

# Package ‘TSS.RESTREND’

July 21, 2025

**Type** Package

**Title** Time Series Segmentation of Residual Trends

**Version** 0.3.1

## Description

Time Series Segmented Residual Trends is a method for the automated detection of land degradation from remotely sensed vegetation and climate datasets. TSS-RESTREND incorporates aspects of two existing degradation detection methods: RESTREND which is used to control for climate variability, and BFAST which is used to look for structural changes in the ecosystem. The full details of the testing and justification of the TSS-RESTREND method (version 0.1.02) are published in Burrell et al., (2017). <[doi:10.1016/j.rse.2017.05.018](https://doi.org/10.1016/j.rse.2017.05.018)>. The changes to the method introduced in version 0.2.03 focus on the inclusion of temperature as an additional climate variable. This allows for land degradation assessment in temperature limited drylands. A paper that details this work is currently under review. There are also a number of bug fixes and speed improvements. Version 0.3.0 introduces additional attribution for eCO<sub>2</sub>, climate change and climate variability the details of which are in press in Burrell et al., (2020). The version under active development and additional example scripts showing how the package can be applied can be found at <<https://github.com/ArdenB/TSSRESTREND>>.

**License** GPL-3

**LazyData** TRUE

**Imports** stats, graphics, utils, bfast (>= 1.5.7), broom, strucchange, ggplot2, RcppRoll, mblm

**Suggests** rgl, car

**Depends** R (>= 3.6.0)

**RoxygenNote** 7.1.1

**NeedsCompilation** no

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TSS.RESTREND-package    *TSS.RESTREND: Time Series Segmented RESidual TREND*

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### Description

The TSS-RESTREND package is designed used via the TSS-RESTREND function which calls all the other functions in the correct order to perform a complete TSS-RESTREND analysis. The individual functions have been made callable to allow for greater user control. The version in active development, as well as additional documentation, data and example scripts, see <https://github.com/ArdenB/TSSRESTREND>.

### Details

Version 0.3.0

**Note**

This code is a demonstration of the method and not the code used in Burrell et. al., (2017). The original code uses both python and R and was designed for batch processing. For the pixels tested using the TSS.RESTREND package it produces identical results.

**Author(s)**

**Maintainer:** Arden Burrell <arden.burrell@gmail.com>

---

ACP.calculator	<i>Antecedental Rainfall (and temperature) Accumulation calculator for the VI Complete Time Series</i>
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**Description**

Takes the Complete Time Series Vegetation Index and a table of every possible accumulation period and offset period for precipitation and temperature(optional). A OLS is calculated [lm](#) for every combination of VI ~ rainfall (and temperature if that is included). if only the VPR is being calculated, this Function preferences those results where slope>0 (increase in rainfall causes an increase in vegetation),returning the rainfall accumulation that has the highest R-squared and a positive slope. If no combination produces a positive slope then the one with the highest R-squared is returned.

**Usage**

```
ACP.calculator(
  CTSR.VI,
  ACP.table,
  ACT.table = NULL,
  allow.negative = FALSE,
  allowneg.retest = FALSE
)
```

**Arguments**

CTSR.VI	Complete Monthly Time Series of Vegetation Index values. An object of class 'ts' object without NA's.
ACP.table	A table of every combination of offset period and accumulation period.for precipitation ACP.table can be calculated using the <a href="#">climate.accumulator</a> .
ACT.table	A table of every combination of offset period and accumulation period.for temperature ACP.table can be calculated using the <a href="#">climate.accumulator</a> .
allow.negative	If true, will not preference positive slope in either CTSR or VI calculations. default=FALSE is set because negative associations between rainfall and vegetation in water limited ecosystems is unexpected If temperature data is included then this paramter is forced to TRUE.
allowneg.retest	default=FALSE If temperature data is provided but found to not be significant then a retest is performed. This paramter is to allow negative on re-test.

**Value**

A list containing:

**summary** a Matrix containing "slope", "intercept", "p.value", "R^2.Value", "Break.Height", "Slope.Change" of the `lm` between Antecedental Rainfall Accumulation (CTSR.RF) and the CTSR.VI

**CTSR.precip** see CTSR.RF in [TSSRESTREND](#) for description

**CTSR.osp** The offset period for the complete time series rainfall

**CTSR.acp** The accumulation period for the complete time series rainfall

**CTSR.tmp** The optimally accumulated CTS temperature

**CTSR.tosp** The offset period for the complete time series temperature

**CTSR.tacp** The accumulation period for the complete time series temperature

**Examples**

```
#Find the data
vi.path <- system.file("extdata", "rabbitVI.csv", package = "TSS.RESTREND", mustWork = TRUE)
in.VI <- read.csv(vi.path)
CTSR.VI <- ts(in.VI, start=c(1982, 1), end=c(2013,12), frequency = 12)
data(rabbitACptable)
ACPres <- ACP.calculator(CTSR.VI, rabbitACptable)
print(ACPres$summary)
```

---

AnMaxVI

*Annual max VI Calculator*


---

**Description**

Takes the monthly time series of the VI and calculates the growing season max VI. In series where the peak occurs in November or December, an interannual growing season is assessed.

**Usage**

```
AnMaxVI(CTSR.VI)
```

**Arguments**

CTSR.VI            Complete Monthly Time Series of Vegetation Index values. An object of class 'ts' object without NA's.

**Value**

Max(anu.VI) The annual (Growing season) max VI. See [TSSRESTREND](#)

Max.Month The month number where max values were observed (1 for January). if month > 12, the peak was detected in Nov, Dec, Jan. In this case the peak seasonal value and position is used.

index(VI.index) the index of the CTSR.VI ts that the anu.VI values occur at. See [TSSRESTREND](#). Note.R indexes from 1 rather than 0.

**Author(s)**

Arden Burrell, arden.burrell@unsw.edu.au

**Examples**

```
anmax <- AnMaxVI(stdRESTRENDCTSR$cts.NDVI)
print(anmax)
```

---

AnnualClim.Cal	<i>Antecedental accumulation calculator for the annual max VI time series</i>
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**Description**

Takes the Annual Max VI Time Series, the VI.index and tables of every possible accumulation period and offset period for precipitation and Temperature (optional). A OLS is calculated `lm` for every combination of VI ~ rainfall. If temperature is provided The formula is (VI ~ rainfall + temperature). By default, this function preferences those results where slope>0 (increase in rainfall causes an increase in vegetation), returning the rainfall accumulation that has the highest R-squared and a positive slope. If no combinations produce a positive slope then the one with the highest Rsquared is returned. TO DO: non parametric and other variables

**Usage**

```
AnnualClim.Cal(
  anu.VI,
  VI.index,
  ACP.table,
  ACT.table = NULL,
  Breakpoint = FALSE,
  allow.negative = FALSE,
  allowneg.retest = FALSE
)
```

**Arguments**

anu.VI	The annual (Growing season) max VI. Must be a object of class 'ts' without NA's. if anu.VI=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
VI.index	the index of the CTSR.VI ts that the anu.VI values occur at. Must be the same length as anu.VI. NOTE. R indexes from 1 rather than 0. if VI.index=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
ACP.table	A table of every combination of offset period and accumulation period.for precipitation ACP.table can be calculated using the <a href="#">climate.accumulator</a> .
ACT.table	A table of every combination of offset period and accumulation period.for temperature ACP.table can be calculated using the <a href="#">climate.accumulator</a> .

Breakpoint	Used when calculating rf.bf and rf.af for ts with breakpoints in the VPR. See <a href="#">CHOW</a>
allow.negative	If true, will not preference positive slope in either CTSR or VI calculations. default=FALSE is set because negative associations between rainfall and vegetation in water limited ecosystems is unexpected If temperature data is included then this paramter is forced to TRUE.
allowneg.retest	default=FALSE If temperature data is provided but found to not be significant then a retest is performed. This paramter is to allow negative on re-test.

### Value

**summary** a Matrix containing "slope", "intercept", "p.value", "R^2.Value", "Break.Height", "Slope.Change" of the `lm` of `VI ~ rainfall`. If Breakpoint, summary covers both rf.b4 and rf.af.

**acu.RF** (aka. annual.precip) The optimal accumulated rainfall for anu.VI. Mut be a object of class 'ts' and of equal length to anu.VI. It is caculated from the ACP.table by finding the acp and osp that has the largest R^2 value. `lm(anu.VI ~ rainfall)`

**acu.TM** (aka, annual.temp) The optimal accumulated rainfall for anu.T<. Mut be a object of class 'ts' and of equal length to anu.VI. It is caculated from the ACT.table by finding the tacp and tosp that has the largest R^2 value. `lm(anu.VI ~ rainfall+temperature)`

**rf.b4** The optimal acumulated rainfall before the Breakpoint

**rf.af** The Optimally accumulated rainfall after the Breakpoint

**tm.b4** The optimal acumulated temperature before the Breakpoint

**tm.af** The Optimally accumulated temperature after the Breakpoint

**osp** The offest period for the annual max time series rainfall

**acp** The accumulation period for the annual max time series rainfall

**tosp** The offest period for the annual max time series temperature

**tacp** The accumulation period for the annual max time series temperature

### Author(s)

Arden Burrell, arden.burrell@unsw.edu.au

### Examples

```
ARC <- AnnualClim.Cal(stdRESTREND$max.NDVI, stdRESTREND$index, stdRESTRENDrfTab)
print(ARC)
## Not run:

#Test the complete time series for breakpoints
VPRBFdem <- VPR.BFAST(segVPRCTSR$cts.NDVI, segVPRCTSR$cts.precip)
bp<-as.numeric(VPRBFdem$bkps)

#test the significance of the breakpoints
reschow <- CHOW(segVPR$max.NDVI, segVPR$acum.RF, segVPR$index, bp)
brkp <- as.integer(reschow$bp.summary["yr.index"])
```

```
ARCseg <-AnnualClim.Cal(segVPR$max.NDVI, segVPR$index, segVPRrfTab, Breakpoint = brkp)
print(ARCseg)

## End(Not run)
```

---

 CHOW

*Chow test on detected breakpoints*


---

### Description

Takes the breakpoints detected by [VPR.BFAST](#), finds the most significant one then tests it in both the residuals and the VPR.

### Usage

```
CHOW(anu.VI, acu.RF, VI.index, breakpoints, acu.TM = NULL, sig = 0.05)
```

### Arguments

anu.VI	The annual (Growing season) max VI. Must be a object of class 'ts' without NA's. if anu.VI=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
acu.RF	The optimal accumulated rainfall for anu.VI. Must be a object of class 'ts' without NA's and be of equal length and temporal range to anu.VI. if anu.RF=FALSE, it will be calculated from ACP.table using the <a href="#">AnnualClim.Cal</a>
VI.index	the index of the CTSR.VI ts that the anu.VI values occur at. Must be the same length as anu.VI. NOTE. R indexes from 1 rather than 0. if VI.index=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
breakpoints	vector containing the breakpoints detected by <a href="#">VPR.BFAST</a> (bkps)
acu.TM	The optimal accumulated rainfall for anu.TM. Must be a object of class 'ts' without NA's and be of equal length and temporal range to anu.TM. if anu.TM=FALSE, it will be calculated from ACT.table using the <a href="#">AnnualClim.Cal</a>
sig	Significance of all the functions. default sig=0.05

### Value

**n.Method** The method that the ts should be tested with. TSSRESTREND internal communication.

**bp.summary** Summary of the most significant breakpoint in the residuals and VPR. see [sctest](#)

**allbp.index** the Annual index of every breakpoint. Used by [plot.TSSRESTREND](#)

bpRESID.chow Chow test in the VPR residuals. See [sctest](#)

bpVPR.chow Chow test in the VPR. See [sctest](#)

### Author(s)

Arden Burrell, arden.burrell@unsw.edu.au

**Examples**

```
## Not run:
#Test the complete time series for breakpoints
VPRBFdem <- VPR.BFAST(segVPRCTSR$cts.NDVI, segVPRCTSR$cts.precip)
bp <- as.numeric(VPRBFdem$bkps)
#test the significance of the breakpoints
reschow <- CHOW(segVPR$max.NDVI, segVPR$accum.RF, segVPR$index, bp)
print(reschow)

## End(Not run)
```

---

climate.accumulator     *Climate Accumulator*

---

**Description**

Takes the time series of rainfall and returns a rainfall accumulation table of every possible combination of the max accumulation period and the max offset period.

**Usage**

```
climate.accumulator(
  CTSR.VI,
  clim.data,
  max.acp,
  max.osp,
  temperature = FALSE,
  cliwindow = 0
)
```

**Arguments**

CTSR.VI	Complete Time Series of Vegetation Index. An object of class 'ts'. Monthly time series of VI values
clim.data	Complete Time Series of monthly rainfall or temperature. An object of class 'ts'. Must have the same end date as CTSR.VI and be longer than the CTSR.VI by more than the max accumulation period (max.acp) plus the max offset period.(max.ops)
max.acp	The max accumulation period. Must be an integer > 1.
max.osp	The max offset period. Must be an integer >1
temperature	Bool. If the clim.data being accumulated is temperature, will take a mean not a sum. This makes it easier to compare regions with different accumulation and offset periods. This is new in v0.3.0. Default=FALSE which replicates the behaviour of TSSRESTREND versions <0.2.16.
cliwindow	The size of the window in years to be used for calculating climate change.



**Value**

ACP.table A matrix with ever possible accumulated climate combination

**Examples**

```
# Define the max accumulation period
acp <- 12
#Define the max offset period
osp <- 4
rftable <- climate.accumulator(segRESTRENDCTSR$cts.NDVI, segRESTRENDctRF$precip, acp, osp)
```

---

franksCO2	<i>Franks CO2 Vegetation correction</i>
-----------	---

---

**Description**

Adjusts a vegetation time series to account for CO2 fertilisation

**Usage**

```
franksCO2(CTSR.VI, C4frac, CO2 = FALSE, refyear = 1980)
```

**Arguments**

CTSR.VI	Complete Monthly Time Series of Vegetation Index values. An object of class 'ts' object without NA's.
C4frac	The fraction of vegetation that follows the C4 photosynthetic pathway, between 0 and 1
CO2	A timeseries containg the CO2 concentration. The default is CMIP5 RCP8.5
refyear	The Year that acts as a baseline for CO2. All vegetation values will be scaled # to the CO2 concentration of this year. Defulat is 1980. THis function will pick the first value in the selected year,

**Value**

**CTSR.VIadj** A version of the CTSR.VI data that has been adjusted to account for CO2

**Author(s)**

Arden Burrell, aburrell@whrc.org

---

`plot.TSSRESTREND`      *Plot Function for objects of the TSSRESTREND class*

---

**Description**

Produces plots for class TSSRESTREND

**Usage**

```
## S3 method for class 'TSSRESTREND'  
plot(x, plots = "all", sig = 0.05, ...)
```

**Arguments**

<code>x</code>	Object of class TSSRESTREND
<code>plots</code>	Defaults to "all", will produce the standard plots, plots can be called individually, "bfast", "chow", "VPR", "anu.VI", "final".
<code>sig</code>	Significance
<code>...</code>	further arguments passed to the function.

---

`print.TSSRESTREND`      *Print function for class TSSRESTREND*

---

**Description**

print function for objects of class TSSRESTREND

**Usage**

```
## S3 method for class 'TSSRESTREND'  
print(x, ...)
```

**Arguments**

<code>x</code>	Object of class TSSRESTREND
<code>...</code>	further arguments passed to the function.

---

rabbitACPtable	<i>Rabbit Impacted Vegetation Precipitation Accumulation Table</i>
----------------	--

---

**Description**

Rainfall Accumulation Table form a part of the Simpson-sStrzelecki Dunefields bioregion impacted by reduced rabbit predation after the release of RHD.

**Usage**

```
rabbitACPtable
```

**Format**

A matrix containing the complete time series of every acp and ofp. See [climate.accumulator](#) for details

**Source**

Awap data from <http://www.csiro.au/awap/cgi/awap2.pl>

**Examples**

```
data(rabbitACPtable)
```

---

RESTREND	<i>RESTREND (RESidual TREND)</i>
----------	----------------------------------

---

**Description**

For ts with no significant breakpoints in the residuals or the VPR. Takes annual VI max and it associated optimal accumulated precipitation

**Usage**

```
RESTREND(  
  anu.VI,  
  acu.RF,  
  VI.index,  
  acu.TM = NULL,  
  sig = 0.05,  
  retnonsig = FALSE  
)
```

**Arguments**

anu.VI	The annual (Growing season) max VI. Must be a object of class 'ts' without NA's. if anu.VI=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
acu.RF	The optimal accumulated rainfall for anu.VI. Must be a object of class 'ts' without NA's and be of equal length and temporal range to anu.VI. if anu.RF=FALSE, it will be calculated from ACP.table using the <a href="#">AnnualClim.Cal</a>
VI.index	the index of the CTSR.VI ts that the anu.VI values occur at. Must be the same length as anu.VI. NOTE. R indexs from 1 rather than 0. if VI.index=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
acu.TM	The optimal accumulated rainfall for anu.TM. Must be a object of class 'ts' without NA's and be of equal length and temporal range to anu.TM. if anu.TM=FALSE, it will be calculated from ACT.table using the <a href="#">AnnualClim.Cal</a>
sig	Significance of all the functions. default sig=0.05
retnonsig	Bool. New in v0.3.0. Allows TSSRESTREND to return change estimates of values that filed the sig component in the residual analysis. default FALSE will give the same result as eralier versions.

**Value**

a list of class TSSRESTREND. See [TSSRESTREND](#) for details. Note. if called seperatly from TSS-RESTREND, this list will be incomplete.

**Author(s)**

Arden Burrell, arden.burrell@unsw.edu.au

**Examples**

```
restrend <- RESTREND(stdRESTREND$max.NDVI, stdRESTREND$acc.precip, stdRESTREND$index)
print(restrend)
```

---

 seg.RESTREND

---

*Segmented RESTREND (RESidual TREND)*


---

**Description**

For ts with a significant breakpoints in the residuals but not in the VPR. Takes annual VI max and it associated optimal accumulated precipitation and regresses it with a dummy variable that is 0 before the breakpoint and 1 after it

**Usage**

```
seg.RESTREND(
  anu.VI,
  acu.RF,
  VI.index,
  breakpoint,
  acu.TM = NULL,
  sig = 0.05,
  retnonsig = FALSE
)
```

**Arguments**

anu.VI	The annual (Growing season) max VI. Must be a object of class 'ts' without NA's. if anu.VI=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
acu.RF	The optimal accumulated rainfall for anu.VI. Must be a object of class 'ts' without NA's and be of equal length and temporal range to anu.VI. if anu.RF=FALSE, it will be calculated from ACP.table using the <a href="#">AnnualClim.Cal</a>
VI.index	the index of the CTSR.VI ts that the anu.VI values occur at. Must be the same length as anu.VI. NOTE. R indexs from 1 rather than 0. if VI.index=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
breakpoint	The index of the most significant breakpoint as determined using <a href="#">CHOW</a> .
acu.TM	The optimal accumulated rainfall for anu.TM. Must be a object of class 'ts' without NA's and be of equal length and temporal range to anu.TM. if anu.TM=FALSE, it will be calculated from ACT.table using the <a href="#">AnnualClim.Cal</a>
sig	Significance of all the functions. default sig=0.05
retnonsig	Bool. New in v0.3.0. Allows TSSRESTREND to return change estimates of values that filed the sig component in the residual analysis. default FALSE will give the same result as eralier versions.

**Value**

a list of class TSSRESTREND. See [TSSRESTREND](#) for details. Note. if called seperatly from TSS-RESTREND, this list will be incomplete.

**Author(s)**

Arden Burrell, arden.burrell@unsw.edu.au

**Examples**

```
# brkp can be determined using VPR.BFAST and CHOW.
brkp <- as.integer(11)
resu <- seg.RESTREND(segRESTREND$max.NDVI, segRESTREND$acc.precip, segRESTREND$index, brkp)
```

seg.VPR

*Segmented Vegetation Climate Relationship***Description**

For a ts with a significant breakpoints in the the VPR/VCR. This function takes annual VI max, the optimal accumulated precipitation (& temperature) before and after the breakpoint, then caculates the Standard Variance of the climate cariables.Then an OLS is performed with a dummy variable to reperesent the breakpoint (0 before the breakpoint and 1 after it)..

**Usage**

```
seg.VPR(
  anu.VI,
  acu.RF,
  VI.index,
  breakpoint,
  rf.b4,
  rf.af,
  acu.TM = NULL,
  tm.b4 = NULL,
  tm.af = NULL,
  sig = 0.05,
  retnonsig = FALSE
)
```

**Arguments**

anu.VI	The annual (Growing season) max VI. Must be a object of class 'ts' without NA's. if anu.VI=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
acu.RF	The optimal accumulated rainfall for anu.VI. Must be a object of class 'ts' without NA's and be of equal length and temporal range to anu.VI. if anu.RF=FALSE, it will be calculated from ACP.table usingthe <a href="#">AnnualClim.Cal</a>
VI.index	the index of the CTSR.VI ts that the anu.VI values occur at. Must be the same length as anu.VI. NOTE. R indexs from 1 rather than 0. if VI.index=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
breakpoint	The index of the most significant breakpoint as determined using <a href="#">CHOW</a> .
rf.b4	If a breakpoint in the VPR is detected this is the optimial accumulated rainfall before the breakpoint. must be the same length as the anu.VI. If ACP.table is provided it will be generated using <a href="#">AnnualClim.Cal</a>
rf.af	If a breakpoint in the VPR is detected this is the optimial accumulated rainfall after the breakpoint. must be the same length as the anu.VI. If ACP.table is provided it will be generated using <a href="#">AnnualClim.Cal</a>
acu.TM	The optimal accumulated rainfall for anu.TM. Must be a object of class 'ts' without NA's and be of equal length and temporal range to anu.TM. if anu.TM=FALSE, it will be calculated from ACT.table usingthe <a href="#">AnnualClim.Cal</a>

tm.b4	If a breakpoint in the VCR is detected this is the optimal accumulated temperature before the breakpoint. It must be the same length as the anu.VI. If ACT.table is provided it will be generated using <a href="#">AnnualClim.Cal</a>
tm.af	If a breakpoint in the VCR is detected this is the optimal accumulated temperature after the breakpoint. It must be the same length as the anu.VI. If ACT.table is provided it will be generated using <a href="#">AnnualClim.Cal</a>
sig	Significance of all the functions. default sig=0.05
retnonsig	Bool. New in v0.3.0. Allows TSSRESTREND to return change estimates of values that filed the sig component in the residual analysis. default FALSE will give the same result as eralier versions.

**Value**

a list of class TSSRESTREND. See [TSSRESTREND](#) for details. Note. if called seperatly from TSSRESTREND, this list will be incomplete.

**Author(s)**

Arden Burrell, arden.burrell@unsw.edu.au

**Examples**

```
brkp <- as.integer(24) #calculated using th CHOW (DONTRUN) example
VPRres <- seg.VPR(segVPR$max.NDVI, segVPR$acum.RF, segVPR$index, brkp, segVPR$RFB4, segVPR$RFAF)
print(VPRres)
```

---

segRESTREND

*Data frame containing the annual data for a segRESTREND analysis*

---

**Description**

contains anu.VI, acu.RF, VI.index, rf.b4, rf.af. Range 1982 - 2013. Breakpoint for this pixel is 24 (2005)

**Usage**

```
segRESTREND
```

**Format**

R data frame

**Source**

[gimms-package](#)

segRESTRENDctRF      *Data frame containing the raw rainfall data set for the segRESTREND data, ending dec 2013 with a frequency of 12*

---

**Description**

contains raw monthly precipitation

**Usage**

segRESTRENDctRF

**Format**

R data frame

**Source**

Awap data from <http://www.csiro.au/awap/cgi/awap2.pl>

**See Also**

[stdRESTREND](#) for the annual values for the same pixel

---

segRESTRENDCTSR      *Data frame containing the Complete Times Series data for a segmented RESTREND analysis*

---

**Description**

contains CTSR.VI and CTSR.RF. See [TSSRESTREND](#). Starts 1/1982 and extend to 12/2013

**Usage**

segRESTRENDCTSR

**Format**

R data frame

**Source**

a single pixel from [monthlyComposite](#)

**See Also**

[stdRESTREND](#) for the annual values for the same pixel



---

segRESTRENDrfTab	<i>Precipitation Accumulation Table for the segRESTREND demonstration pixel</i>
------------------	---

---

**Description**

Rainfall Accumulation Table

**Usage**

segRESTRENDrfTab

**Format**

A matrix containing the complete time series of every acp and ofp. See [climate.accumulator](#) for details

**Source**

Awap data from <http://www.csiro.au/awap/cgi/awap2.pl>

---

segVPR	<i>Data frame containing the annual data for a segVPR analysis</i>
--------	--

---

**Description**

contains anu.VI, acu.RF, VI.index, rf.b4, rf.af. Range 1982 - 2013. Breakpoint for this pixel is 24 (2005)

**Usage**

segVPR

**Format**

R data frame

**Source**

[gimms-package](#)

---

segVPRctRF	<i>Data frame containing the raw rainfall data set for the segVPR data, ending dec 2013 with a frequency of 12</i>
------------	--

---

**Description**

contains raw monthly precipitation

**Usage**

segVPRctRF

**Format**

R data frame

**Source**

Awap data from <http://www.csiro.au/awap/cgi/awap2.pl>

**See Also**

[stdRESTREND](#) for the annual values for the same pixel

---

segVPRCTSR	<i>Data frame containing the Complete Times Series data for a segmented VPR (VEGETATION PRECIPTATION RELATIONSHIP) analysis</i>
------------	---

---

**Description**

contains CTSR.VI and CTSR.RF. See [TSSRESTREND](#). Starts 1/1982 and extend to 12/2013

**Usage**

segVPRCTSR

**Format**

R data frame

**Source**

a single pixel from [monthlyComposite](#)

**See Also**

[stdRESTREND](#) for the annual values for the same pixel

---

`segVPRrfTab`*Precipitation Accumulation Table for the segVPR demonstration pixel*

---

**Description**

Rainfall Accumulation Table

**Usage**`segVPRrfTab`**Format**

A matrix containing the complete time series of every acp and ofp. See [climate.accumulator](#) for details

**Source**

Awap data from <http://www.csiro.au/awap/cgi/awap2.pl>

---

`stdRESTREND`*Data frame containing the annual data for a standard Restrend analysis*

---

**Description**

contains anu.VI, acu.RF and VI.index. Range 1982 - 2013

**Usage**`stdRESTREND`**Format**

R data frame

**Source**[gimms-package](#)

---

stdRESTRENDctRF	<i>Data frame containing the raw rainfall data set ending dec 2013 with a frequency of 12</i>
-----------------	---

---

**Description**

contains raw monthly precipitation

**Usage**

stdRESTRENDctRF

**Format**

R data frame

**See Also**

[stdRESTREND](#) for the annual values for the same pixel

---

stdRESTRENDCTSR	<i>Data frame containing the Complete Times Series data for a standard Restrend analysis</i>
-----------------	--

---

**Description**

contains CTSR.VI and CTSR.RF. See [TSSRESTREND](#). Starts 1/1982 and extend to 12/2013

**Usage**

stdRESTRENDCTSR

**Format**

R data frame

**Source**

a single pixel from [monthlyComposite](#)

**See Also**

[stdRESTREND](#) for the annual values for the same pixel

---

stdRESTRENDrfTab	<i>Precipitation Accumulation Table for the standard RESTREND demonstration pixel</i>
------------------	---

---

**Description**

Rainfall Accumulation Table

**Usage**

stdRESTRENDrfTab

**Format**

A matrix containing the complete time series of every acp and ofp. See [climate.accumulator](#) for details

**Source**

Awap data from <http://www.csiro.au/awap/cgi/awap2.pl>

---

TSSRattribution	<i>Vegetation change attribution using the Time Series Segmentation of Residual Trends (MAIN FUNCTION)</i>
-----------------	--

---

**Description**

This is a wrapper function around the TSS-RESTREND main function that does additional attribution. It measures the Observed vegetation change, land use, climate change and climate variability. Unlike TSSRESTREND function, this requires both temperature and precipitation data to work.

**Usage**

```
TSSRattribution(
  CTSR.VI,
  CTSR.RF,
  CTSR.TM,
  max.acp,
  max.osp,
  C4frac = 0,
  sig = 0.05,
  season = "none",
  exclude = 0,
  allow.negative = FALSE,
  allowneg.retest = FALSE,
  h = 0.15,
```

```

returnmodels = FALSE,
AnnualRes = FALSE,
SkipError = TRUE,
retnonsig = TRUE,
splitclim = TRUE,
cliwindow = 20,
CO2 = FALSE,
refyear = 1980
)

```

### Arguments

CTSR.VI	Complete Monthly Time Series of Vegetation Index values. An object of class 'ts' object without NA's.
CTSR.RF	Complete Time Series of Rainfall. An object of class 'ts' object without NA's and be the same length and cover the same time range as CTSR.VI. If ACP.table is provided, CTSR.RF will be automitacly calculated using the <a href="#">ACP.calculator</a>
CTSR.TM	Complete Time Series of temperature. An object of class 'ts' object without NA's and be the same length and cover the same time range as CTSR.VI. Default (CTSR.TM=NULL). If ACT.table is provided, CTSR.RF will be automitacly calculated using the <a href="#">ACP.calculator</a>
max.acp	The max accumulation period. Must be an integer > 1.
max.osp	The max offset period. Must be an integer >1
C4frac	The fraction of vegetation that follows the C4 photosynthetic pathway, between 0 and 1
sig	Significance of all the functions. default sig=0.05
season	See <a href="#">bfast</a> . This season value only applies to bfast done using the CTS VPR. if a non VPR adjusted BFAST is performed.a harmonic season is used.
exclude	A numeric vector containg months excluded from breakpoint detection. This was included to allow sensor transitions to be masked.
allow.negative	If true, will not preference positive slope in either CTSR or VI calculations. default=FALSE is set because negative associations between rainfall and vegetation in water limited ecosystems is unexpected If temperature data is included then this paramter is forced to TRUE.
allowneg.retest	default=FALSE If temperature data is provided but found to not be significant then a retest is performed. This paramter is to allow negative on re-test.
h	See <a href="#">bfast</a> , The.minimal segment size between potentially detected breaks in the trend model given as fraction relative to the sample size (i.e. the minimal number of observations in each segment divided by the total length of the timeseries. Default h = 0.15.
returnmodels	Return all the created models as well as the original data
AnnualRes	Report results in change per year. Default is False. Instead reports total change from the start to the end of the time series.

SkipError	Bool, If TRUE will handle most errors and return a dataframe filled with NA's. Usefull when processing large datasets to stop analysis failing on a single pixel. Use with caution. Default=TRUE
retnonsig	Bool. New in v0.3.0. Allows TSSRESTREND to return change estimates of values that filed the sig component in the residual analysis. default FALSE will give the same result as eralier versions.
splitclim	Bool, If TRUE Climate will be split into climate change and climate varibility as per Burrell et al., (2020). If FALSE. will just return climate as per IPCC: Chapter 3: Desertification in the IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems. Default=True.
cliwindow	The size of the window in years to be used for calculating climate change.
CO2	A timeseries containg the CO2 concentration. The default is CMIP5 RCP8.5
refyear	The Year that acts as a baseline for CO2. All vegetation values will be scaled # to the CO2 concentration of this year. Defulat is 1980. THis function will pick the first value in the selected year,

### Value

**tacp** The accumulation period for the annual max time series temperature

### Author(s)

Arden Burrell, [aburrell@whrc.org](mailto:aburrell@whrc.org)

---

TSSRESTREND

*Time Series Segmentation of Residual Trends (MAIN FUNCTION)*

---

### Description

Time Series Segmented Residual Trend (TSS.RESTREND) methodology. Takes in a complete monthly time series of a VI and its corrsponding precipitation (and temperature). It then looks looks for breakpoints using the BFAST function. The significance of the breakpoin in the residuals and the VPR is assessed using a Chow test, then, the total time series change is calculated.

### Usage

```
TSSRESTREND(
  CTSR.VI,
  ACP.table = FALSE,
  ACT.table = NULL,
  CTSR.RF = FALSE,
  CTSR.TM = NULL,
  anu.VI = FALSE,
  acu.RF = FALSE,
  acu.TM = NULL,
```

```

VI.index = FALSE,
rf.b4 = FALSE,
rf.af = FALSE,
sig = 0.05,
season = "none",
exclude = 0,
allow.negative = FALSE,
allowneg.retest = FALSE,
h = 0.15,
retnonsig = FALSE
)

```

### Arguments

CTSR.VI	Complete Monthly Time Series of Vegetation Index values. An object of class 'ts' object without NA's.
ACP.table	A table of every combination of offset period and accumulation period.for precipitation ACP.table can be calculated using the <a href="#">climate.accumulator</a> .
ACT.table	A table of every combination of offset period and accumulation period.for temperature ACP.table can be calculated using the <a href="#">climate.accumulator</a> .
CTSR.RF	Complete Time Series of Rainfall. An object of class 'ts' object without NA's and be the same length and cover the same time range as CTSR.VI. If ACP.table is provided, CTSR.RF will be automitacly calculated using the <a href="#">ACP.calculator</a>
CTSR.TM	Complete Time Series of temperature. An object of class 'ts' object without NA's and be the same length and cover the same time range as CTSR.VI. Default (CTSR.TM=NULL). If ACT.table is provided, CTSR.RF will be automitacly calculated using the <a href="#">ACP.calculator</a>
anu.VI	The annual (Growing season) max VI. Must be a object of class 'ts' without NA's. if anu.VI=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
acu.RF	The optimal accumulated rainfall for anu.VI. Must be a object of class 'ts' without NA's and be of equal length and temporal range to anu.VI. if anu.RF=FALSE, it will be calculated from ACP.table usingthe <a href="#">AnnualClim.Cal</a>
acu.TM	The optimal accumulated rainfall for anu.TM. Must be a object of class 'ts' without NA's and be of equal length and temporal range to anu.TM. if anu.TM=FALSE, it will be calculated from ACT.table usingthe <a href="#">AnnualClim.Cal</a>
VI.index	the index of the CTSR.VI ts that the anu.VI values occur at. Must be the same length as anu.VI. NOTE. R indexs from 1 rather than 0. if VI.index=FALSE, it will be calculated from the CTSR.VI using <a href="#">AnMaxVI</a> .
rf.b4	If a breakpoint in the VPR is detected this is the optimal accumulated rainfall before the breakpoint. must be the same length as the anu.VI. If ACP.table is provided it will be generated using <a href="#">AnnualClim.Cal</a>
rf.af	If a breakpoint in the VPR is detected this is the optimal accumulated rainfall after the breakpoint. must be the same length as the anu.VI. If ACP.table is provided it will be generated using <a href="#">AnnualClim.Cal</a>
sig	Significance of all the functions. default sig=0.05



season	See <a href="#">bfast</a> . This season value only applies to bfast done using the CTS VPR. if a non VPR adjusted BFAST is performed.a harmonic season is used.
exclude	A numeric vector containg months excluded from breakpoint detection. This was included to allow sensor transitions to be masked.
allow.negative	If true, will not preference positive slope in either CTSR or VI calculations. default=FALSE is set because negative associations between rainfall and vegetation in water limited ecosystems is unexpected If temperature data is included then this paramter is forced to TRUE.
allowneg.retest	default=FALSE If temperature data is provided but found to not be significant then a retest is performed. This paramter is to allow negative on re-test.
h	See <a href="#">bfast</a> , The.minimal segment size between potentially detected breaks in the trend model given as fraction relative to the sample size (i.e. the minimal number of observations in each segment divided by the total length of the timeseries. Default h = 0.15.
retnonsig	Bool. New in v0.3.0. Allows TSSRESTREND to return change estimates of values that filed the sig component in the residual analysis. default FALSE will give the same result as eralier versions.

## Value

An object of class 'TSSRESTREND' is a list with the following elements:

**summary Method** The method used to determine total change. (*RESTREND* see [RESTREND](#), *segmented.RESTREND* see [seg.RESTREND](#), *segmented.VPR* see [seg.VPR](#))

**Total.Change** The total significant change. Residual.Change + VPR.HeightChange.

**Residual.Change** The change in the VPR Residuals over the time period

**VPR.HeightChange** The change in VI at mean rainfall for a "ts" with a significant breakpoint in the VPR

**model.p** p value of the regression model fitted to the VPR. See [lm](#)

**residual.p** p value of the regression model fitted to the VPR Residuals. See [lm](#)

**VPRbreak.p** the p value associated with the break height. See [lm](#)

**bp.year** The Year of the most significant breakpoint

**ts.data** The Time series used in analysis. See Arguments for description

- CTSR.VI
- CTSR.RF
- anu.VI
- VI.index
- acu.RF
- StdVar.RF see [seg.VPR](#))

**ols.summary chow.summary** summary of the most significant breakpoint.

**chow.ind** Summary of every detected breakpoint

**OLS.table** A matrix containing the coefficients for the CTS.fit, VPR.fit, RESTREND.fit and segVPR.fit

**TSSRmodels** models of class "lm" [lm](#) and class "bfast" [bfast](#) generated.

**Note**

if `ACP.table = FALSE`, `CTSR.RF` and `acu.RF` must be provided as well as `rf.b4` and `rf.af` for 'ts' with a breakpoint in the VPR.

**Author(s)**

Arden Burrell, arden.burrell@unsw.edu.au

**See Also**

- [plot.TSSRESTREND](#)
- [print.TSSRESTREND](#)

**Examples**

```
## Not run:
##To get the latest version of the package (Still in development)
install.packages("devtools")
library("devtools")
install_github("ArdenB/TSSRESTREND", subdir="TSS.RESTREND")
library(TSS.RESTREND)
##Find the path of the rabbitRF.csv dataset, read it in and turn it into a time series
rf.path<- system.file("extdata", "rabbitRF.csv", package = "TSS.RESTREND", mustWork = TRUE)
in.RF <- read.csv(rf.path)
rf.data <- ts(in.RF, end=c(2013,12), frequency = 12)

##Find the path of the rabbitVI.csv dataset and read it in
vi.path <- system.file("extdata", "rabbitVI.csv", package = "TSS.RESTREND", mustWork = TRUE)
in.VI <- read.csv(vi.path)
CTSR.VI <- ts(in.VI, start=c(1982, 1), end=c(2013,12), frequency = 12)

##Define the max accumulation period
max.acp <- 12
##Define the max offset period
max.osp <- 4
##Create a table of every possible precipitation value given the max.acp and max.osp
ACP.table <- climate.accumulator(CTSR.VI, rf.data, max.acp, max.osp)
results <- TSSRESTREND(CTSR.VI, ACP.table)
print(results)
plot(results, verbose=TRUE)

## End(Not run)
```

**Description**

takes the Complete VI and optimally accumulated Rainfall (and temperature if included), calculates a [lm](#) between them And then performs a [bfast](#).in the residuals. If BFAST.raw=TRUE, it will perform bfast on the Complete VI ts

**Usage**

```
VPR.BFAST(
  CTSR.VI,
  CTSR.RF,
  CTSR.TM = NULL,
  season = "none",
  BFAST.raw = FALSE,
  h = 0.15
)
```

**Arguments**

CTSR.VI	Complete Monthly Time Series of Vegetation Index values. An object of class 'ts' object without NA's.
CTSR.RF	Complete Time Series of Rainfall. An object of class 'ts' object without NA's and be the same length and cover the same time range as CTSR.VI. If ACP.table is provided, CTSR.RF will be automatically calculated using the <a href="#">ACP.calculator</a>
CTSR.TM	Complete Time Series of temperature. An object of class 'ts' object without NA's and be the same length and cover the same time range as CTSR.VI. Default (CTSR.TM=NULL).
season	See <a href="#">bfast</a> . This season value only applies to bfast done using the CTS VPR. if a non VPR adjusted BFAST is performed.a harmonic season is used.
BFAST.raw	Default = FALSE If TRUE will perform a BFAST (season="harmonic") on the CTSR.VI If FALSE will perform BFAST on the CTSR VPR residuals
h	See <a href="#">bfast</a> , The.minimal segment size between potentially detected breaks in the trend model given as fraction relative to the sample size (i.e. the minimal number of observations in each segment divided by the total length of the timeseries. Default h = 0.15.

**Value**

List of objects:

**bkps** The index of the Breakpoints detected. If no breakpoints are detected, bkps = FALSE

**BFAST.obj** See [bfast](#)

**CTS.lm** the [lm](#) of CTSR.VI and CTSR.RF

**BFAST.type** the type of BFAST done (VPR residuals or on the VI timeseris itself)

**Author(s)**

Arden Burrell, arden.burrell@unsw.edu.au

**Examples**

```
## Not run:  
VPRBFdem <- VPR.BFAST(segVPRCTSR$cts.NDVI, segVPRCTSR$cts.precip)  
print(VPRBFdem)  
## End(Not run)
```

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