Mann Kendall tests correcting for serial correlation

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```r
# LOAD REQUIRED PACKAGES # #####
library(pander)
library(tidyverse)
library(xts)
library(zoo)
library(HKprocess)
library(mgcv)
library(oz)
library(deseasonalize)
require(doParallel)
```

This rmarkdown document and the resulting pdf are stored on github. All directories (apart from the root working directory) refer to the directories in this repository.

Introduction

This document is related to the manuscript "Disentangling climate change trends in Australian streamflow" (vervoort et al.), originally submitted to Journal of Hydrology, but since that time modified and rewritten and submitted to a different journal. This is the an extenstion on the second document as part of the response to reviewers of earlier versions of the manuscript outlining a mann-kendall statistical test that corrects for the autocorrelation and long-term persistence in the streamflow, rainfall and temperature data. This is based on the paper by Hamed [-@Hamed_2008]. There are two available packages in R that can perform this analysis but here we are using the package `HKprocess` that actually incorporates a modified Mann Kendal test based on Hamed (2008). The results of these tests are incorporated in the submitted manuscript and discussed around **Table 3**.

Most of this document is exactly the same as the second document, except that we are now using the function `MannKendallLTP()` rather than `MannKendall`. The bootstrap analysis is also dropped in this document, as we already analyse this in the second document. In addition, using the bootstrap is not really needed if we do the long term persistence analysis. The problem with the `MannKendallLTP()` function is that the analysis takes very, very long. One analysis on a weekly streamflow series (40 years) takes 18 hours on a single core i7, so we needed to run the weekly analysis on the HPC on multiple cores. The results are imported back into this document to display the tables. THe HPC scripts are in Rcode/HPC folder

The key point of the analysis on the weekly data is to provide a non-parametric trend test, which can deal with the correlated timeseries stream flow, rainfall and temperature data. To check, whether the weekly summaries bias the analysis, we will also run the Mann Kendall tests on the monthly and annual data.

The data

Using the datasets that were developed earlier, we can load in the daily data for streamflow, rainfall and temperature. The difference is that the Mann Kendal analysis should concentrate on analysing the anomalies rather than the actual data, and therefore we have to resummarise to weekly data after calculating the anomalies.

The other thing that is missing is a dataset for the anomalies in weekly "maximum maximum temperature", rather than the weekly average maximum temperature.

A further point to note is that the observed data contain missing values, which remain in the analysis. The gridded data does not contain missing data as this is interpolated predicted data.

Deseasonalise the data

The first step is to calculate the anomalies by deseasonalising the data using the package `deseasonalize` in R: deseasonalize.

```
load("data/DailyDataIncludingGridded.Rdata")
load("data/ClimCh_project_MD.Rdata")


# daily observed flow
flow_deseas <- flow_zoo
# now assign to a new dataframe
for (i in (seq_along(Stations[,1]))) {
  foo <- flow_zoo[,i]
# replace missing values with mean flow
  bad <- is.na(foo)
  foo[bad] <- mean(foo,na.rm=T)
  flow_deseas[,i]    <- ds(as.ts(foo),ic="AIC")$z
# put NA values back
  flow_deseas[bad,i] <- NA
}
# daily obseverved rainfall
rain_deseas <- rain_zoo
# now assign to a new dataframe
for (i in seq_along(Stations[,1])) {
  foo <- rain_zoo[,i]
  # replace NA values with mean flow
  bad <- is.na(foo)
  foo[bad] <- mean(foo,na.rm=T)
  rain_deseas[,i]  <- ds(as.ts(foo),ic="AIC")$z
  # put NA values back
  rain_deseas[bad,i] <- NA
}

# daily observed maximum temperature
maxT_deseas <- maxT_zoo
# now assign to a new dataframe
for (i in seq_along(Stations[,1])) {
  foo <- maxT_zoo[,i]
  # replace NA values with mean flow
  bad <- is.na(foo)
  foo[bad] <- mean(foo,na.rm=T)
  maxT_deseas[,i]  <- ds(as.ts(foo),ic="AIC")$z
  # put NA values back
  maxT_deseas[bad,i] <- NA
}

# do the same for the gridded rainfall data
```

```r
rain_griddeseas <- rain_zoo
#
for (i in seq_along(Stations[,1])) {
  foo <- GridRainAllDataout[substr(GridRainAllDataout$Station,1,4)==Stations[i,1],2]
  foo.z <- zoo(foo,  order.by=time(rain_zoo))
  rain_griddeseas[,i]  <- ds(as.ts(foo.z),ic="AIC")$z
}
```

Summarise to weekly, monthly and annual data

Similar to the original data the package `xts` can be used to summarise the data to weekly mean values. For the flow and rainfall data, we calculate the sum by week, month and year, while for the temperature we calculate the mean. As indicated, for the maximum temperature, we also calculate the "maximum" weekly maximum temperature, as this might be more meaningful than just the mean value.
In addition, the monthly and annual anomalies are also generated so the difference between the trend analysis on a weekly, monthly and annual scale can be checked.

```r
# flow (sum flow)
flow_xts <- xts(flow_deseas,
                order.by=time(flow_deseas),
                frequency=1)

# weekly data summarising (destroys xts object)
flow_weekly <- apply(flow_xts,2,
                             function(x) apply.weekly(x,
                                                      sum,na.rm=T))
# define weekly dates
Dates <- time(apply.weekly(flow_xts[,1],sum))
# restore the xts object
flow_weekly_xts <- as.xts(flow_weekly,
                              order.by=Dates)
# monthly data summarising (destroys xts object)
flow_monthly <- apply(flow_xts,2,
                             function(x) apply.monthly(x,
                                                      sum,na.rm=T))
# define monthly dates
Dates <- time(apply.monthly(flow_xts[,1],sum))
# restore the xts object
flow_monthly_xts <- as.xts(flow_monthly,
                              order.by=Dates)
# annual data (destroys xts object)
flow_annual <- apply(flow_xts,2,
                             function(x) apply.yearly(x,
                                                      sum,na.rm=T))
# define annual dates
Dates <- time(apply.yearly(flow_xts[,1],sum))
# restore the xts object
flow_annual_xts <- as.xts(flow_annual,
                              order.by=Dates)


# rainfall (sum rainfall)
rainfall_xts <- xts(rain_deseas,
```

```
                    order.by=time(rain_deseas),
                    frequency=1)
# weekly data summarising (destroys xts object)
rainfall_weekly <- apply(rainfall_xts,2,
                             function(x) apply.weekly(x,
                                                          sum,na.rm=T))
# define weekly dates
Dates <- time(apply.weekly(rainfall_xts[,1],sum))
# restore the xts object
rainfall_weekly_xts <- as.xts(rainfall_weekly,
                              order.by=Dates)
# monthly data summarising (destroys xts object)
rainfall_monthly <- apply(rainfall_xts,2,
                             function(x) apply.monthly(x,
                                                          sum,na.rm=T))
# define monthly dates
Dates <- time(apply.monthly(rainfall_xts[,1],sum))
# restore the xts object
rainfall_monthly_xts <- as.xts(rainfall_monthly,
                              order.by=Dates)
# annual data (destroys xts object)
rainfall_annual <- apply(rainfall_xts,2,
                             function(x) apply.yearly(x,
                                                          sum,na.rm=T))
# define annual dates
Dates <- time(apply.yearly(rainfall_xts[,1],sum))
# restore xts object
rainfall_annual_xts <- as.xts(rainfall_annual,
                              order.by=Dates)

# gridded rainfall (sum rainfall)
rainfall_grdxts <- xts(rain_griddeseas,
                    order.by=time(rain_griddeseas),
                    frequency=1)
# weekly data summarising (destroys xts object)
rainfall_grdweekly <- apply(rainfall_grdxts,2,
                             function(x) apply.weekly(x,
                                                          sum,na.rm=T))
# define weekly dates
Dates <- time(apply.weekly(rainfall_grdxts[,1],sum))
# restore the xts object
rainfall_grdweekly_xts <- as.xts(rainfall_grdweekly,
                              order.by=Dates)
# monthly data summarising (destroys xts object)
rainfall_grdmonthly <- apply(rainfall_grdxts,2,
                             function(x) apply.monthly(x,
                                                          sum,na.rm=T))
# define monthly dates
Dates <- time(apply.monthly(rainfall_grdxts[,1],sum))
# restore the xts object
rainfall_grdmonthly_xts <- as.xts(rainfall_grdmonthly,
                              order.by=Dates)
# annual data (destroys xts object)
```

```r
rainfall_grdannual <- apply(rainfall_grdxts,2,
                            function(x) apply.yearly(x,
                                                     sum,na.rm=T))
# define annual dates
Dates <- time(apply.yearly(rainfall_grdxts[,1],sum))
# restore the xts object
rainfall_grdannual_xts <- as.xts(rainfall_grdannual,
                             order.by=Dates)


# maxT
maxT_xts <- xts(maxT_deseas,
                order.by=time(maxT_deseas),
                frequency=1)
# weekly data summarising (destroys xts object)
maxT_weekly <- apply(maxT_xts,2,
                            function(x) apply.weekly(x,
                                                     sum,na.rm=T))
# define weekly dates
Dates <- time(apply.weekly(maxT_xts[,1],sum))
# restore the xts object
maxT_weekly_xts <- as.xts(maxT_weekly,
                             order.by=Dates)
# monthly data summarising (destroys xts object)
maxT_monthly <- apply(maxT_xts,2,
                            function(x) apply.monthly(x,
                                                     sum,na.rm=T))
# define monthly dates
Dates <- time(apply.monthly(maxT_xts[,1],sum))
# restore the xts object
maxT_monthly_xts <- as.xts(maxT_monthly,
                             order.by=Dates)
# annual data (destroys xts object)
maxT_annual <- apply(maxT_xts,2,
                            function(x) apply.yearly(x,
                                                     sum,na.rm=T))
# define annual dates
Dates <- time(apply.yearly(maxT_xts[,1],sum))
# restore the xts object
maxT_annual_xts <- as.xts(maxT_annual,
                             order.by=Dates)

# Also calculate the "max" maximum temperature
# first substitute a large value into all NA values
maxT_xts2 <- maxT_xts
maxT_xts2 <- apply(maxT_xts2,2,function(x) ifelse(is.na(x)==T,99999,x))

# calculate the maximum by week and month
m_maxT_weekly_xts <- apply.weekly(maxT_xts2,function(x) apply(x,2,max,na.rm=T))
m_maxT_monthly_xts <- apply.monthly(maxT_xts2,function(x) apply(x,2,max,na.rm=T))
# annual
m_maxT_annual_xts <- apply.yearly(maxT_xts2,function(x) apply(x,2,max,na.rm=T))
```

```r
# now relace the 99999 values with NA again
m_maxT_weekly_xts <- as.xts(apply(m_maxT_weekly_xts,2,
                                  function(x) ifelse(x==99999,NA,x)))
m_maxT_monthly_xts <- as.xts(apply(m_maxT_monthly_xts,2,
                                   function(x) ifelse(x==99999,NA,x)))
m_maxT_annual_xts <- as.xts(apply(m_maxT_annual_xts,2,
                                   function(x) ifelse(x==99999,NA,x)))

# need to save this environment
save(flow_weekly, rainfall_weekly, maxT_weekly, rainfall_grdweekly,
     file="Data/weeklyMKdata.Rdata")
save(flow_monthly, rainfall_monthly, maxT_monthly,rainfall_grdmonthly,
     file="Data/monthlyMKdata.Rdata")
```

Mann Kendall LTP analysis on weekly data using [@Hamed2008]

Basically the same analysis is repeated for each of the data sets, similar to part 2 in this series of documents.

```r
# import the analysis of the weekly data from the HPC runs:
datadir <-
  "../ProjectData/HPCresults"

# read in the results from the MannKendallLTP analysis
# start with flow
load(paste(datadir,"Store_flow.Rdata",sep="/"))
MK_standard <- lapply(Store, "[[","Mann_Kendall")
Hsignif <- lapply(Store, "[[","Significance_of_H")
MK_LTP <- lapply(Store, "[[","Mann_Kendall_LTP")

flow_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(flow_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
                                          "2_sided_pvalue",sep="_")
# -------- end flow -----------------
# rainfall
load(paste(datadir,"Store_rain.Rdata",sep="/"))
MK_standard <- lapply(Store_rain, "[[","Mann_Kendall")
Hsignif <- lapply(Store_rain, "[[","Significance_of_H")
MK_LTP <- lapply(Store_rain, "[[","Mann_Kendall_LTP")

rain_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(rain_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
                                          "2_sided_pvalue",sep="_")
# -------- end rainfall -----------------

# gridded rainfall
load(paste(datadir,"Store_gridrain.Rdata",sep="/"))
MK_standard <- lapply(Store_gridRain, "[[","Mann_Kendall")
Hsignif <- lapply(Store_gridRain, "[[","Significance_of_H")
MK_LTP <- lapply(Store_gridRain, "[[","Mann_Kendall_LTP")
```

```
gridrain_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(gridrain_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
                                          "2_sided_pvalue",sep="_")
# -------- end gridded rainfall -----------------

# maxT
load(paste(datadir,"Store_maxT.Rdata",sep="/"))
MK_standard <- lapply(Store_maxT, "[[","Mann_Kendall")

Hsignif <- lapply(Store_maxT, "[[","Significance_of_H")
MK_LTP <- lapply(Store_maxT, "[[","Mann_Kendall_LTP")
maxT_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(maxT_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
                                          "2_sided_pvalue",sep="_")
# -------- end maxT -----------------
```

Summary of weekly analysis in a table

This section brings together the data from all the weekly Mann Kendall analyses and puts this into a table. Some of these results are in **Table 3** in the manuscript.

```
weeklyTable_flow <- data.frame(Catchment = Stations[,1],
                  "Streamflow tau MK" = flow_MKLTP[,1],
                  "Streamflow Sen's slope" = flow_MKLTP[,4],
                  "Streamflow p-value MK" = flow_MKLTP[,6],
                  "Streamflow Hurst value" = flow_MKLTP[,7],
                  "Streamflow Hurst p-value" = flow_MKLTP[,8],
                  "Streamflow MK LTP p-value" = flow_MKLTP[,10])

weeklyTable_rain <- data.frame(Catchment = Stations[,1],
                  "Rainfall tau MK" = rain_MKLTP[,1],
                  "Rainfall Sen's slope" = rain_MKLTP[,4],
                  "Rainfall p-value MK" = rain_MKLTP[,6],
                  "Rainfall Hurst value" = rain_MKLTP[,7],
                  "Rainfall Hurst p-value" = rain_MKLTP[,8],
                  "Rainfall MK LTP p-value" = rain_MKLTP[,10])


weeklyTable_grid <- data.frame(Catchment = Stations[,1],
        "Gridded Rainfall tau MK" = gridrain_MKLTP[,1],
        "Gridded Rainfall Sen's slope" = gridrain_MKLTP[,4],
        "Gridded Rainfall p-value MK" = gridrain_MKLTP[,6],
        "Gridded Rainfall Hurst value" = gridrain_MKLTP[,7],
        "Gridded Rainfall Hurst p-value" = gridrain_MKLTP[,8],
        "Gridded Rainfall MK LTP p-value" = gridrain_MKLTP[,10])

weeklyTable_maxT <- data.frame(Catchment = Stations[,1],
        "Max Temp tau MK" = maxT_MKLTP[,1],
        "Max Temp Sen's slope" = maxT_MKLTP[,4],
        "Max Temp p-value MK" = maxT_MKLTP[,6],
        "Max Temp Hurst value" = maxT_MKLTP[,7],
```

```
        "Max Temp Hurst p-value" = maxT_MKLTP[,8],
        "Max Temp MK LTP p-value" = maxT_MKLTP[,10])

pander(weeklyTable_flow,
       caption="Mann-Kendall test (Hamed, 2008)
      results on de-seasonalised weekly flow time series.
       p-values are considered significant at the 5% level.")
```

Table 1: Mann-Kendall test (Hamed, 2008) results on de-seasonalised weekly flow time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Streamflow.tau.MK	Streamflow.Sen.s.slope	Streamflow.p.value.MK
COTT	-0.1414	-0.001095	1.065e-22
RUTH	-0.3113	-0.002453	2.429e-103
CORA	-0.09138	-0.0002879	2.365e-10
ELIZ	-0.05058	0	0.0004616
COCH	-0.008627	-0.0003129	0.5498
COEN	-0.01073	-1.596e-06	0.4568
SCOT	-0.03999	-4.389e-05	0.005561
HELL	-0.05613	-0.001878	9.952e-05
NIVE	-0.02455	-0.0007111	0.0887
MURR	-0.1743	-0.001795	1.273e-33
SOUT	-0.09736	-0.002838	1.477e-11
YARR	-0.1475	0	1.892e-24
DOMB	-0.08913	-0.0001405	6.45e-10

Streamflow.Hurst.value	Streamflow.Hurst.p.value	Streamflow.MK.LTP.p.value
0.9995	0	0.6989
0.9983	0	0.3912
0.9938	0	0.7961
0.9997	0	0.8903
0.9994	0	0.9812
0.9997	0	0.9766
0.9996	0	0.9129
0.9993	0	0.8779
0.9996	0	0.9465
0.999	0	0.6326
0.9975	0	0.7876
0.9998	0	0.6877
0.9997	0	0.8076

```
write_csv(weeklyTable_flow,"../ProjectData/MannKendallTest_Flow.csv")

pander(weeklyTable_rain,
       caption="Mann-Kendall test (Hamed, 2008)
      results on de-seasonalised weekly Rainfall time series.
       p-values are considered significant at the 5% level.")
```

Table 3: Mann-Kendall test (Hamed, 2008) results on de-seasonalised weekly Rainfall time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Rainfall.tau.MK	Rainfall.Sen.s.slope	Rainfall.p.value.MK
COTT	0.01999	0	0.1678
RUTH	-0.02649	0	0.06629
CORA	-0.002961	0	0.8374
ELIZ	0.08666	0	2.03e-09
COCH	-0.03001	0	0.03747
COEN	0.01793	0	0.2142
SCOT	-0.02289	0	0.1125
HELL	-0.04031	-0.0008197	0.005197
NIVE	-0.02515	-0.0001575	0.08125
MURR	-0.03171	-0.0004338	0.02789
SOUT	-0.06434	-0.002081	8.171e-06
YARR	-0.0189	0	0.1902
DOMB	-0.01489	0	0.3021

Rainfall.Hurst.value	Rainfall.Hurst.p.value	Rainfall.MK.LTP.p.value
0.6949	9.44e-78	0.6924
0.6261	4.561e-34	0.4171
0.5863	3.971e-17	0.9078
0.9676	0	0.7745
0.7376	3.967e-114	0.6506
0.8924	6.95e-305	0.9235
0.7024	1.209e-83	0.6642
0.588	1.062e-17	0.1186
0.6206	2.207e-31	0.4256
0.6249	1.692e-33	0.3279
0.5991	6.742e-22	0.01995
0.798	1.433e-177	0.8486
0.78	3.356e-157	0.8653

```r
write_csv(weeklyTable_rain,"../ProjectData/MannKendallTest_Rain.csv")

pander(weeklyTable_grid,
       caption="Mann-Kendall test (Hamed, 2008)
      results on de-seasonalised weekly gridded Rainfall time series.
       p-values are considered significant at the 5% level.")
```

Table 5: Mann-Kendall test (Hamed, 2008) results on de-seasonalised weekly gridded Rainfall time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Gridded.Rainfall.tau.MK	Gridded.Rainfall.Sen.s.slope
COTT	-0.05263	-0.0009798
RUTH	-0.02103	-1.78e-05
CORA	-0.01551	0
ELIZ	0.01079	0

Catchment	Gridded.Rainfall.tau.MK	Gridded.Rainfall.Sen.s.slope
COCH	-0.004112	0
COEN	-0.00204	0
SCOT	-0.03033	-9.606e-05
HELL	-0.00411	-0.0001982
NIVE	-0.0281	-0.0009326
MURR	-0.04115	-0.001015
SOUT	-0.06716	-0.002638
YARR	-0.007433	0
DOMB	-0.02163	-0.0003365

Table 6: Table continues below

Gridded.Rainfall.p.value.MK	Gridded.Rainfall.Hurst.value
0.0002634	0.5843
0.1449	0.6263
0.2821	0.6024
0.4551	0.9921
0.7756	0.8095
0.8876	0.9498
0.03548	0.6897
0.7757	0.6729
0.05135	0.6321
0.004331	0.63
3.222e-06	0.5887
0.6064	0.8025
0.1337	0.8012

Gridded.Rainfall.Hurst.p.value	Gridded.Rainfall.MK.LTP.p.value
2.043e-16	0.03714
3.417e-34	0.5201
2.936e-23	0.5825
0	0.9754
3.133e-191	0.9693
0	0.994
7.107e-74	0.5329
8.511e-62	0.9251
3.722e-37	0.4068
4.708e-36	0.2185
5.695e-18	0.009642
8.952e-183	0.9419
2.848e-181	0.8305

```
write_csv(weeklyTable_grid,"../ProjectData/MannKendallTest_GriddedRain.csv")


pander(weeklyTable_maxT,
       caption="Mann-Kendall test (Hamed, 2008)
      results on de-seasonalised weekly maximum Temperature time series.
```

```
    p-values are considered significant at the 5% level.")
```

Table 8: Mann-Kendall test (Hamed, 2008) results on de-seasonalised weekly maximum Temperature time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Max.Temp.tau.MK	Max.Temp.Sen.s.slope	Max.Temp.p.value.MK
COTT	0.04461	0.0006808	0.001982
RUTH	0.04461	0.0006808	0.001982
CORA	0.02721	0.0002765	0.05933
ELIZ	0.04795	0.0001647	0.0008868
COCH	0.03225	0.0003241	0.02568
COEN	0.07027	0.0003322	1.189e-06
SCOT	0.01277	0.0001906	0.3759
HELL	0.0222	0.0002506	0.1242
NIVE	0.0222	0.0002506	0.1242
MURR	0.03773	0.0004169	0.008891
SOUT	0.03773	0.0004169	0.008891
YARR	0.02347	0.000293	0.1037
DOMB	0.01315	8.826e-05	0.3623

Max.Temp.Hurst.value	Max.Temp.Hurst.p.value	Max.Temp.MK.LTP.p.value
0.9992	0	0.9027
0.9992	0	0.9027
0.9747	0	0.9312
0.9446	0	0.8546
0.9985	0	0.9293
0.9971	0	0.8455
0.9978	0	0.9719
0.9694	0	0.942
0.9694	0	0.942
0.998	0	0.9171
0.998	0	0.9171
0.9974	0	0.9482
0.9898	0	0.9696

```
write_csv(weeklyTable_maxT,"../ProjectData/MannKendallTest_maxT.csv")
```

Discussion of the weekly results

Essentially the results show that in all cases the Hurst coefficient is significant and often close to 1. This means the adjusted test should be used and this it the last p-value in the Tables above. Based on this, none of the trends in the streamflow are significant, and only 2 of the gridded rainfall stations (COTT and SOUT) induicate significant trends. The original Mann Kendall analysis showed much more significant trends.

Monthly Mann Kendall LTP results

This is a repeat of the weekly analysis to make sure that there is no major bias in the aggregation.

Basically the same analysis is repeated for each of the data sets. None of this is shown in the manuscript. However, the results are discussed in the section on the Mann Kendall trend analysis results.

```
nc <- 6 # number of cores
registerDoParallel(cores=nc)

# run in parallel
Store = foreach(j = 1:length(Stations[,1]),
                .packages=c("HKprocess")) %dopar%
{
  run <- MannKendallLTP(flow_monthly[,j])
}


# rainfall
# run in parallel
Store_rain = foreach(j = 1:length(Stations[,1]),
                .packages=c("HKprocess")) %dopar%
{
  run <- MannKendallLTP(rainfall_monthly[,j])
}

# gridded rainfall
# run in parallel
Store_gridRain = foreach(j = 1:length(Stations[,1]),
                .packages=c("HKprocess")) %dopar%
{
  run <- MannKendallLTP(rainfall_grdmonthly[,j])
}


# maxT
# run in parallel
Store_maxT = foreach(j = 1:length(Stations[,1]),
                .packages=c("HKprocess")) %dopar%
{
  run <- MannKendallLTP(maxT_monthly[,j])
}

#stopCluster(nc)

# results from the MannKendallLTP analysis
# flow
MK_standard <- lapply(Store, "[[","Mann_Kendall")
Hsignif <- lapply(Store, "[[","Significance_of_H")
MK_LTP <- lapply(Store, "[[","Mann_Kendall_LTP")

flow_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(flow_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
```

```r
                                         "2_sided_pvalue",sep="_")
# -------- end flow -----------------
# rainfall
MK_standard <- lapply(Store_rain, "[[","Mann_Kendall")
Hsignif <- lapply(Store_rain, "[[","Significance_of_H")
MK_LTP <- lapply(Store_rain, "[[","Mann_Kendall_LTP")

rain_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(rain_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
                                         "2_sided_pvalue",sep="_")
# -------- end rainfall -----------------

# gridded rainfall
MK_standard <- lapply(Store_gridRain, "[[","Mann_Kendall")
Hsignif <- lapply(Store_gridRain, "[[","Significance_of_H")
MK_LTP <- lapply(Store_gridRain, "[[","Mann_Kendall_LTP")

gridrain_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(gridrain_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
                                         "2_sided_pvalue",sep="_")
# -------- end gridded rainfall -----------------

# maxT
MK_standard <- lapply(Store_maxT, "[[","Mann_Kendall")
Hsignif <- lapply(Store_maxT, "[[","Significance_of_H")
MK_LTP <- lapply(Store_maxT, "[[","Mann_Kendall_LTP")

maxT_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(maxT_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
                                         "2_sided_pvalue",sep="_")
# -------- end maxT -----------------
```

Summary of monthly analysis in a table

This section brings together the data from all the monthlyly Mann Kendall analyses and puts this into a table. These results are only for comparison and are not repeated in the manuscript.

```r
monthlyTable_flow <- data.frame(Catchment = Stations[,1],
                  "Streamflow tau MK" = flow_MKLTP[,1],
                  "Streamflow Sen's slope" = flow_MKLTP[,4],
                  "Streamflow p-value MK" = flow_MKLTP[,6],
                  "Streamflow Hurst est" = flow_MKLTP[,7],
                  "Streamflow Hurst p-value" = flow_MKLTP[,8],
                  "Streamflow MK LTP p-value" = flow_MKLTP[,10])

monthlyTable_rain <- data.frame(Catchment = Stations[,1],
                  "Rainfall tau MK" = rain_MKLTP[,1],
                  "Rainfall Sen's slope" = rain_MKLTP[,4],
                  "Rainfall p-value MK" = rain_MKLTP[,6],
                  "Rainfall Hurst est" = rain_MKLTP[,7],
```

```
                  "Rainfall Hurst p-value" = rain_MKLTP[,8],
                  "Rainfall MK LTP p-value" = rain_MKLTP[,10])


monthlyTable_grid <- data.frame(Catchment = Stations[,1],
        "Gridded Rainfall tau MK" = gridrain_MKLTP[,1],
        "Gridded Rainfall Sen's slope" = gridrain_MKLTP[,4],
        "Gridded Rainfall p-value MK" = gridrain_MKLTP[,6],
        "Gridded Rainfall Hurst est" = gridrain_MKLTP[,7],
        "Gridded Rainfall Hurst p-value" = gridrain_MKLTP[,8],
        "Gridded Rainfall MK LTP p-value" = gridrain_MKLTP[,10])

monthlyTable_maxT <- data.frame(Catchment = Stations[,1],
        "Gridded Max Temp tau MK" = maxT_MKLTP[,1],
        "Gridded Max Temp Sen's slope" = maxT_MKLTP[,4],
        "Gridded Max Temp p-value MK" = maxT_MKLTP[,6],
        "Gridded Max Temp Hurst est" = maxT_MKLTP[,7],
        "Gridded Max Temp Hurst p-value" = maxT_MKLTP[,8],
        "Gridded Max Temp MK LTP p-value" = maxT_MKLTP[,10])

pander(monthlyTable_flow,
       caption="Mann-Kendall test (Hamed, 2008)
      results on de-seasonalised monthly flow time series.
       p-values are considered significant at the 5% level.")
```

Table 10: Mann-Kendall test (Hamed, 2008) results on de-seasonalised monthly flow time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Streamflow.tau.MK	Streamflow.Sen.s.slope	Streamflow.p.value.MK
COTT	-0.1825	-0.02602	1.45e-09
RUTH	-0.2487	-0.009593	1.672e-16
CORA	-0.1061	-0.002666	0.0004384
ELIZ	-0.02138	-0.0002322	0.4787
COCH	-0.02287	-0.004553	0.4485
COEN	-0.03943	-0.0009677	0.1913
SCOT	-0.02694	-0.003611	0.3719
HELL	-0.1251	-0.02172	3.358e-05
NIVE	-0.04643	-0.008054	0.1238
MURR	-0.242	-0.04788	1.042e-15
SOUT	-0.1752	-0.02489	6.289e-09
YARR	-0.1794	-0.00345	2.705e-09
DOMB	-0.06819	-0.004721	0.0238

Streamflow.Hurst.est	Streamflow.Hurst.p.value	Streamflow.MK.LTP.p.value
0.9757	6.974e-64	0.6122
0.969	3.479e-62	0.4745
0.7804	5.79e-24	0.4028
0.7183	2.04e-15	0.8166
0.9946	8.353e-69	0.954
0.7105	1.743e-14	0.6564

Streamflow.Hurst.est	Streamflow.Hurst.p.value	Streamflow.MK.LTP.p.value
0.9962	3.268e-69	0.9463
0.6816	2.671e-11	0.1033
0.6664	8.499e-10	0.5151
0.9936	1.557e-68	0.5397
0.8154	1.189e-29	0.2508
0.8227	6.495e-31	0.258
0.947	9.146e-57	0.8258

```r
pander(monthlyTable_rain,
       caption="Mann-Kendall test (Hamed, 2008)
      results on de-seasonalised monthly Rainfall time series.
       p-values are considered significant at the 5% level.")
```

Table 12: Mann-Kendall test (Hamed, 2008) results on de-seasonalised monthly Rainfall time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Rainfall.tau.MK	Rainfall.Sen.s.slope	Rainfall.p.value.MK
COTT	0.0234	0	0.4401
RUTH	-0.05926	-0.002758	0.04948
CORA	-0.02408	-0.00148	0.4249
ELIZ	-0.1019	-0.01499	0.0007428
COCH	0.1493	0.013	7.494e-07
COEN	0.005249	7.859e-05	0.8621
SCOT	-0.03489	-0.00236	0.2475
HELL	-0.02323	-0.001709	0.4413
NIVE	-0.05638	-0.003643	0.06163
MURR	-0.04039	-0.002757	0.1807
SOUT	-0.1328	-0.008315	1.069e-05
YARR	-0.02295	-0.001372	0.4469
DOMB	0.02586	0.001686	0.3913

Rainfall.Hurst.est	Rainfall.Hurst.p.value	Rainfall.MK.LTP.p.value
0.6076	4.191e-05	0.6658
0.5483	0.04143	0.1463
0.5445	0.05649	0.548
0.9928	2.566e-68	0.7957
0.5778	0.002206	0.001434
0.562	0.01199	0.9041
0.556	0.02108	0.4094
0.5324	0.1378	0.5394
0.5461	0.04977	0.1625
0.6051	6.08e-05	0.4483
0.5324	0.1377	0.0004494
0.5022	0.6623	0.485
0.5066	0.5541	0.4409

```r
pander(monthlyTable_grid,
       caption="Mann-Kendall test (Hamed, 2008)
      results on de-seasonalised monthly gridded Rainfall time series.
       p-values are considered significant at the 5% level.")
```

Table 14: Mann-Kendall test (Hamed, 2008) results on de-seasonalised monthly gridded Rainfall time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Gridded.Rainfall.tau.MK	Gridded.Rainfall.Sen.s.slope
COTT	-0.07266	-0.005208
RUTH	-0.0489	-0.002621
CORA	-0.03027	-0.001972
ELIZ	0.009024	0.0004805
COCH	-0.01631	-0.001484
COEN	-0.01828	-0.002614
SCOT	-0.05184	-0.003435
HELL	-0.0151	-0.001229
NIVE	-0.04929	-0.003837
MURR	-0.06537	-0.004871
SOUT	-0.1604	-0.01162
YARR	0.01709	0.0012
DOMB	-0.0464	-0.003155

Table 15: Table continues below

Gridded.Rainfall.p.value.MK	Gridded.Rainfall.Hurst.est
0.01601	0.6109
0.1051	0.5363
0.3157	0.5532
0.765	0.9828
0.5889	0.572
0.5447	0.9431
0.0857	0.5538
0.6168	0.4978
0.1023	0.4959
0.03023	0.6158
1.042e-07	0.555
0.5712	0.483
0.1241	0.5024

Gridded.Rainfall.Hurst.p.value	Gridded.Rainfall.MK.LTP.p.value
2.541e-05	0.1843
0.1049	0.2047
0.02721	0.4683
1.073e-65	0.9807
0.004248	0.7205
7.867e-56	0.952
0.02596	0.2153

Gridded.Rainfall.Hurst.p.value	Gridded.Rainfall.MK.LTP.p.value
0.7747	0.6392
0.8256	0.1224
1.181e-05	0.2432
0.02329	0.0001368
0.8181	0.5694
0.6569	0.1584

```r
pander(monthlyTable_maxT,
       caption="Mann-Kendall test (Hamed, 2008)
      results on de-seasonalised monthly mean Maximum Temperature time series.
       p-values are considered significant at the 5% level.")
```

Table 17: Mann-Kendall test (Hamed, 2008) results on de-seasonalised monthly mean Maximum Temperature time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Gridded.Max.Temp.tau.MK	Gridded.Max.Temp.Sen.s.slope
COTT	0.2109	0.02915
RUTH	0.2109	0.02915
CORA	0.1097	0.01201
ELIZ	0.09327	0.01275
COCH	0.1136	0.01811
COEN	0.1791	0.03049
SCOT	0.07537	0.008207
HELL	0.09844	0.01057
NIVE	0.09844	0.01057
MURR	0.1694	0.01895
SOUT	0.1694	0.01895
YARR	0.1201	0.01426
DOMB	0.07931	0.009323

Table 18: Table continues below

Gridded.Max.Temp.p.value.MK	Gridded.Max.Temp.Hurst.est
2.723e-12	0.6934
2.723e-12	0.6934
0.0002745	0.6165
0.001988	0.7305
0.0001658	0.7496
2.868e-09	0.7663
0.01247	0.6094
0.001101	0.6089
0.001101	0.6089
1.952e-08	0.6185
1.952e-08	0.6185
6.836e-05	0.6266
0.008557	0.7104

Gridded.Max.Temp.Hurst.p.value	Gridded.Max.Temp.MK.LTP.p.value
1.489e-12	0.009591
1.489e-12	0.009591
1.05e-05	0.05088
6.109e-17	0.3412
1.825e-19	0.2927
7.757e-22	0.128
3.216e-05	0.1654
3.466e-05	0.06938
3.466e-05	0.06938
7.662e-06	0.002825
7.662e-06	0.002825
1.963e-06	0.04165
1.814e-14	0.3704

Annual Mann Kendall LTP analysis

Basically the same analysis is repeated for each of the data sets. Some of this is discussed in the manuscript.

```
nc <- 6 # number of cores
registerDoParallel(cores=nc)

# run in parallel
Store = foreach(j = 1:length(Stations[,1]),
                .packages=c("HKprocess")) %dopar%
{
  run <- MannKendallLTP(flow_annual[,j])
}


# rainfall
# run in parallel
Store_rain = foreach(j = 1:length(Stations[,1]),
                .packages=c("HKprocess")) %dopar%
{
  run <- MannKendallLTP(rainfall_annual[,j])
}

# gridded rainfall
# run in parallel
Store_gridRain = foreach(j = 1:length(Stations[,1]),
                .packages=c("HKprocess")) %dopar%
{
  run <- MannKendallLTP(rainfall_grdannual[,j])
}


# maxT
# run in parallel
Store_maxT = foreach(j = 1:length(Stations[,1]),
                .packages=c("HKprocess")) %dopar%
{
```

```r
  run <- MannKendallLTP(maxT_annual[,j])
}

#stopCluster(nc)

# results from the MannKendallLTP analysis
# flow
MK_standard <- lapply(Store, "[[","Mann_Kendall")
Hsignif <- lapply(Store, "[[","Significance_of_H")
MK_LTP <- lapply(Store, "[[","Mann_Kendall_LTP")

flow_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(flow_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
                                         "2_sided_pvalue",sep="_")
# -------- end flow -----------------
# rainfall
MK_standard <- lapply(Store_rain, "[[","Mann_Kendall")
Hsignif <- lapply(Store_rain, "[[","Significance_of_H")
MK_LTP <- lapply(Store_rain, "[[","Mann_Kendall_LTP")

rain_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(rain_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
                                         "2_sided_pvalue",sep="_")
# -------- end rainfall -----------------

# gridded rainfall
MK_standard <- lapply(Store_gridRain, "[[","Mann_Kendall")
Hsignif <- lapply(Store_gridRain, "[[","Significance_of_H")
MK_LTP <- lapply(Store_gridRain, "[[","Mann_Kendall_LTP")

gridrain_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(gridrain_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
                                         "2_sided_pvalue",sep="_")
# -------- end gridded rainfall -----------------

# maxT
MK_standard <- lapply(Store_maxT, "[[","Mann_Kendall")
Hsignif <- lapply(Store_maxT, "[[","Significance_of_H")
MK_LTP <- lapply(Store_maxT, "[[","Mann_Kendall_LTP")

maxT_MKLTP <- cbind(do.call(rbind, MK_standard),do.call(rbind, Hsignif),
                    do.call(rbind, MK_LTP))
colnames(maxT_MKLTP)[c(6,8,10)] <- paste(c("MK","Hest","MKLTP"),
                                         "2_sided_pvalue",sep="_")
# -------- end maxT -----------------
```

Summary of annual analysis in a table

This section brings together the data from all the annually Mann Kendall analyses and puts this into a table. These results are only for comparison and are not repeated in the manuscript. The are briefly discussed in the manuscript in the section on the Mann Kendall results.

```
annualTable_flow <- data.frame(Catchment = Stations[,1],
                  "Streamflow tau MK" = flow_MKLTP[,1],
                  "Streamflow Sen's slope" = flow_MKLTP[,4],
                  "Streamflow p-value MK" = flow_MKLTP[,6],
                  "Streamflow Hurst est" = flow_MKLTP[,7],
                  "Streamflow Hurst p-value" = flow_MKLTP[,8],
                  "Streamflow MK LTP p-value" = flow_MKLTP[,10])

annualTable_rain <- data.frame(Catchment = Stations[,1],
                  "Rainfall tau MK" = rain_MKLTP[,1],
                  "Rainfall Sen's slope" = rain_MKLTP[,4],
                  "Rainfall p-value MK" = rain_MKLTP[,6],
                  "Rainfall Hurst est" = rain_MKLTP[,7],
                  "Rainfall Hurst p-value" = rain_MKLTP[,8],
                  "Rainfall MK LTP p-value" = rain_MKLTP[,10])


annualTable_grid <- data.frame(Catchment = Stations[,1],
        "Gridded Rainfall tau MK" = gridrain_MKLTP[,1],
        "Gridded Rainfall Sen's slope" = gridrain_MKLTP[,4],
        "Gridded Rainfall p-value MK" = gridrain_MKLTP[,6],
        "Gridded Rainfall Hurst est" = gridrain_MKLTP[,7],
        "Gridded Rainfall Hurst p-value" = gridrain_MKLTP[,8],
        "Gridded Rainfall MK LTP p-value" = gridrain_MKLTP[,10])

annualTable_maxT <- data.frame(Catchment = Stations[,1],
        "Max Temp tau MK" = maxT_MKLTP[,1],
        "Max Temp Sen's slope" = maxT_MKLTP[,4],
        "Max Temp p-value MK" = maxT_MKLTP[,6],
        "Max Temp Hurst est" = maxT_MKLTP[,7],
        "Max Temp Hurst p-value" = maxT_MKLTP[,8],
        "Max Temp MK LTP p-value" = maxT_MKLTP[,10])

pander(annualTable_flow,
       caption="Mann-Kendall test (Hamed, 2008)
      results on de-seasonalised annual flow time series.
       p-values are considered significant at the 5% level.")
```

Table 20: Mann-Kendall test (Hamed, 2008) results on de-seasonalised annual flow time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Streamflow.tau.MK	Streamflow.Sen.s.slope	Streamflow.p.value.MK
COTT	-0.3122	-5.258	0.004181
RUTH	-0.3683	-2.168	0.0007227
CORA	-0.2366	-1.152	0.03018
ELIZ	0.1049	0.8448	0.3397
COCH	-0.122	-1.131	0.2662
COEN	-0.1732	-1.004	0.1133
SCOT	-0.1659	-1.093	0.1294
HELL	-0.3659	-3.63	0.0007841

Catchment	Streamflow.tau.MK	Streamflow.Sen.s.slope	Streamflow.p.value.MK
NIVE	-0.1341	-1.633	0.2208
MURR	-0.3171	-7.115	0.003625
SOUT	-0.3244	-4.381	0.002916
YARR	-0.3171	-2.722	0.003625
DOMB	-0.1854	-1.251	0.08988

Streamflow.Hurst.est	Streamflow.Hurst.p.value	Streamflow.MK.LTP.p.value
0.511	0.3391	0.05072
0.5624	0.1609	0.04537
0.556	0.1781	0.1917
0.6156	0.06221	0.624
0.5225	0.291	0.4626
0.4909	0.4346	0.2528
0.5948	0.09211	0.4108
0.338	0.5837	0.0001205
0.3533	0.6782	0.1817
0.7756	0.001134	0.3206
0.6113	0.06771	0.1222
0.5372	0.2365	0.06508
0.308	0.4189	0.03252

```r
pander(annualTable_rain,
      caption="Mann-Kendall test (Hamed, 2008)
     results on de-seasonalised annual Rainfall time series.
      p-values are considered significant at the 5% level.")
```

Table 22: Mann-Kendall test (Hamed, 2008) results on de-seasonalised annual Rainfall time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Rainfall.tau.MK	Rainfall.Sen.s.slope	Rainfall.p.value.MK
COTT	0.02938	0.0548	0.796
RUTH	-0.239	-1.179	0.02851
CORA	-0.1098	-0.5723	0.3175
ELIZ	-0.3268	-2.115	0.002709
COCH	0.3659	1.724	0.0007841
COEN	-0.09512	-0.3291	0.3871
SCOT	-0.1122	-0.3418	0.3067
HELL	-0.06098	-0.2807	0.5821
NIVE	-0.09756	-0.4311	0.3749
MURR	-0.1463	-0.6593	0.1814
SOUT	-0.3902	-1.49	0.0003397
YARR	-0.1268	-0.3179	0.2473
DOMB	0.09512	0.3112	0.3871

Rainfall.Hurst.est	Rainfall.Hurst.p.value	Rainfall.MK.LTP.p.value
0.3813	0.8642	0.7962

Rainfall.Hurst.est	Rainfall.Hurst.p.value	Rainfall.MK.LTP.p.value
0.4931	0.4236	0.116
0.5058	0.3625	0.4889
0.7767	0.001097	0.3072
0.5885	0.1033	0.06389
0.2019	0.08358	0.12
0.2563	0.2086	0.1266
0.2593	0.2181	0.4154
0.3411	0.6026	0.3145
0.3816	0.8662	0.182
0.3607	0.7263	0.0001345
0.425	0.8346	0.3112
0.3671	0.7683	0.3663

```
pander(annualTable_grid,
       caption="Mann-Kendall test (Hamed, 2008)
      results on de-seasonalised annual gridded Rainfall time series.
       p-values are considered significant at the 5% level.")
```

Table 24: Mann-Kendall test (Hamed, 2008) results on de-seasonalised annual gridded Rainfall time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Gridded.Rainfall.tau.MK	Gridded.Rainfall.Sen.s.slope
COTT	-0.2341	-1.07
RUTH	-0.1902	-0.9003
CORA	-0.1463	-0.7191
ELIZ	0.1463	0.4791
COCH	-0.03659	-0.1637
COEN	-0.1171	-0.4665
SCOT	-0.1585	-0.6262
HELL	-0.0561	-0.2512
NIVE	-0.122	-0.4681
MURR	-0.1951	-0.907
SOUT	-0.4463	-1.975
YARR	-0.01707	-0.02714
DOMB	-0.1439	-0.5051

Table 25: Table continues below

Gridded.Rainfall.p.value.MK	Gridded.Rainfall.Hurst.est
0.03193	0.3545
0.08169	0.4118
0.1814	0.5697
0.1814	0.5119
0.7446	0.4009
0.286	0.2051
0.1474	0.2738
0.6133	0.4824
0.2662	0.4287

Gridded.Rainfall.p.value.MK	Gridded.Rainfall.Hurst.est
0.07412	0.4088
4.138e-05	0.4147
0.8839	0.3104
0.1888	0.4225

Gridded.Rainfall.Hurst.p.value	Gridded.Rainfall.MK.LTP.p.value
0.6859	0.01974
0.9256	0.1128
0.1426	0.438
0.3354	0.363
0.9994	0.7591
0.08869	0.0578
0.269	0.04106
0.4794	0.7084
0.8102	0.3356
0.9462	0.1007
0.9051	0.0002147
0.431	0.8551
0.852	0.2464

```
pander(annualTable_maxT,
       caption="Mann-Kendall test (Hamed, 2008)
      results on de-seasonalised annual mean Maximum Temperature time series.
       p-values are considered significant at the 5% level.")
```

Table 27: Mann-Kendall test (Hamed, 2008) results on de-seasonalised annual mean Maximum Temperature time series. p-values are considered significant at the 5% level. (continued below)

Catchment	Max.Temp.tau.MK	Max.Temp.Sen.s.slope	Max.Temp.p.value.MK
COTT	0.422	4.592	0.0001066
RUTH	0.422	4.592	0.0001066
CORA	0.2366	1.685	0.03018
ELIZ	0.1561	1.748	0.1537
COCH	0.2244	2.662	0.03984
COEN	0.3317	4.375	0.002336
SCOT	0.2195	1.272	0.04438
HELL	0.2268	1.481	0.03772
NIVE	0.2268	1.481	0.03772
MURR	0.3756	2.828	0.0005643
SOUT	0.3756	2.828	0.0005643
YARR	0.2317	2.145	0.03377
DOMB	0.1683	1.273	0.1239

Max.Temp.Hurst.est	Max.Temp.Hurst.p.value	Max.Temp.MK.LTP.p.value
0.5537	0.1847	0.01883
0.5537	0.1847	0.01883

Max.Temp.Hurst.est	Max.Temp.Hurst.p.value	Max.Temp.MK.LTP.p.value
0.5446	0.2122	0.178
0.2685	0.2494	0.04062
0.6252	0.05144	0.3034
0.4274	0.8183	0.008164
0.4401	0.7343	0.09239
0.6297	0.04689	0.3039
0.6297	0.04689	0.3039
0.5075	0.3547	0.01752
0.5075	0.3547	0.01752
0.3741	0.8153	0.03003
0.4595	0.6113	0.2238