Package ‘modifiedmk’

June 14, 2019

Title Modified Versions of Mann Kendall and Spearman's Rho Trend Tests

Version 1.4.0

Description Power of non-parametric Mann-Kendall test and Spearman’s Rho test is highly influenced by serially correlated data. To address this issue, trend tests may be applied on the modified versions of the time series data by Block Bootstrapping (BBS), Prewhitening (PW) , Trend Free Prewhitening (TFPW), Bias Corrected Prewhitening and Variance Correction Approach by calculating effective sample size.
Mann, H. B. (1945).<doi:10.1017/CBO9781107415324.004>.
Kendall, M. (1975). Multivariate analysis. Charles Griffin&Company Ltd,.
sen, P. K. (1968).<doi:10.2307/2285891>.
Önöz, B., & Bayazit, M. (2012) <doi:10.1002/hyp.8438>.
Hamed, K. H. (2009).<doi:10.1016/j.jhydrol.2009.01.040>.
Yue, S., & Wang, C. Y. (2002) <doi:10.1029/2001WR000861>.
Yue, S., Pilon, P., Phinney, B., & Cavadias, G. (2002) <doi:10.1002/hyp.1095>.
Hamed, K. H., & Ramachandra Rao, A. (1998) <doi:10.1016/S0022-1694(97)00125-X>.
Yue, S., & Wang, C. Y. (2004) <doi:10.1023/B:WARM.0000043140.61082.60>.

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Suggests testthat, knitr, rmarkdown,covr

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R topics documented:

`bbsmk` *Nonparametric Block Bootstrapped Mann-Kendall Trend Test*

Description

Significant serial correlation present in time series data can be accounted for using the nonparametric block bootstrap technique, which incorporates the Mann-Kendall trend test (Mann, 1945; Kendall, 1975; Kundzewicz and Robson, 2000). Predetermined block lengths are used in resampling the original time series, thus retaining the memory structure of the data. If the value of the test statistic falls in the tails of the empirical bootstrapped distribution, there is likely a trend in the data. The block bootstrap technique is powerful in the presence of autocorrelation (Khaliq et al. 2009; Önöz and Bayazit, 2012).

Usage

```
bbsmk(x, ci=0.95, nsim=2000, eta=1, bl.len=NULL)
```

Arguments

`x`	- Time series data vector
`ci`	- Confidence interval
`nsim`	- Number of bootstrapped simulations
`eta`	- Added to the block length
`bl.len`	- Block length

Details

Block lengths are automatically selected using the number of contiguous significant serial correlations, to which the eta (η) term is added. A value of $\eta = 1$ is used as the default as per Khaliq et al. (2009). Alternatively, the user may define the block length. 2000 bootstrap replicates are recommended as per Svensson et al. (2005) and Önöz, B. and Bayazit (2012).

Value

Z-Value - Mann-Kendall Z statistic

Sen's slope - Sen's trend slope

S - Mann-Kendall S statistic

Tau - Mann-Kendall's Tau value

Kendall's Tau Empirical Bootstrapped CI - Kendall's Tau empirical bootstrapped confidence interval

Z-value Empirical Bootstrapped CI - Z-value empirical bootstrapped confidence interval

References

Box, G. E. P. and Jenkins, G. M. (1970). Time Series Analysis Forecasting and Control. Holden-Day, San Fransisco, California, 712 pp.

Kendall, M. (1975). Rank Correlation Methods. Griffin, London, 202 pp.

Khaliq, M. N., Ouarda, T. B. M. J., Gachon, P., Sushama, L., and St-Hilaire, A. (2009). Identification of hydrological trends in the presence of serial and cross correlations: A review of selected methods and their application to annual flow regimes of Canadian rivers. Journal of Hydrology, 368: 117-130.

Kundzewicz, Z. W. and Robson, A. J. (2000). Detecting Trend and Other Changes in Hydrological Data. World Climate Program-Data and Monitoring. World Meteorological Organization, Geneva (WMO/TD-No. 1013).

Kundzewicz, Z. W. and Robson, A. J. (2004). Change detection in hydrological records-A review of the methodology. Hydrological Sciences Journal, 49(1): 7-19.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3): 245-259.

Önöz , B. and Bayazit M. (2012). Block bootstrap for Mann-Kendall trend test of serially dependent data. Hydrological Processes, 26: 3552-3560.

Svensson, C., Kundzewicz, Z. W., and Maurer, T. (2005). Trend detection in river flow series: 2. Floods and low-flow index series. Hydrological Sciences Journal, 50(5): 811-823.

Examples

```
x<-c(Nile[1:10])
bbsmk(x)
```

`bbssr` *Nonparametric Block Bootstrapped Spearman's Rank Correlation Trend Test*

Description

Significant serial correlation present in time series data can be accounted for using the nonparametric block bootstrap technique, which incorporates Spearman's Rank Correlation trend test (Lehmann, 1975; Sneyers, 1990;Kundzewicz and Robson, 2000). Predetermined block lengths are used in resampling the original time series, thus retaining the memory structure of the data. If the value of the test statistic falls in the tails of the empirical bootstrapped distribution, there is likely a trend in the data. The block bootstrap technique is powerful in the presence of autocorrelation (Khaliq et al. 2009; Önöz and Bayazit, 2012).

Usage

```
bbssr(x, ci=0.95, nsim=2000, eta=1, bl.len=NULL)
```

Arguments

`x`	- Time series data vector
`ci`	- Confidence interval
`nsim`	- Number of bootstrapped simulations
`eta`	- Added to the block length
`bl.len`	- Block length

Details

Block lengths are the number of contiguous significant serial correlations, to which the (η) term is added. A value of $\eta = 1$ is used as the default as per Khaliq et al. (2009). Alternatively, the user may define the block length. 2000 bootstrap replicates are recommended as per Svensson et al. (2005) and Önöz, B. and Bayazit (2012).

Value

Spearman's Correlation Coefficient - Spearman's correlation coefficient value

Test Statistic - Z-transformed value to test significance $\rho(\sqrt{n-1})$

Test Statistic Empirical Bootstrapped CI - Test statistic empirical bootstrapped confidence interval

References

Box, G. E. P. and Jenkins, G. M. (1970). Time Series Analysis Forecasting and Control. Holden-Day, San Fransisco, California, 712 pp.

Khaliq, M. N., Ouarda, T. B. M. J., Gachon, P., Sushama, L., and St-Hilaire, A. (2009). Identification of hydrological trends in the presence of serial and cross correlations: A review of selected methods and their application to annual flow regimes of Canadian rivers. Journal of Hydrology, 368: 117-130.

Kundzewicz, Z. W. and Robson, A. J. (2000). Detecting Trend and Other Changes in Hydrological Data. World Climate Program-Water, Data and Monitoring. World Meteorological Organization, Geneva (WMO/TD-No. 1013).

Kundzewicz, Z. W. and Robson, A. J. (2004). Change detection in hydrological records-A review of the methodology. Hydrological Sciences Journal, 49(1): 7-19.

Lehmann, E. L. (1975). Nonparametrics: statistical methods based on ranks. Holden-Day, Inc., California, 457 pp.

Önöz, B. and Bayazit M. (2012). Block bootstrap for Mann-Kendall trend test of serially dependent data. Hydrological Processes, 26: 3552-3560.

Sneyers, R. (1990). On the statistical analysis of series of observations. World Meteorological Organization, Technical Note no. 143, WMO no. 415, 192 pp.

Svensson, C., Kundzewicz, Z. W., and Maurer, T. (2005). Trend detection in river flow series: 2. Floods and low-flow index series. Hydrological Sciences Journal, 50(5): 811-823.

Examples

```
x<-c(Nile[1:10])
bbssr(x)
```

---

bcpw *Hamed (2009) Bias Corrected Prewhitening.*

Description

Hamed (2009) proposed a prewhitening technique in which the slope and lag-1 serial correltaion coefficient are simultaneously estimated. The lag-1 serial correlation coefficient is then corrected for bias before prewhitening.

Usage

```
bcpw(x)
```

Arguments

x	- Time series data vector

Details

Employs ordinary least squares (OLS) to simultaneously estimate the lag-1 serial correlation coefficient and slope of trend. The lag-1 serial correlation coefficient is then bias corrected.

Value

Z-Value - Mann-Kendall Z-statistic after bias corrected prewhitening

Prewhitened Sen's Slope - Sen's slope of the prewhitened data

Sen's Slope - Sen's slope for the original data series 'x'

P-value - p-value after prewhitening

S - Mann-Kendall 'S' statistic

Var(s) - Variance of 'S'

Tau - Mann-Kendall's Tau

References

Hamed, K. H. (2009). Enhancing the effectiveness of prewhitening in trend analysis of hydrologic data. Journal of Hydrology, 368: 143-155.

Kendall, M. (1975). Multivariate analysis. Charles Griffin. Londres. 0-85264-234-2.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3), 245-259. <doi:10.1017/CBO9781107415324

van Giersbergen, N. P. A. (2005). On the effect of deterministic terms on the bias in stable AR models. Economic Letters, 89: 75-82.

Examples

```
x<-c(Nile)
bcpw(x)
```

`mkttest` *Mann-Kendall Trend Test of Time Series Data Without Modifications*

Description

The Mann-Kendall trend test is a nonparametric trend test used to identify monotonic trends present in time series data.

Usage

```
mkttest(x)
```

Arguments

`x`	- Time series data vector

Details

The Mann-Kendall trend test is a nonparametric trend tests which assumes no distribution of the data. The null hypothesis of the test is that there is no trend in the data and the alternative hypothesis is that the data represents a monotonic trend.

Value

Z - Mann-Kendall Z statistic

Sen's slope - Sen's slope

S - Mann-Kendall S statistic

Var(s) - Variance of S

P-value - Mann-Kendall p-value

Tau - Mann-Kendall's Tau

References

Kendall, M. (1975). Rank Correlation Methods. Griffin, London, 202 pp.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3): 245-259.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American statistical Association, 63(324): 1379. <doi:10.2307/2285891>

Examples

```
x<-c(Nile)
mkttest(x)
```

---

mmkh — *Modified Mann-Kendall Test For Serially Correlated Data Using the Hamed and Rao (1998) Variance Correction Approach*

Description

Time series data is often influenced by previous observations. When data is not random and influenced by autocorrelation, modified Mann-Kendall tests may be used for trend detction studies. Hamed and Rao (1998) have proposed a variance correction approach to address the issue of serial correlation in trend analysis. Data are initially detrended and the effective sample size is calulated using the ranks of significant serial correlation coefficients which are then used to correct the inflated (or deflated) variance of the test statistic.

Usage

```
mmkh(x,ci=0.95)
```

Arguments

`x`	- Time series data vector
`ci`	- Confidence interval

Details

A detrended time series is constructed using Sen's slope and the lag-1 autocorreltation coefficient of the ranks of the data. The variance correction approach proposed by Hamed and Rao (1998) uses only significant lags of autocorrelation coefficients.

Value

Corrected Zc - Z statistic after variance Correction

new P.value - P-value after variance correction

N/N* - Effective sample size

Original Z - Original Mann-Kendall Z statistic

Old P-value - Original Mann-Kendall p-value

Tau - Mann-Kendall's Tau

Sen's Slope - Sen's slope

old.variance - Old variance before variance Correction

new.variance - Variance after correction

References

Hamed, K. H. and Rao, A. R. (1998). A modified Mann-Kendall trend test for autocorrelated data. Journal of Hydrology, 204(1–4): 182–196. <doi:10.1016/S0022-1694(97)00125-X>

Kendall, M. (1975). Rank Correlation Methods. Griffin, London, 202 pp.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3): 245-259.

Rao, A. R., Hamed, K. H., & Chen, H.-L. (2003). Nonstationarities in hydrologic and environmental time series. Ringgold Inc., Portland, Oregon, 362 pp. <doi:10.1007/978-94-010-0117-5>

Salas, J.D. (1980). Applied modeling of hydrologic times series. Water Resources Publication, 484 pp.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American statistical Association, 63(324): 1379. <doi:10.2307/2285891>

Examples

```
x<-c(Nile)
mmkh(x)
```

mmkh3lag *Modified Mann-Kendall Test For Serially Correlated Data Using the Hamed and Rao (1998) Variance Correction Approach Considering Only the First Three Lags*

Description

Time series data is often influenced by serial correlation. When data are not random and influenced by autocorrelation, modified Mann-Kendall tests may be used for trend detction. Hamed and Rao (1998) have proposed variance correction approach to address the issue of serial correlation in Trend analysis. Data are initially detrended and the effective sample size is calulated using the ranks of significant serial correlation coefficients which are then used to correct the inflated (or deflated) variance of the test statistic.

Usage

```
mmkh3lag(x,ci=0.95)
```

Arguments

`x`	- Time series data vector
`ci`	- Confidence interval

Details

A detrended time series is constructed using Sen's slope and the lag-1 autocorreltation coefficient of the ranks of the data. The variance correction approach proposed by Hamed and Rao (1998) uses only significant lags of autocorrelation coefficients. As suggested by Rao et al. (2003), only the first three autocorrelation coefficients are used in this function.

Value

Corrected Zc - Z statistic after variance Correction

new P.value - P-value after variance correction

N/N* - Effective sample size

Original Z - Original Mann-Kendall Z statistic

Old P-value - Original Mann-Kendall p-value

Tau - Mann-Kendall's Tau

Sen's Slope - Sen's slope

old.variance - Old variance before variance Correction

new.variance - Variance after correction

References

Hamed, K. H. and Rao, A. R. (1998). A modified Mann-Kendall trend test for autocorrelated data. Journal of Hydrology, 204(1–4): 182–196. <doi:10.1016/S0022-1694(97)00125-X>.

Kendall, M. (1975). Rank Correlation Methods. Griffin, London, 202 pp.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3): 245-259.

Rao, A. R., Hamed, K. H., & Chen, H.-L. (2003). Nonstationarities in hydrologic and environmental time series. Ringgold Inc., Portland, Oregon, 362 pp. <doi:10.1007/978-94-010-0117-5>

Salas, J.D. (1980). Applied modeling of hydrologic times series. Water Resources Publication, 484 pp.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American statistical Association, 63(324): 1379. <doi:10.2307/2285891>

Examples

```
x<-c(Nile)
mmkh3lag(x)
```

`mmky` *Modified Mann-Kendall Test For Serially Correlated Data Using the Yue and Wang (2004) Variance Correction Approach*

Description

Time series data is often influenced by serial correlation. When data are not random and influenced by autocorrelation, modified Mann-Kendall tests may be used for trend detction. Yue and Wang (2004) have proposed variance correction approach to address the issue of serial correlation in trend analysis. Data are initially detrended and the effective sample size is calculated using significant serial correlation coefficients.

Usage

```
mmky(x)
```

Arguments

`x`	- Time series data vector

Details

The variance correction approach suggested by Yue and Wang (2004) is implemeted in this function. Serial correlation coefficients for all lags are used in calculating the effective sample size.

Value

Corrected Zc - Z statistic after variance Correction

new P.value - P-value after variance correction

N/N* - Effective sample size

Original Z - Original Mann-Kendall Z statistic

Old P-value - Original Mann-Kendall p-value

Tau - Mann-Kendall's Tau

Sen's Slope - Sen's slope

old.variance - Old variance before variance Correction

new.variance - Variance after correction

References

Kendall, M. (1975). Rank Correlation Methods. Griffin, London, 202 pp.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3): 245-259.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American statistical Association, 63(324): 1379. <doi:10.2307/2285891>

Yue, S. and Wang, C. Y. (2004). The Mann-Kendall test modified by effective sample size to detect trend in serially correlated hydrological series. Water Resources Management, 18(3): 201–218. <doi:10.1023/B:WARM.0000043140.61082.60>

Examples

```
x<-c(Nile)
mmky(x)
```

`mmky1lag` *Modified Mann-Kendall Test For Serially Correlated Data Using the Yue and Wang (2004) Variance Correction Approach Using the Lag-1 Correlation Coefficient Only*

Description

Time series data is often influenced by serial correlation. When data are not random and influenced by autocorrelation, modified Mann-Kendall tests may be used for trend detction. Yue and Wang (2004) have proposed a variance correction approach to address the issue of serial correlation in trend analysis. Data are initially detrended and the effective sample size is calculated using the lag-1 autocorrelation coefficient.

Usage

```
mmky1lag(x)
```

Arguments

`x`	- Time series data vector

Details

The variance correction approach suggested by Yue and Wang (2004) is implemeted in this function. Effective sample size is calculated based on the AR(1) assumption.

Value

Corrected Zc - Z statistic after variance Correction

new P.value - P-value after variance correction

N/N* - Effective sample size

Original Z - Original Mann-Kendall Z statistic

Old P-value - Original Mann-Kendall p-value

Tau - Mann-Kendall's Tau

Sen's Slope - Sen's slope

old.variance - Old variance before variance Correction

new.variance - Variance after correction

References

Kendall, M. (1975). Rank Correlation Methods. Griffin, London, 202 pp.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3): 245-259.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American statistical Association, 63(324): 1379. <doi:10.2307/2285891>

Yue, S. and Wang, C. Y. (2004). The Mann-Kendall test modified by effective sample size to detect trend in serially correlated hydrological series. Water Resources Management, 18(3): 201–218. <doi:10.1023/B:WARM.0000043140.61082.60>

Examples

```
x<-c(Nile)
mmky1lag(x)
```

pbmk — *Bootstrapped Mann-Kendall Trend Test with Optional Bias Corrected Prewhitening*

Description

The empirical distribution of the Mann-Kendall test statistic is calculated by bootstrapped resampling. The Hamed (2009) bias correction prewhitening technique can optionally be applied as the default for prewhitening before the bootstrapped Mann-Kendall test is applied (Lacombe et al., 2012).

Usage

```
pbmk(x, nsim=1000, pw="Hamed")
```

Arguments

`x`	- Time series data vector
`nsim`	- Number of bootstrapped simulations
`pw`	- Optional bias corrected prewhitening suggested by Hamed (2009)

Details

Bootstrapped samples are calculated by resampling one value at a time from the time series with replacement. The p-value (p_s) of the resampled data is estimated by (Yue and Pilon, 2004):

$$p_s = m_s/M$$

The Mann-Kendall test statistics (S) is calculated for each resampled dataset. The resultant vector of resampled S statistics is then sorted in ascending ordering, where p_s is the rank corresponding the largest bootstrapped value of S being less than the test statistic value calculated from the actual data. M is the total number of bootstrapped resamples. The default value of M is 1000, however, Yue and Pilon (2004) suggest values between 1000 and 2000. If the user does not choose to apply prewhitening, this argument 'pw' can be set to NULL.

Value

Z Value - Mann-Kendall Z statistic from original data

Sen's Slope - Sen's slope from the original data

S - Mann-Kendall S statistic

Kendall's Tau - Mann-Kendall's Tau

BCP Z Value - Bias corrected prewhitened Z value

BCP Sen's Slope - Bias corrected prewhitened Sen's slope

BCP S - Bias corrected prewhitened S

BCP Kendall's Tau - Bias corrected prewhitened Kendall's Tau

Bootstrapped P-Value - Mann-Kendall bootstrapped p-value

References

Hamed, K. H. (2009). Enhancing the effectiveness of prewhitening in trend analysis of hydrologic data. Journal of Hydrology, 368: 143-155.

Kendall, M. (1975). Rank Correlation Methods. Griffin, London, 202 pp.

Kundzewicz, Z. W. and Robson, A. J. (2004). Change detection in hydrological records - a review of the methodology. Hydrological Sciences Journal, 49(1): 7-19.

Lancombe, G., McCartney, M., and Forkuor, G. (2012). Drying climate in Ghana over the period 1960-2005: evidence from the resampling-based Mann-Kendall test at local and regional levels. Hydrological Sciences Journal, 57(8): 1594-1609.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3): 245-259.

van Giersbergen, N. P. A. (2005). On the effect of deterministic terms on the bias in stable AR models. Economic Letters, 89: 75-82.

Yue, S. and Pilon, P. (2004). A comparison of the power of the t test, Mann-Kendall and bootstrap tests for trend detection, Hydrological Sciences Journal, 49(1): 21-37.

Examples

```
x<-c(Nile[1:10])
pbmk(x)
```

---

pwmk — *Mann-Kendall Test of Prewhitened Time Series Data in Presence of Serial Correlation Using the von Storch (1995) Approach*

Description

When time series data are not random and influenced by autocorrelation, prewhitening the time series prior to application of trend test is suggested.

Usage

```
pwmk(x)
```

Arguments

x	- Time series data vector

Details

The lag-1 serial correlation coefficient is used for prewhitening.

Value

Z-Value - Z statistic after prewhitening

Sen's Slope - Sen's slope for prewhitened series

old. Sen's Slope - Sen's slope for original data series (x)

P-value - P-value after prewhitening

S - Mann-Kendall S statistic

Var(s) - Variance of S

Tau - Mann-Kendall's Tau

References

Kendall, M. (1975). Rank Correlation Methods. Griffin, London, 202 pp.

Kulkarni, A. and H. von Storch. 1995. Monte carlo experiments on the effects of serial correlation on the MannKendall test of trends. Meteorologische Zeitschrift N.F, 4(2): 82-85.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3): 245-259.

Salas, J.D. (1980). Applied modeling of hydrologic times series. Water Resources Publication, 484 pp.

von Storch, V. H. (1995). Misuses of statistical analysis in climate research, In: Analysis of Climate Variability: Applications of Statistical Techniques, ed. von H. V. Storch and A. Navarra A. Springer-Verlag, Berlin: 11-26.

Yue, S. and Wang, C. Y. (2002). Applicability of prewhitening to eliminate the influence of serial correlation on the Mann-Kendall test. Water Resources Research, 38(6), <doi:10.1029/2001WR000861>

Examples

```
x<-c(Nile)
pwmk(x)
```

---

spear — *Spearman's Rank Correlation Test*

Description

Spearman's Rank Correlation test by Lehmann (1975) and Sneyers (1990) is useful in detecting trends.

Usage

```
spear(x)
```

Arguments

`x`	- Time series data vector

Details

Spearman's Rank Correlation test by Lehmann (1975) and Sneyers (1990) is implemeted in this function.

Value

Correlation coefficient - Spearman's Correlation coefficient value

Z-Tranformed Test Statistic value - Z-transform value to test significance $\rho(\sqrt{n-1})$

References

Lehmann, E. L. (1975). Nonparametrics: statistical methods based on ranks. Holden-Day, Inc., California, 457 pp.

Sneyers, R. (1990). On the statistical analysis of series of observations. World Meteorological Organization, Technical Note no. 143, WMO no. 415, 192 pp.

Examples

```
x<-c(Nile)
spear(x)
```

---

tfpwmk *Mann-Kendall Trend Test Applied to Trend-Free Prewhitened Time Series Data in Presence of Serial Correlation Using Yue et al. (2002) Approach*

Description

When the time series data are not random and influenced by autocorrelation, the trend component is removed from the data and is prewhitened prior to the application of the trend test.

Usage

```
tfpwmk(x)
```

Arguments

`x`	- Time series data vector

Details

The linear trend component is removed from the original data and then prewhitened using the lag-1 serial correlation coefficient. The prewhitening data are then tested with Mann-Kendall trend test.

Value

Z-Value - Z statistic after trend-free prewhitening (TFPW)

Sen's Slope - Sen's slope for TFPW series

Old Sen's Slope - Sen's slope for original data series (x)

P-value - P-value after trend-free prewhitening

S - Mann-Kendall S statistic

Var(s) - Variance of S

Tau - Mann-Kendall's Tau

References

Kendall, M. (1975). Rank Correlation Methods. Griffin, London, 202 pp.

Kulkarni, A. and H. von Storch. 1995. Monte carlo experiments on the effects of serial correlation on the MannKendall test of trends. Meteorologische Zeitschrift N.F, 4(2): 82-85.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3): 245-259.

Salas, J.D. (1980). Applied modeling of hydrologic times series. Water Resources Publication, 484 pp.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American Statistical Association, 63(324): 1379. <doi:10.2307/2285891>

von Storch, V. H. (1995). Misuses of statistical analysis in climate research, In: Analysis of Climate Variability: Applications of Statistical Techniques, ed. von H. V. Storch and A. Navarra A. Springer-Verlag, Berlin: 11-26.

Yue, S., Pilon, P., Phinney, B., and Cavadias, G. (2002). The influence of autocorrelation on the ability to detect trend in hydrological series. Hydrological Processes, 16(9): 1807–1829. <doi:10.1002/hyp.1095>

Examples

```
x<-c(Nile)
tfpwmk(x)
```

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