for each season, including annual series. All indices are calculated seasonally except for degree days, growing season length and frost season length. Indices with all missing values are not output.

The last two lines of each column contain the linear trend of the index and the significance of the trend calculated using a kendall-tau significance test.

For any problems associated with compiling or running the software e-mail Malcolm Haylock (**M.Haylock@uea.ac.uk**).

Use of the software

This software is provided free of charge for public use. Please acknowledge its source (the STARDEX project) in any publications. The STARDEX co-ordinator (c.goodess@uea.ac.uk) would also appreciate receiving a copy of such publications.

Acknowledgements

Work undertaken on the diagnostics extremes indices software at King's College London and the Climatic Research Unit was funded by the Commission of the European Union under the STARDEX (Statistical and Regional dynamic Downscaling of Extremes for European regions – see http://www.cru.uea.ac.uk/projects/stardex) project (contract EUK2-CT-2001-00115). The European Climate Assessment project (http://www.knmi.nl/samenw/eca/) and US National Climatic Data Centre are thanked for the code, which forms the basis of this software.

Recent Version History

3.3.1, 2nd June 2004

Fixed problem whereby annual Frost Days and Ice Days indices would appear as missing for years with no frost or ice occurrence

Changed checks for fraction of missing data to >= *frac_thresh* for consistency throughout program

Added *top10* parameter to station_indices.f90 to output just the STARDEX favourite indices

Station_indices now has *new_names* set on by default

3.3.0 same as 3.2.7

3.2.7, 21st November 2003

Now 57 indices

Added mean Tmin, Tmax and Tmean indices

Added new heat wave index txhw90 and cold wave index tnhw10 that find the maximum consecutive days above or below a percentile threshold.

Fixed problem with erroneous trend probability calculation for constant data

Changed missing value in this document to agree with source (-999.9)

Added optional new (clearer) names for indices – use variable 'newnames' to switch

3.2.6, 22nd May 2003: Bug reports thanks to *Institute de Recherche*, Canada.

Fixed problems with wet_spell_stats and dry_spell_stats when there are less than 19 years.

Fixed bug in RThresh (no. of days > X rainfall). Only affects seasonal indices.

Consecutive dry days and consecutive wet days now require no missing values in the longest spell.

Fixed initialisation bug in prec_pww and prec_pdd (dry and wet day persistence).

3.2.5, 6th May 2003

Removed calls to FORTRAN77 function 'malloc'.

3.2.4, 9th January 2003

Note that there are now 52 indices

Fixed bug in CDD (consecutive dry days) which gave no dry days for 0mm wet day cutoff (affects 0mm threshold only).

Removed max wet and dry spells (same as condecutive wet and dry days).

3.2.3, 3rd January 2003

Fixed bug in wet and dry-day persistence routines (affects annual indices only).

3.2.2, 26th November 2002

Added check for missing data in FSL and DegreeDays.

3.2.1, 15th November 2002

Added minPercentileDays parameter.

3.2, 13th November 2002

All indices calculated seasonally apart from degree days, growing season length and frost season length.

3.1, 8th November 2002

Added seasonal indices for STARDEX 'top 10'.

3.0, 9th July 2002

First STARDEX release

Old Name	New Name	Description
txav	txav	Mean Tmax
tnav	tnav	Mean Tmin
tav	tav	Mean Tmean
Trange_mean	trav	mean diurnal temperature range
Trange10p	trq10	10th percentile diurnal temperature range
Trange90p	trq90	90th percentile diurnal temperature range
tmax10p	txq10	Tmax 10^{th} percentile
tmax90p	txq90	Tmax 90^{th} percentile
tmin10p	tnq10	Tmin 10th percentile
tmin90p	tnq90	Tmin 90th percentile
125Fd	tnfd	Number of frost days Tmin < 0 degC
114Id	txice	Number of days without defrost (ice days) Tmax < 0 degC
135GD	tgdd	Growing degree days > threshold
141ETR	tiaetr	Intra-annual extreme temperature range
143GSL	tgsl	Growing Season Length
144HWDI	txhwd	Heat Wave Duration
txhw90	txhw90	90^{th} Percentile Heat Wave Duration
145CWDI	tncwd	Cold Wave Duration
tncw10	tncw10	10^{th} Percentile Cold Wave Duration
147FSL0	tnfsl	Frost Season Length (0 degC)
191Tx10	txf10	% days Tmax < 10th percentile
192Tx90	txf90	% days Tmax > 90th percentile
193Tn10	tnf10	% days Tmin < 10th percentile
194Tn90	tnf90	% days Tmin > 90th percentile
601R	pav	Mean climatological precipitation (mm/day)
prec20p	pq20	20th percentile of rainday amounts (mm/day)
prec40p	pq40	40th percentile of rainday amounts (mm/day)
prec50p	pq50	50th percentile of rainday amounts (mm/day)
prec60p	pq60	60th percentile of rainday amounts (mm/day)
prec80p	pq80	80th percentile of rainday amounts (mm/day)
prec90p	pq90	90th percentile of rainday amounts (mm/day)
prec95p	pq95	95th percentile of rainday amounts (mm/day)
frac20p	pf20	Fraction of total precipitation above annual 20th percentile
frac40p	pf40	Fraction of total precipitation above annual 40th percentile
frac50p	pf50	Fraction of total precipitation above annual 50th percentile
frac60p	pf60	Fraction of total precipitation above annual 60th percentile
frac80p	pf80	Fraction of total precipitation above annual 80th percentile
frac90p	pf90	Fraction of total precipitation above annual 90th percentile
frac95p	pf95	Fraction of total precipitation above annual 95th percentile
606R10	pn10mm	No. of days precip >= 10mm
641CDD	pxcdd	Max no. consecutive dry days
642CWD	pxcwd	Max no. consecutive wet days
pww	ppww	Mean wet-day persistence
persist_dd	ppdd	Mean dry-day persistence
persist_corr	ppcr	Correlation for spell lengths
wet_spell_mean	pwsav	mean wet spell lengths (days)
wet_spell_perc	pwsmed	median wet spell lengths (days)
wet_spell_sd	pwssdv	standard deviation wet spell lengths (days)
dry_spell_mean	pdsav	mean dry spell lengths (days)
dry_spell_perc	pdsmed	median dry spell lengths (days)
dry_spell_sd	pdssdv	standard deviation dry spell lengths (days)
643R3d	px3d	Greatest 3-day total rainfall
644R5d	px5d	Greatest 5-day total rainfall
645R10d	px10d	Greatest 10-day total rainfall
646SDII	pint	Simple Daily Intensity (rain per rainday)

691R90T	pfl90	% of total rainfall from events > long-term 90th percentile
692R90N	pnl90	No. of events > long-term 90th percentile

Table 1: STARDEX Diagnostic Extremes Indices

Appendix

Diurnal temperature range

Subroutine name： `temp_range`

- *Mean of diurnal temperature range*

Let Tx_{ij} and Tn_{ij} be the daily maximum and minimum temperature at day *i* of period *j*. Then the mean diurnal temperature range in period *j* is:

$$Trange\_mean_j = \sum_{i=1}^{I} \left(Tx_{ij} - Tn_{ij}\right) / I$$

Index name: ‘Trange_mean’

- *10th percentile of diurnal temperature range*

Index name: ‘Trange10p’

- *90th percentile of diurnal temperature range*

Index name: ‘Trange90p’

Tmax percentiles

Subroutine name： `tmax_perc`

- *10th percentile of maximum temperatures*

Index name:’tmax10p’

- *90th percentile of maximum temperatures*

Index name:’tmax90p’

Tmin percentiles

Subroutine name： `tmin_perc`

- *10th percentile of minimum temperatures*

Index name: ’tmin10p’

- *90th percentile of minimum temperatures*

Index name: ’tmin90p’

Number of frost days Tmin < 0 degC

Subroutine name: `Fd`

Let Tn_{ij} be the daily minimum temperature at day *i* of period *j*, then counted are the number of days where:

$$Tn_{ij} < 0°c$$

Index name: '125Fd'

Number days without defrost (ice days) Tmax < 0 degC

Subroutine name: `Fd_Tx`

Let Tx_{ij} be the daily maximum temperature at day *i* of period *j*, then counted are the number of days where:

$$Tx_{ij} < 0°c$$

Index name: '114Id'

Growing degree days > User Defined Threshold

Subroutine name: `DegDays`

Let T_{ij} be the daily mean temperature at day *i* of period *j*. Then the growing degree days are :

$$GD_j = \sum_{i=1}^{I} \left(T_{ij} \mid T_{ij} > \text{User Defined Threshold} \right)$$

Index name: '135GD'

Intra-annual extreme temperature range

Subroutine name: `ETR`

Let Tx_{ij} and Tn_{ij} be the daily maximum and minimum temperature at day *i* of period *j*. Then the extreme temperature range in period *j* is:

$$ETR_j = \max(Tx_{ij}) - \min(Tn_{ij})$$

Index name: '141ETR'

Growing Season Length

Subroutine name: `GSL`

Let T_{ij} be the mean temperature at day *i* of period *j*. Then counted are the number of days between the first Autumn-Winter occurrence of at least 6 consecutive days with:

$$T_{ij} > \text{User Defined Threshold}$$

and the first Winter-Spring occurrence of at least 6 consecutive days with:

$$T_{ij} < \text{User Defined Threshold}$$

Index name: '143GSL'

Heat Wave Duration

Subroutine name: `hcwdi`

Let Tx_{ij} be the daily maximum temperature at day *i* of period *j* and let Tx_{inorm} be the calendar day mean calculated for a 5 day window centred on each calendar day during a specified period. Then counted is the number of days per period where, in intervals of at least 6 consecutive days:

$$Tx_{ij} > Tx_{inorm} + 5$$

Index name: '144HWDI'

Subroutine name: `hcwdi_perc`

Let Tx_{ij} be the daily maximum temperature at day *i* of period *j* and let $Txq90_{inorm}$ be the calendar day 90th percentile calculated for a 5 day window centred on each calendar day during a specified period. Then counted is the maximum number of consecutive days per period where:

$$Tx_{ij} > Txq90_{inorm}$$

Index name: 'txhw90'

Cold Wave Duration

Subroutine name: `hcwdi`

Let Tn_{ij} be the daily minimum temperature at day *i* of period *j* and let Tn_{inorm} be the calendar day mean calculated for a 5 day window centred on each calendar day during a specified period. Then counted is the number of days per period where, in intervals of at least 6 consecutive days:

$$Tn_{ij} < Tn_{inorm} - 5$$

Index name: '145CWDI'

Subroutine name: `hcwdi_perc`

Let Tn_{ij} be the daily maximum temperature at day *i* of period *j* and let $Tnq10_{inorm}$ be the calendar day 10th percentile calculated for a 5 day window centred on each calendar day during a specified period. Then counted is the maximum number of consecutive days per period where:

$$Tn_{ij} < Tnq10_{inorm}$$

Index name: 'tncw10'

Frost Season Length (0 degC)

Subroutine name: `FSL`

Let Tn_{ij} be the daily minimum temperature at day *i* of period *j*. Then counted are the number of days between the first occurrence of:

$$Tn_{ij} < 0$$

and the last occurrence.

Index name: '147FSL0'

% days Tmax < 10th percentile

Subroutine name: `Tx10`

Let Tx_{ij} be the daily maximum temperature at day *i* of period *j* and let $Tx_{in}10$ be the calendar day 10th percentile for a specified period. Then the percentage of time is determined where:

$$Tx_{ij} < Tx_{in}10$$

Index name: '191Tx10'

% days Tmax > 90th percentile

Subroutine name: `Tx90`

Let Tx_{ij} be the daily maximum temperature at day *i* of period *j* and let $Tx_{in}90$ be the calendar day 90th percentile for a specified period. Then the percentage of time is determined where:

$$Tx_{ij} > Tx_{in}90$$

Index name: '192Tx90'

% days Tmin < 10th percentile

Subroutine name: `Tn10`

Let Tn_{ij} be the daily minimum temperature at day i of period j and let $Tn_{in}10$ be the calendar day 10^{th} percentile for a specified period. Then the percentage of time is determined where:

$$Tn_{ij} < Tn_{in}10$$

Index name: '193Tn10'

% days Tmin > 90th percentile

Subroutine name: `Tn90`

Let Tn_{ij} be the daily minimum temperature at day i of period j and let $Tn_{in}90$ be the calendar day 90^{th} percentile for a specified period. Then the percentage of time is determined where:

$$Tn_{ij} > Tn_{in}90$$

Index name: '194Tn90'

Mean climatological precipitation (mm/day)

Subroutine name: `prec_mean`

Let R_{wj} be the daily precipitation amount for day w of period j. Then the mean climatological precipitation in period j is:

$$prec\_mean_j = \sum_{w=1}^{W} \left(R_{wj}\right) / W$$

Index name: '601R'

Quantiles (20,40,50,60,80,90,95%)of rainday amounts (mm/day)

Subroutine name: `prec_perc`

- *20th percentile of rainday amounts*

Index name: 'prec20p'

- *40th percentile of rainday amounts*

Index name: 'prec40p'

- *50th percentile of rainday amounts*

Index name: ‘prec50p’

- *60th percentile of rainday amounts*

Index name: ‘prec60p’

- *80th percentile of rainday amounts*

Index name: ‘prec80p’

- *90th percentile of rainday amounts*

Index name: ‘prec90p’

- *95th percentile of rainday amounts*

Index name: ‘prec95p’

Fraction of total precipitation above annual quantiles

Subroutine name: `prec_quant`

- *Fraction of total precipitation above 20th percentile of rainday amounts*

Index name: ‘frac20p’

Fraction of total precipitation above 40th percentile of rainday amounts

Index name: ‘frac40p’

Fraction of total precipitation above 50th percentile of rainday amounts

Index name: ‘frac50p’

Fraction of total precipitation above 60th percentile of rainday amounts

Index name: ‘frac60p’

Fraction of total precipitation above 80th percentile of rainday amounts

Index name: ‘frac80p’

Fraction of total precipitation above 90th percentile of rainday amounts

Index name: ‘frac90p’

Fraction of total precipitation above 95th percentile of rainday amounts

Index name: ‘frac95p’

No. of days precip >= 10mm

Subroutine name: `RThresh`

Let R_{ij} be the daily precipitation amount for day i of period j. Then counted are the number of days where:

$$R_{ij} \geq 10\text{mm}$$

Index name: '606R10'

Max no. consecutive dry days

Subroutine name: `cdd`

Let R_{ij} be the daily precipitaion amount for day i of period j. Then counted is the largest number of consecutive days where:

$$R_{ij} \leq \text{wd\_cutoff}$$

where wd_cutoff is a user specified variable.

Index name: '641CDD'

Max no. consecutive wet days

Subroutine name: `cwd`

Let R_{ij} be the daily precipitaion amount for day i of period j. Then counted is the largest number of consecutive days where:

$$R_{ij} > \text{wd\_cutoff}$$

where wd_cutoff is a user specified variable.

Index name: '642CWD'

Mean wet-day persistence (Pww)

Subroutine name: `prec_pww`

Let $totalPww_j$ be the total number of consecutive wet days for period j and let $totalPw_j$ be the total number of wet days for period j. Then the mean wet-day persistence is given by:

$$Pww_j = totalPww_j / totalPw_j$$

Index name: 'pww'

Mean dry-day persistence (Pdd)

Subroutine name: `prec_pdd`

Let $totalPdd_j$ be the total number of consecutive dry days for period *j* and let $totalPd_j$ be the total number of dry days for period *j*. Then the mean dry-day persistence is given by:

$$Pdd_j = totalPdd_j / totalPd_j$$

Index name: 'persist_dd'

Correlation for spell lengths

Subroutine name: `persist_corr`

The correlation of the spell lengths for priod *j* is given by:

$$r = Pww_j - (1 - Pdd_j)$$

Index name: 'persist_corr'

Quantiles (statistics) of wet spell lengths (days)

mean/median(50th percentile)/standard deviation

Subroutine name: `wet_spell_stats`

Let $\{x_i, i = 1...n\}$ be the time series of the totals of wet spell lengths for period *j*.

- *mean of wet spell lengths*

$$wet\_spell\_mean_j = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Index name: 'wet_spell_mean'

- *median or 50th percentile of wet spell lengths*

Index name: 'wet_spell_perc'

- *standard deviation of wet spell lengths*

$$wet\_spell\_sd_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Index name: 'wet_spell_sd'

Quantiles (statistics) of dry spell lengths (days)

mean/median(50th percentile)/ standard deviation

Subroutine name: `dry_spell_stats`

Let $\{x_i, i = 1...n\}$ be the time series of the totals of dry spell lengths for period *j*.

- *mean of dry spell lengths*

$$dry\_spell\_mean_j = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Index name: 'dry_spell_mean'

- *median or 50th percentile of dry spell lengths*

Index name: 'dry_spell_perc'

- *standard deviation of dry spell lengths*

$$dry\_spell\_sd_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Index name: 'dry_spell_sd'

Greatest 3/5/10-day total rainfall

Subroutine name: r3_5_10d

Let R_{kj} be the precipitation amount for the *N* day interval *k* of period *j*, where *k* is defined by the last day. Then the maximum *N* day values for period *j* are:

$$RxN_j = \max(R_{kj})$$

Index name for 3 day total: '643R3d'

Index name for 5 day total: '644R5d'

Index name for 10 day total: '645R10d'

Simple Daily Intensity (rain per rainday)

Subroutine name: `sdii`

Let R_{wj} be the daily precipitation amount for wet day $w(R > \text{wd\_cutoff})$ of period *j*, where wd_cutoff is a user specified variable. Then the mean precipitation amount at wet days is:

$$SDII_j = \sum_{w=1}^{w} R_{wj} \Big/ W$$

Index name: '646SDII'

No. of events > long-term 90th percentile

Subroutine name: `RThreshN`

Let R_{wj} be the daily precipitation amount at wet day $w(R > \text{wd\_cutoff})$ of period *j* and let $R_{wn}90$ be the 90th percentile of precipitation at wet days in the specified period. Then the percent of time is determined where:

$$R_{wj} > R_{wn}90$$

Index name: '692R90N'

% of total rainfall from events > long-term 90th percentile

Subroutine name: `RThreshT`

Let R_j be the sum of daily precipitation amount for period *j* and let R_{wj} be the daily precipitation amount at wet day $w(R > \text{wd\_cutoff})$ of period *j* and $R_{wn}90$ the 90th percentile of precipitation at wet days in the specified period. Then $R90T_j$ is determined as:

$$R90T_j = \frac{\sum_{w=1}^{w} R_{wj}, \text{where } R_{wj} > R_{wn}90}{R_j}$$

Index name: '691R90T '
