

# Package ‘baytrends’

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**Type** Package

**Title** Long Term Water Quality Trend Analysis

**Description** Enable users to evaluate long-term trends using a Generalized Additive Modeling (GAM) approach. The model development includes selecting a GAM structure to describe nonlinear seasonally-varying changes over time, incorporation of hydrologic variability via either a river flow or salinity, the use of an intervention to deal with method or laboratory changes suspected to impact data values, and representation of left- and interval-censored data. The approach has been applied to water quality data in the Chesapeake Bay, a major estuary on the east coast of the United States to provide insights to a range of management- and research-focused questions.

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**Collate** 'a1\_smwrQW\_qw-class.R' 'a2\_smwrQW\_licens-class.R'  
'a3\_smwrQW\_mcens-class.R' 'analysisOrganizeData.R'  
'appendDateFeatures.R' 'as.licens.R' 'as.mcens.R' 'as.qw.R'  
'baytrends.R' 'checkRange.R' 'chkParameter.R' 'closeOut.R'

'createResiduals.R' 'data.R' 'detrended.flow.R'  
 'detrended.salinity.R' 'expectMaxFunctions.r' 'findFile.R'  
 'flwAveragePred.R' 'fmtPval.R' 'gamDiff.R' 'gamPlotCalc.r'  
 'gamPlotDisp.R' 'gamPlotDispSeason.R' 'gamTables.R' 'gamTest.r'  
 'gamTestSeason.r' 'getUSGSflow.R' 'headers2.R'  
 'imputeCensored.R' 'initializeResults.r' 'layerAggregation.R'  
 'loadData.R' 'loadExcel.R' 'loadModels.R' 'loadModelsResid.R'  
 'mergeFlow.R' 'mergeSalinity.R' 'qw.export.R' 'qw.import.R'  
 'reAttDF.R' 'saveDF.R' 'seasAdjflow2.R' 'selectData.R'  
 'smwrBase\_baseDay.R' 'smwrBase\_baseDay2decimal.R'  
 'smwrBase\_dectime.R' 'smwrBase\_dectime2Date.R'  
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 'smwrGraphs\_refLine.R' 'smwrGraphs\_renderPretty.R'  
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 'smwrGraphs\_setExplan.R' 'smwrGraphs\_setGD.R'  
 'smwrGraphs\_setMargin.R' 'smwrGraphs\_setMultiPlot.R'  
 'smwrGraphs\_setPage.R' 'smwrGraphs\_setPlot.R'  
 'smwrGraphs\_strip.blanks.R' 'smwrGraphs\_timePlot.R'  
 'smwrGraphs\_timePretty.R' 'smwrGraphs\_transData.R'  
 'smwrGraphs\_xyPlot.R' 'smwrQW\_censoring.R' 'smwrQW\_is.na.R'  
 'smwrQW\_mcenKM.R' 'smwrQW\_mcenMLE.R' 'smwrQW\_mcenROS.R'  
 'smwrQW\_mdMLE.R' 'smwrQW\_mdIROS.R' 'smwrQW\_pcodeNWISqw.R'  
 'smwrQW\_x\_Arith-censored.R' 'smwrQW\_x\_Math-censored.R'  
 'smwrQW\_x\_View.r' 'smwrQW\_x\_add.R' 'smwrQW\_x\_as.character.R'  
 'smwrQW\_x\_as.data.frame.R' 'smwrQW\_x\_as.double.R'  
 'smwrQW\_x\_c.R' 'smwrQW\_x\_censorlevels.R' 'smwrQW\_x\_censpp.R'  
 'smwrQW\_x\_convert2qw.R' 'smwrQW\_x\_convertFqw.R'  
 'smwrQW\_x\_dlimit.R' 'smwrQW\_x\_format.R'  
 'smwrQW\_x\_importNWISqw.R' 'smwrQW\_x\_importQW.R'  
 'smwrQW\_x\_imputeLessThans.R' 'smwrQW\_x\_length.R'  
 'smwrQW\_x\_makeColNames.R' 'smwrQW\_x\_mdIKM.R'  
 'smwrQW\_x\_mdIKMstats.R' 'smwrQW\_x\_mean.qw.R'  
 'smwrQW\_x\_meanStats.R' 'smwrQW\_x\_medianStats.R'  
 'smwrQW\_x\_print.censMCT.R' 'smwrQW\_x\_print.censQuantile.R'  
 'smwrQW\_x\_print.censReg.R' 'smwrQW\_x\_print.censStats.R'  
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 'smwrQW\_x\_quantile.R' 'smwrQW\_x\_qw2mcens.R'  
 'smwrQW\_x\_qwCoalesce.R' 'smwrQW\_x\_ratio.R' 'smwrQW\_x\_rbindQW.R'  
 'smwrQW\_x\_readNWQLdl.R' 'smwrQW\_x\_residuals.censReg.R'  
 'smwrQW\_x\_sdlFill.R' 'smwrQW\_x\_show-censored.R'  
 'smwrQW\_x\_sort.censored.R' 'smwrQW\_x\_splitQual.R'

'smwrQW\_x\_str.R' 'smwrQW\_x\_subset.R' 'smwrQW\_x\_summary.R'  
 'smwrQW\_x\_summary.censReg.R' 'smwrQW\_x\_vcov.censReg.R'  
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analysisOrganizeData *Analysis Organization & Data Preparation*

---

### Description

This function assesses the user supplied specifications in the argument, `analySpec`, and prepares the data (argument `df`) for analysis. In those cases where the user doesn't supply a needed specification, a basic option is supplied by this function.

### Usage

```
analysisOrganizeData(
  df,
  analySpec = list(),
  reports = c(0, 1, 2, 3, 4),
  parameterList = NA,
  stationMasterList = NA,
  layerLukup = NA
)
```

### Arguments

<code>df</code>	Data frame of water quality data
<code>analySpec</code>	Specifications for analysis
<code>reports</code>	Optional reports about parameters, layers and stations [default = c(0,1,2,3)]
<code>parameterList</code>	User-supplied dataframe with list of parameters [default = NA]
<code>stationMasterList</code>	User-supplied dataframe with list of stations [default = NA]
<code>layerLukup</code>	User-supplied dataframe with list of layers [default = NA]

### Details

The supplied data frame, `df`, is a data frame with the variables `station`, `date`, and `layer` included along with multiple additional columns for a variety of water quality variables structured as "qw" objects. An example data frame, `dataCensored`, is included with `baytrends` as an example.

The argument, `analySpec`, is a list that includes basic specifications for performing GAM analyses. The components in `analySpec` are identified below. The user may create `analySpec` (which can include all or some of the below components; and pass the user-supplied `analySpec` to this function. Or, the user may accept the default argument and allow `analysisOrganizeData` to create and return `analySpec`. If the user passes a user-supplied `analySpec`, then `analysisOrganizeData` will "fill in" required arguments not provided by the user. The user can also adjust `analySpec` after it is returned from `analysisOrganizeData` although requirements for down selecting the data frame, `df`, or aggregating data by layer would need to be passed to `analysisOrganizeData`.

The default setting for the argument `report` is to provide tabular summary reports about the parameters, stations, and layers to be analyzed. Setting `report=NA` will suppress the tabular summary reports.

The user can supply their own parameterList, stationMasterList, or layerLukup data sets; or the user can use the example data frames included with baytrends.

The following steps are performed by analysisOrganizeData:

- 1) Review user supplied specifications through the analySpec argument. Fill in with default values. For example, if the user doesn't specify a dataframe with a list of stations, parameters, or layers, then the built-in data frames, baytrends::stationMasterList, baytrends::parameterList, and baytrends::layerLukup are used. Some other default values include the following: date range (1/1/1984-present), parameter list (all parameters in data set parameterList), layers (all layers in data set layerLukup), layer aggregation option (0, no aggregation), minimum number of observations to perform a GAM analysis (60), GAM formulas (Linear Trend with Seasonality, Non-linear Trend with Seasonality, and Non-linear trend with Seasonality (plus Interactions)), GAM alpha level for plots and output (0.05), periods for multi-time period analyses using GAM (Full Record, 1999/00-Present, and 2005/06-Present), and seasons for sub-annual analyses using GAM (All, Spring1, Spring2, Summer1, Summer2, SAV1, SAV2, Winter, and Fall.)
- 2) Based on the settings in analySpec, the data frame df, is down selected based on parameters, stations, dates, and layers. A dependent variable list (depVarList) is created that includes variable descriptions, units, and log transformation selections. A station list (stationList) is created that includes the station ID, a selected USGS gage for correlating flow, and latitude/longitude.
- 3) Aggregate data layers. If analySpec\$layerAggOption is equal to 0, then there is no aggregation. The analySpec\$layerAggOption of 1 would result in averaging (mean) surface and above pycnocline data. In this example, records with layer = "S" and layer = "AP" are relabeled as "SAP". Other layerAggOption values are 2) "B"&"BP"; 3) "S"&"AP" and "B"&"BP"; 4) all layers; and 5) "S"&"B", respectively. A layer list (layerList) is created and returned.
- 4) Data are then averaged (mean) by date.
- 5) Date features are added. Columns for year, day of year (doy), decimal year (dyear), and month are added based on date. Note that the doy is based on a 366 day calendar regardless of leap year.
- 6) Reports on the number of records (0), parameters (1), layers (2) and stations (3) can be controlled with the reports option.

## Value

Returns a list. Use dfr[["df"]] and dfr[["analySpec"]] to extract updated data frame and updated (or created) analySpec. analySpec is a list that includes the following components:

analyTitle - Analysis trend title

parameterFilt - Parameter filter used for data down selection

stationFilt - Station filter used for data down selection

dateFilt - Date filter for data down selection

setTZ - time zone (default = "America/New\_York")

layerFilt - Layer filter

layerAggOption - Layer averaging option (default = 0). Other options are: 1: combine "S" & "AP" ("SAP"); 2: combine "B" & "BP" ("BBP"); 3: opt 1 & 2 ("SAP", "BBP"); 4: combine all ("ALL"); 5: combine "S" and "B" ("SB")

obsMin - Minimum number of observations required to allow GAM analysis to proceed for a specific station, parameter, and layer combination (default = 60).

obsMinInter - Minimum number of observations required to allow GAM analysis to proceed for a specific intervention (default = 10).

gamAlpha - Alpha level used GAM analyses (default = 0.05).

sensorTrim - Values to apply for trimming data due to too much censoring (default = c(0.5, 0.4)). First argument indicates fraction of observations in a year that are allowed to be censored. Second argument is the fraction of years, starting from the beginning of the record, that are allowed to be "flagged" for too much censoring. A minimum of two years must have too much censoring before data are removed. The default settings can be read as no more than 40 percent of the beginning years of data are allowed to have more than 50 percent censoring before the beginning portion of the record is trimmed. For example, years 1 and 3 of data have more than 50 percent censoring then the first three years of data are trimmed. Similarly, for years 1 and 4, then the first four years are removed. If years 1 and 5 have more than 50 percent censoring the data are kept since 2/5 is not greater than 0.4.

gamModels - model formulations. See baytrends::loadModels() for simplified approach for selecting which built-in models to include

showGamNumOnPlot - Show gam option (i.e., 0-6) on gam plots (TRUE/FALSE)

gamDiffPeriods - list of time periods (years) used for computing changes (differences). The default options are: full record, 1999/00-present, and 2005/06-present.

gamDiffSeasons - list List of seasons used for sub-annual analyses of computing differences. The default options include the following: All (months 1:12), Spring1 (3:5), Spring2 (months: 4:6), Summer1 (months: 6:9), Summer2 (months: 7:9)), SAV1 (months: 4:10)), SAV2 (months: 3:5,9:11)), Winter (months: 1:2)), and Fall (months: 10:12))).

gamPenalty - allow the user to set the mgcv::gam select argument to TRUE, FALSE, or baytrend algorithm default (default = NA). When the default option is specified, then the mgcv::gam select argument is set to FALSE when none of the data are censored; otherwise (when some censoring exists in the data set) the select argument is set to TRUE

gamPenaltyCrit - edf and F-stat values used to flag ANOVA table results (default = c(1, 9e9))

gamCoeffDeltaMaxCrit - convergence criteria for expectation maximization (default = 1e-6)

gamFlw\_Sal.Wgt.Perc - percentiles of flow [or salinity] to use for computing flow [salinity] averaged result (default = c(0.05, 0.25, 0.50, 0.75, 0.95))

gamLegend - default settings for gam figure legend

idVar - primary key for data frame returned as df

depVarList - data frame of dependent variables (useful for setting up gam analyses in for loops)

stationList - data frame of stations (useful for setting up gam analyses in for loops)

layerList - data frame of layers (useful for setting up gam analyses in for loops)

## Examples

```
# run analysis relying on default specifications, examine analySpec for
# default options
dfr <- analysisOrganizeData(dataCensored)
df    <- dfr[["df"]]
analySpec <- dfr[["analySpec"]]
```

```
# analyze bottom dissolved oxygen at 2 stations
analySpec <-list()
analySpec$parameterFilt <- c('do')
analySpec$layerFilt <- c('B')
analySpec$stationFilt <- c('CB3.3C', 'CB5.4')
dfr <- analysisOrganizeData(dataCensored, analySpec)
df <- dfr[["df"]]
analySpec <- dfr[["analySpec"]]
```

---

baytrends

*baytrends: Long Term Water Quality Trend Analysis*

---

### Description

The baytrends package was developed to enable users to evaluate long-term trends in the Chesapeake Bay using a Generalized Additive Modeling (GAM) approach. The model development includes selecting a GAM structure to describe nonlinear seasonally-varying changes over time, incorporation of hydrologic variability via either a river flow or salinity, the use of an intervention to deal with method or laboratory changes suspected to impact data values, and representation of left- and interval-censored data. This approach, which is fully transferable to other systems, allows for Chesapeake Bay water quality data to be evaluated in a statistically rigorous, yet flexible way to provide insights to a range of management- and research-focused questions.

---

closeOut

*Document Processing Time and Other Session Time*

---

### Description

Document Processing Time and Other Session Time

### Usage

```
closeOut(timeProcess = TRUE, contInfo = TRUE, sessInfo = TRUE)
```

### Arguments

timeProcess	Processing time
contInfo	Contact information
sessInfo	Session information

### Value

Reports out processing time, contact information and session information

### Examples

```
closeOut()
```

---

createResiduals      *Calculate GAM residuals*

---

### Description

Use GAM analysis to compute residuals. Relies on `mgcv::gam` to perform general additive model.

### Usage

```
createResiduals(
  df,
  dep,
  residualModel = "doy_flw_sal",
  analySpec = analySpec,
  gamTable = FALSE,
  gamPlot = FALSE,
  flow.detrended = NA,
  salinity.detrended = NA,
  width = 10,
  height = 3.5,
  folder_r = "pltResiduals",
  ProjRoot
)
```

### Arguments

<code>df</code>	data frame
<code>dep</code>	variable
<code>residualModel</code>	which gam formula is used to compute . Default: 'doy_flw_sal'.
<code>analySpec</code>	analytical specifications
<code>gamTable</code>	gam table setting (set to FALSE to turn off table output)
<code>gamPlot</code>	gam plot setting (set to FALSE to turn off plotting)
<code>flow.detrended</code>	data generated by <code>detrended.flow</code> . Default = NA.
<code>salinity.detrended</code>	data generated by <code>detrended.flow</code> . Default = NA.
<code>width</code>	width of png figure (inches). Default = 10
<code>height</code>	height of png figure (inches). Default = 3.5
<code>folder_r</code>	folder to store residual plots
<code>ProjRoot</code>	Root folder for project.

### Value

Returns `df` with appended column of data



---

dataCensored

*Chesapeake Bay Program Monitoring Data, 1985-2016*

---

### Description

Selected 1985-2016 data for eight (8) stations from the Chesapeake Bay Monitoring Program. Water quality variables are stored as class `qw` that allows for left- and interval-censored data.

### Usage

`dataCensored`

### Format

A data frame with 13,062 rows and 17 variables:

**station** station identifier

**date** sample date

**layer** sample layer

**secchi** Secchi depth [m]

**salinity** Salinity [ppt]

**do** Dissolved Oxygen [mg/L]

**wtemp** Water Temperature [deg C]

**chla** Corrected Chlorophyll-a [ug/L]

**tn** Total Nitrogen [mg/L]

**tp** Total Phosphorus [mg/L]

**tss** Total Suspended Solids [mg/L]

**din** Dissolved Inorganic Nitrogen [mg/L]

**po4** Orthophosphorus [mg/L]

**tdn** Total Dissolved Nitrogen [mg/L]

**tdp** Total Dissolved Phosphorus [mg/L]

**nh4** Ammonium [mg/L]

**no23** Nitrite + Nitrate [mg/L]

detrended.flow

*Create Seasonally Detrended Flow Data Set***Description**

This function creates a seasonally detrended flow data set for selected USGS gages. The created data set is used to support application of GAMs that include a hydrologic term as one of the independent variables. The output from this function should be stored as an .rda file for repeated use with baytrends.

**Usage**

```
detrended.flow(
  usgsGageID,
  siteName,
  yearStart,
  yearEnd,
  dvAvgWinSel = c(1, 5, 10, 15, 20, 30, 40, 50, 60, 90, 120, 150, 180, 210),
  dvAvgWgtSel = "uniform",
  dvAvgSidesSel = 1,
  lowess.f = 0.2,
  span = 10,
  max.fill = 10
)
```

**Arguments**

usgsGageID	USGS GageIDs (e.g., "01491000")
siteName	USGS SiteName (only used for plots)
yearStart	start year (recommended as at least one year before corresponding water quality data set)
yearEnd	end year
dvAvgWinSel	Averaging window (days) for smoothing the residuals of the seasonally adjusted daily flow values [default = c(1, 5, 10, 15, 20, 30, 40, 50, 60, 90, 120, 150, 180, 210)]
dvAvgWgtSel	Averaging method ("uniform", "weighted", or "centered") for creating weights. If using "weighted" then use dvAvgSidesSel=1. If using "centered" then use dvAvgSidesSel=2. [default = "uniform"]
dvAvgSidesSel	If dvAvgSidesSel=1 only past values are used, if dvAvgSidesSel=2 then values are centered around lag 0. [default = 1]
lowess.f	lowess smoother span applied to computed standard deviation (see Details). This gives the proportion of points which influence the smooth at each value. Larger values give more smoothness. [default = 0.2]
span	maximum number of observations on each side of range of missing values to use in filling in data [default = 10]
max.fill	maximum gap to fill in [default = 10]

## Details

This function returns a list of seasonally detrended flow and companion statistics; and relies on USGS' dataRetrieval package to retrieve daily flow data.

It is the user responsibility to save the resulting list as **flow.detrended** for integration with baytrends.

For the purposes of baytrends, it is expected that the user would identify all USGS gages that are expected to be evaluated so that a single data file is created. To best match up with water quality data, we recommend retrieving flow data for one year prior to the first year of water quality data. This allows for creating a time-averaged flow data set and not lose the first few months of water quality data due to lack of matching flow data. Data retrievals should also be made in light of the time needed by the USGS to review and approve their flow records.

After retrieval, the following computation steps are performed to create a data frame for each USGS gage (the data frame naming convention is **qNNNNNNNN** where NNNNNNNN is the USGS gage ID):

- 1) The daily flow data are converted to cubic meters per second [cms] and stored as the variable **q**.
- 2) The day of year (**doy**) is added to the data set. We use a 366 day calendar regardless of leap year.
- 3) The Log (ln) flow is computed and stored as **LogQ**.
- 4) A seasonal GAM, i.e., `gamoutput <- gam(LogQ ~ s(doy, bs='cc'))` is evaluated and the predicted values stored as **qNNNNNNNN.gam**.
- 5) The GAM residuals, i.e., "residuals(gamoutput)" are extracted and stored as the variable, **d1**.
- 6) Based on the specifications for `dvAvgWinSel`, `dvAvgWgtSel`, and `dvAvgSidesSel`, the values of **d1** are time averaged and additional variables **dxxx** are added to the data frame where xxx corresponds to list of averaging windows specified in `dvAvgWinSel`. These values of **dxxx** are used in GAMs that include a hydrologic independent variable.

After the above data frame is created, the following four (4) additional data frames are created for each USGS gage and combined into a list named **qNNNNNNNN.sum**:

**mean** – For each doym (i.e., 366 days of year), the mean across all years for each value of d in the above data frame, **qNNNNNNNN**.

**sd** – For each doym (i.e., 366 days of year), the standard deviation across all years for each value of d in the above data frame, **qNNNNNNNN**.

**nobs** – For each doym (i.e., 366 days of year), the number of observations across all years for each value of d in the above data frame, **qNNNNNNNN**.

**lowess.sd** – Lowess smoothed standard deviations. (These values are used for computing confidence intervals in the flow averaged GAM.)

The process of creating the above data frame, **qNNNNNNNN**, and list, **qNNNNNNNN.sum**, is repeated for each USGS gage and combined together in a single list. The beginning of the list includes meta data documenting the retrieval parameters.

This function can be used in conjunction with an RMD file to knit (create) a report (DOCX or HTML).

## Value

Returns a list of seasonally detrended flow data. You should save the resulting list as `flow.detrended` for use with baytrends. This function also creates diagnostic plots that can be saved to a report when this function is called from an .Rmd script.

**Examples**

```
## Not run:
# Define Function Inputs
usgsGageID   <- c("01491000", "01578310")
siteName     <- c("Choptank River near Greensboro, MD",
                 "Susquehanna River at Conowingo, MD")

yearStart    <- 1983
yearEnd      <- 2016
dvAvgWinSel  <- c(1, 5, 10, 15, 20, 30, 40, 50, 60, 90, 120, 150, 180, 210)
dvAvgWgtSel  <- "uniform"
dvAvgSidesSel <- 1
lowess.f     <- 0.2

# Run Function
flow.detrended <- detrended.flow(usgsGageID, siteName, yearStart, yearEnd
                                , dvAvgWinSel, dvAvgWgtSel, dvAvgSidesSel
                                , lowess.f)

## End(Not run)
```

---

detrended.salinity      *Create Seasonally Detrended Salinity Data Set*

---

**Description**

This function creates a seasonally detrended salinity data set for selected stations. The created data set is used to support application of GAMs that include a hydrologic term as one of the independent variables. The output from this function should be stored as an .rda file for repeated use with baytrends.

**Usage**

```
detrended.salinity(
  df.sal,
  dvAvgWinSel = 30,
  lowess.f = 0.2,
  minObs = 40,
  minObs.sd = 10
)
```

**Arguments**

df.sal	data frame with salinity data (required variables in data frame are: station, date, layer, and salinity)
dvAvgWinSel	Averaging window (days) selection for pooling data to compute summary statistics

lowess.f	lowess smoother span applied to computed standard deviation (see Details). This gives the proportion of points which influence the smooth at each value. Larger values give more smoothness.
minObs	Minimum number of observations for performing analysis (default is 40)
minObs.sd	Minimum number of observations in averaging window for calculation of the standard deviation (default is 10)

## Details

This function returns a list of seasonally detrended salinity and companion statistics; and relies on a user supplied data frame that contains the following variables: station, date, layer, and salinity. See structure of sal data in example below.

It is the user responsibility to save the resulting list as **salinity.detrended** for integration with baytrends.

For the purposes of baytrends, it is expected that the user would identify a data set with all salinity data that are expected to be evaluated so that a single data file is created. The following computation steps are performed:

- 1) Extract the list of stations, minimum year, and maximum year in data set. Initialize the **salinity.detrended** list with this information along with meta data documenting the retrieval parameters.
- 2) Downselect the input data frame to only include data where the layer is equal to 'S', 'AP', 'BP' or 'B'.
- 3) Average the 'S' and 'AP' salinity data; and the 'B' and 'BP' salinity data together to create average salinity values for SAP (surface and above pycnocline) and BBP (bottom and below pycnocline), respectively. These values are stored as the variables, **salinity.SAP** and **salinity.BBP** together with the **date** and day of year (**doy**) in a data frame corresponding to the station ID.
- 4) For each station/layer combination with atleast **minObs** observations, a seasonal GAM, i.e., `gamoutput <- gam(salinity ~ s(doy, bs='cc'))` is evaluated and the predicted values stored in the above data frame as **salinity.SAP.gam** and **salinity.BBP.gam**.
- 5) The GAM residuals, i.e., "residuals(gamoutput)" are extracted and stored as the variable, **SAP** or **BBP** in the above data frame. (These are the values that are used for GAMs that include salinity.)
- 6) After the above data frame is created and appended to the list **salinity.detrended**, the following four (4) additional data frames are created for each station.

**mean** – For each doym (i.e., 366 days of year), the mean across all years for each value of d. Since samples are not collected on a daily basis it is necessary to aggregate data from within a +/- one-half of **dvAvgWinSel**-day window around d. (This includes wrapping around the calendar year. That is, the values near the beginning of the year, say January 2, would include values from the last part of December and the first part of January. The variables in the mean data frame are doym, SAP, and BBP.

**sd** – For each doym (i.e., 366 days of year), the standard deviation across all years for each value of d. (See mean calculations for additional details.)

**nobs** – For each doym (i.e., 366 days of year), the number of observations across all years for each value of d. (See mean calculations for additional details.)

**lowess.sd** – Lowess smoothed standard deviations. It is noted that some stations do not include regular sampling in all months of the year or for other reasons have few observations from which

to compute standard deviations. Through visual inspection of plots, we found that the standard deviation could become unstable when the number of observations is small. For this reason, when the number of observations is less than **minObs.sd**, the corresponding value of `lowess.sd` is removed and interpolated from the remaining observations.

The above four data frames (`mean`, `sd`, `nobs`, and `lowess.sd`) are created, they are added to a list using a **station.sum** naming convention and appended to the list **salinity.detrended**.

## Value

Returns a list of seasonally detrended salinity data. You should save the resulting list as `salinity.detrended` for use with `baytrends`. This function also creates diagnostic plots that can be saved to a report when this function is called from an `.Rmd` script.

## Examples

```
## Not run:
# Show Example Dataset (sal)
str(sal)

# Define Function Inputs
df.sal      <- sal
dvAvgWinSel <- 30
lowess.f    <- 0.2
minObs     <- 40
minObs.sd  <- 10

# Run Function
salinity.detrended <- detrended.salinity(df.sal, dvAvgWinSel,
                                         lowess.f, minObs, minObs.sd)

## End(Not run)
```

---

gamDiff

*Compute an estimate of difference based on GAM results*

---

## Description

Compute an estimate of difference based on GAM results

## Usage

```
gamDiff(
  gamRslt,
  iSpec,
  analySpec,
  base.yr.set = NA,
  test.yr.set = NA,
  doy.set = NA,
```

```

alpha = 0.05,
flow.detrended = NA,
salinity.detrended = NA
)

```

### Arguments

gamRslt	output from gam model
iSpec	data set specifications (see details for required content)
analySpec	analytical specifications
base.yr.set	vector of years used for baseline period
test.yr.set	vector of years used for test period
doy.set	vector of days used to establish sub-annual analyses (see details)
alpha	alpha level for computing confidence intervals
flow.detrended	data generated by detrended.flow. Default = flow.detrended.
salinity.detrended	data generated by detrended.salinity. Default = detrended.salinity.

### Details

iSpec is a list containing information about the date range and transformations. Specifically, iSpec must include iSpec\$yearBegin, iSpec\$yearEnd, iSpec\$centerYear corresponding to beginning year of record, ending year of record and centering year. Also, iSpec must include iSpec\$transform and iSpec\$logConst. (See online help for selectData for more information on these values.)

base.yr.set and test.yr.set represent two time periods used to compare differences. For example, base.yr.set=c(1999,2000) and test.yr.set=c(2013,2014) would compare GAM predictions from 1999-2000 versus 2013-2014. There is no particular limit to the number of years included in the specification for base.yr.set and test.yr.set. For example, a user could specify c(2001:2002,2004) to use the years 2001, 2002, and 2004, skipping 2003 because 2003 was an abnormal year (particularly wet, particularly dry, hurricanes, etc.).

base.yr.set and test.yr.set must be within the years specified by the range from iSpec\$yearBegin to iSpec\$yearEnd (inclusive). If not, this function defaults to using the first two years (or last two years) of record. If base.yr.set and test.yr.set are left to their default values of NA, then the first two and last two years will be used

doy.set represents the days of year for which GAM predictions are made and used to compute base.yr and test.yr means. For example doy.set= c(15, 46, 75, 106, 136, 167, 197, 228, 259, 289, 320, 350) would result in the 15th of each month being used in the analysis; whereas doy.set= c(15, 46, 75) would just use Jan-15, Feb-15, and Mar-15. (Keep in mind that this package uses a 366 day calendar every year such that Mar-1 is always day 61, regardless of leap year.) If doy.set is left to the default value of NA, then c(15, 46, 75, 106, 136, 167, 197, 228, 259, 289, 320, 350) is used.

The baseDay function has been added to this package from the smwrBase package.

**Value**

Returns a nest list that includes the base and test years, doys, period means in analyzed units, period means in observed units, percent change, difference estimate, difference estimate in observed units, standard error, confidence intervals, t statistic, p value, and alpha level. The alpha level corresponds to the confidence intervals. The first list (gamDiff.regular) uses the computed model to estimate differences and is applicable for GAM formulas that do not involve an intervention term. The second list (gamDiff.adjusted) performs computations by projecting the most recent intervention (e.g., the current lab method) to all time periods.

**Examples**

```
# run analysisOrganizeData function to create the list analySpec
dfr <- analysisOrganizeData (dataCensored, report=NA)
df      <- dfr[["df"]]
analySpec <- dfr[["analySpec"]]

# set GAM models to just one model
analySpec$gamModels <- list(
  list(option=2, name= "Non-linear trend with Seasonality (plus Interactions)",
    model= "~ cyear + s(cyear) + s(doy,bs='cc')+ ti(cyear,doy,bs=c('tp','cc'))", deriv=FALSE))

# run GAM for a single water quality variable, station and layer
gamResult <- gamTest(df, 'tn', 'CB5.4', 'S', analySpec=analySpec)

# use gamDiff to replicate estimates of change calculated in the above
gamDiff(gamRslt=gamResult[["gamOutput2"]]$gamRslt,
  iSpec=gamResult$iSpec, analySpec=analySpec,
  base.yr.set = NA, test.yr.set = NA,
  doy.set = NA, alpha = 0.05)

# use gamDiff to calculate changes from 2005/06 to 2013/14
gamDiff(gamRslt=gamResult[["gamOutput2"]]$gamRslt,
  iSpec=gamResult$iSpec, analySpec=analySpec,
  base.yr.set = c(2004:2005), test.yr.set = c(2013:2014),
  doy.set = NA, alpha = 0.05)
```

---

gamPlotDisp

*Plot censored gam fits vs. time*


---

**Description**

Plot censored gam fits vs. time

**Usage**

```
gamPlotDisp(
  gamResult = gamResult,
  analySpec = analySpec,
```



```

fullModel = 2,
seasAvgModel = 2,
seasonalModel = 2,
diffType = "regular",
obserPlot = TRUE,
interventionPlot = TRUE,
seasAvgPlot = TRUE,
seasAvgConfIntPlot = TRUE,
seasAvgSigPlot = TRUE,
fullModelPlot = TRUE,
seasModelPlot = TRUE,
BaseCurrentMeanPlot = TRUE,
adjustedPlot = FALSE
)

```

### Arguments

gamResult	output from procedure gamTest
analySpec	analytical specifications
fullModel	GAM # for displaying full GAM (e.g., 0, 1, 2)
seasAvgModel	GAM # for displaying seasonally average GAM
seasonalModel	GAM # for displaying seasonal GAM
diffType	plot predicted baseline mean ('regular') or adjusted baseline mean ('adjusted')
obserPlot	logical field indicating whether to plot observations
interventionPlot	logical field indicating whether to plot interventions (e.g., method changes)
seasAvgPlot	logical field indicating whether to plot seasonal average GAM
seasAvgConfIntPlot	logical field indicating whether to plot confidence interval for seasonal average GAM
seasAvgSigPlot	logical field indicating whether to plot significant increasing and decreasing trends for seasonal average GAM
fullModelPlot	logical field indicating whether to plot full GAM
seasModelPlot	logical field indicating whether to plot seasonal GAM
BaseCurrentMeanPlot	logical field indicating whether to plot baseline and current mean
adjustedPlot	logical field indicating whether to plot adjusted model

---

gamPlotDispSeason      *Plot censored gam fits vs. time*

---

### Description

Plot censored gam fits vs. time

### Usage

```
gamPlotDispSeason(
  gamResult = gamResult,
  analySpec = analySpec,
  fullModel = 2,
  seasAvgModel = 2,
  seasonalModel = 2,
  diffType = "regular",
  obserPlot = TRUE,
  interventionPlot = TRUE,
  seasAvgPlot = TRUE,
  seasAvgConfIntPlot = TRUE,
  seasAvgSigPlot = TRUE,
  fullModelPlot = TRUE,
  seasModelPlot = TRUE,
  BaseCurrentMeanPlot = TRUE,
  adjustedPlot = FALSE,
  gamSeasonFocus = TRUE
)
```

### Arguments

gamResult	output from procedure gamTest
analySpec	analytical specifications
fullModel	GAM # for displaying full GAM (e.g., 0, 1, 2)
seasAvgModel	GAM # for displaying seasonally average GAM
seasonalModel	GAM # for displaying seasonal GAM
diffType	plot predicted baseline mean ('regular') or adjusted baseline mean ('adjusted')
obserPlot	logical field indicating whether to plot observations
interventionPlot	logical field indicating whether to plot interventions (e.g., method changes)
seasAvgPlot	logical field indicating whether to plot seasonal average GAM
seasAvgConfIntPlot	logical field indicating whether to plot confidence interval for seasonal average GAM

seasAvgSigPlot logical field indicating whether to plot significant increasing and decreasing trends for seasonal average GAM  
 fullModelPlot logical field indicating whether to plot full GAM  
 seasModelPlot logical field indicating whether to plot seasonal GAM  
 BaseCurrentMeanPlot logical field indicating whether to plot baseline and current mean  
 adjustedPlot logical field indicating whether to plot adjusted model  
 gamSeasonFocus logical field indicating whether to plot focus on season mean

### See Also

[gamPlotDisp](#)

### Examples

```

## Not run:
# Specify parameter and station to analyze
dep      <- 'do'
stat     <- 'CB5.4'
layer    <- 'B'

# Prepare data and set up specifications for analysis
dfr <- analysisOrganizeData (dataCensored)
df   <- dfr[[1]]
analySpec <- dfr[[2]]

# Apply gamTest
gamResult <- gamTest(df, dep, stat, layer, analySpec=analySpec)
gamPlotDisp(gamResult = gamResult, analySpec = analySpec,
            fullModel = 2, seasAvgModel = 2, seasonalModel = 2,
            diffType = "regular", obserPlot = TRUE, interventionPlot = TRUE,
            seasAvgPlot = TRUE, seasAvgConfIntPlot = FALSE,
            seasAvgSigPlot = FALSE, fullModelPlot = TRUE, seasModelPlot = TRUE,
            BaseCurrentMeanPlot = FALSE, adjustedPlot = FALSE)

# Apply gamTestSeason
gamResult2 <- gamTestSeason(df, dep, stat, layer, analySpec=analySpec,
                          gamSeasonPlot = c("7/15-8/15", "purple", "range"))
gamPlotDispSeason(gamResult = gamResult2, analySpec = analySpec,
                 fullModel = 2, seasAvgModel = 2, seasonalModel = 2,
                 diffType = "regular", obserPlot = TRUE, interventionPlot = TRUE,
                 seasAvgPlot = TRUE, seasAvgConfIntPlot = FALSE,
                 seasAvgSigPlot = FALSE, fullModelPlot = FALSE, seasModelPlot = FALSE,
                 BaseCurrentMeanPlot = TRUE, adjustedPlot = FALSE, gamSeasonFocus = TRUE)

## End(Not run)

```

gamTest

*Perform GAM analysis***Description**

Perform GAM analysis. Relies on `mgecv::gam` to perform general additive model. `gam` The baseDay function has been added to this package from the `smwrBase` package.

**Usage**

```
gamTest(
  df,
  dep,
  stat,
  layer = NA,
  analySpec,
  gamTable = TRUE,
  gamPlot = 10,
  gamDiffModel = NA,
  flow.detrended = NA,
  salinity.detrended = NA
)
```

**Arguments**

<code>df</code>	data frame
<code>dep</code>	dependent variable
<code>stat</code>	station
<code>layer</code>	layer
<code>analySpec</code>	analytical specifications
<code>gamTable</code>	gam table setting (set to FALSE to turn off table output)
<code>gamPlot</code>	gam plot setting (set to FALSE to turn off plotting)
<code>gamDiffModel</code>	GAM model(s) used for computing differences on sub-annual/multi-period basis
<code>flow.detrended</code>	data generated by <code>detrended.flow</code> . Default = NA.
<code>salinity.detrended</code>	data generated by <code>detrended.flow</code> . Default = NA.

**Details**

Set `gamPlot=FALSE` to turn off plotting. Computing the information ("predictions") to create plots is one of the more time consuming aspects of the `gamTest` function. Setting `gamPlot=FALSE` turns off these computations and speeds up `gamTest`. The disadvantage is that no predictions are returned; however, the tabularized results stored in `stat.gam.result` and, if requested, `chn.gam.result` are still returned.

Setting `gamPlot` to a value between 1-30 changes the resolution of the resulting figure by setting the interval on which the prediction data set is made. By default `gamPlot` is set to 10. That is, a prediction is made every 10th day, or about 36 predictions per year. Values closer to 1 result in larger returned prediction data sets and take more computation time. Values closer to 30 result in smaller returned data sets and take less computation time. Although there is no change in the fitted model, values closer to 30 may have slight degraded figure quality if there is substantial seasonality in the fitted model since the seasonal minimum and maximum might not be included in the prediction data set and therefore not plotted. Values greater than 30 are treated as 30. Setting `gamPlot=30` might be advantageous when the analysis only requires cursory figure examination.

Setting `gamTable=FALSE` will turn off table output to the console. This may be advantageous to reduce the amount of output. Since these computations do not significantly affect `gamTest` run time, the standard Analysis of Variance, GAM Parameter Coefficients, Diagnostics, and Estimates of Change tables are returned from `gamTest` regardless of the `gamTable` setting. Many of the values from these tables are also returned as part of tabularized `stat.gam.result`.

The default settings for `gamDiffModel` (i.e., `gamDiffModel=NA`) will not result in sub-annual (i.e., seasonal) differences being computed. In this default setting, the returned `chn.gam.result` that is returned from `gamTest` will be empty. If `gamDiffModel` is a value (i.e., not NA), then `chn.gam.result` will include one row for each combination of years specified in `analySpec$gamDiffPeriods`, seasons specified in `analySpec$gamDiffSeason`, and the number of models listed in `gamDiffModel`. For example `gamDiffModel=c(0, 1, 2)` would result in sub-annual being computed for `gam0`, `gam1`, and `gam2`.

**Flow and Salinity Adjustments (gam4).** It is necessary to create and pass properly formatted data via the `flow.detrended` and `salinity.detrended` arguments to evaluate `gam4` models. See [detrended.flow](#) and [detrended.salinity](#) for more information on how to create properly formatted data.

## Value

Returns a list with results

- **stat.gam.result** – Data frame with summary results in a tabular format suitable for output to a csv file
- **chn.gam.result** – Data frame with estimate of change for sub-annual differences based on the settings specified in `gamDiffModel`. Includes all data from `stat.gam.result` and sub-annual estimates of change in a tabular format suitable for output to a csv file.
- **data** – Data frame of data used in analysis (for example years with large proportion of censored data might be removed from the analysis and not included in this data frame)
- **data.all** – Data frame of all potential data available for analysis
- **iSpec** – List of baytrends analysis settings used for a specific analysis of station and parameter
- **gamOutput0** – Results including model predictions for gam formula 0 (i.e., `gam0`)
- **gamOutput1** – Results including model predictions for gam formula 1 (i.e., `gam1`)
- **gamOutput2** – Results including model predictions for gam formula 2 (i.e., `gam2`)
- **gamOutput3** – Results including model predictions for gam formula 3 (i.e., `gam3`)
- **gamOutput4** – Results including model predictions for gam formula 4 (i.e., `gam4`)
- **gamOutput5** – Results including model predictions for gam formula 5 (i.e., `gam5`)

- **gamOutput6** – Results including model predictions for gam formula 6 (i.e., gam6)

**gamOutput\*** – For each evaluated model, gamOutput\* (see above element list) is a list with the following elements:

- **gamOption** – gam formula ID, i.e., 0, 1, 2, 3, 4, 5, 6 corresponding to gam0, gam1, gam2, etc.
- **gamRslt** – mgcv::gam output
- **gamRsltSum** – "summary" of mgcv::gam, i.e., summary(mgcv::gam)
- **gamANOVAtbl** – GAM Analysis of Variance table
- **gamCoefftbl** – GAM Parameter Coefficients table
- **gamDiagnostics** – GAM Diagnostics table(AIC, RMSE, and Adj. R-squared)
- **perChange** – Estimates of Change table
- **porDiff.regular** – Estimate of change in list format
- **porDiff.adjusted** – Estimate of change adjusted for interventions in list format
- **predictions** – Data frame of gam predictions (all information used to create baytrends graphics excluding measurements)

## Examples

```
## Not run:
# Specify parameter and station to analyze
dep      <- 'do'
stat     <- 'CB5.4'
layer    <- 'B'

# Prepare data and set up specifications for analysis
dfr <- analysisOrganizeData (dataCensored)
df    <- dfr[[1]]
analySpec <- dfr[[2]]

# Apply gamTest
gamResult <- gamTest(df, dep, stat, layer, analySpec=analySpec)
gamPlotDisp(gamResult = gamResult, analySpec = analySpec,
            fullModel = 2, seasAvgModel = 2, seasonalModel = 2,
            diffType = "regular", obserPlot = TRUE, interventionPlot = TRUE,
            seasAvgPlot = TRUE, seasAvgConfIntPlot = FALSE,
            seasAvgSigPlot = FALSE, fullModelPlot = TRUE, seasModelPlot = TRUE,
            BaseCurrentMeanPlot = FALSE, adjustedPlot = FALSE)

# Apply gamTestSeason
gamResult2 <- gamTestSeason(df, dep, stat, layer, analySpec=analySpec,
                           gamSeasonPlot = c("7/15-8/15", "purple", "range"))
gamPlotDispSeason(gamResult = gamResult2, analySpec = analySpec,
                 fullModel = 2, seasAvgModel = 2, seasonalModel = 2,
                 diffType = "regular", obserPlot = TRUE, interventionPlot = TRUE,
                 seasAvgPlot = TRUE, seasAvgConfIntPlot = FALSE,
                 seasAvgSigPlot = FALSE, fullModelPlot = FALSE, seasModelPlot = FALSE,
                 BaseCurrentMeanPlot = TRUE, adjustedPlot = FALSE, gamSeasonFocus = TRUE)
```

```
## End(Not run)
```

---

gamTestSeason	<i>Perform GAM analysis for Specified Season</i>
---------------	--

---

### Description

Perform GAM analysis for Specified Season. Relies on `mgev::gam` to perform general additive model.

### Usage

```
gamTestSeason(
  df,
  dep,
  stat,
  layer = NA,
  analySpec,
  gamTable = TRUE,
  gamPlot = 10,
  gamDiffModel = c(2),
  flow.detrended = NA,
  salinity.detrended = NA,
  gamSeasonPlot = c("7/1-9/30", "purple", "range")
)
```

### Arguments

<code>df</code>	data frame
<code>dep</code>	dependent variable
<code>stat</code>	station
<code>layer</code>	layer
<code>analySpec</code>	analytical specifications
<code>gamTable</code>	gam table setting (set to FALSE to turn off table output)
<code>gamPlot</code>	gam plot setting (set to FALSE to turn off plotting)
<code>gamDiffModel</code>	GAM model(s) used for computing differences on sub-annual/multi-period basis
<code>flow.detrended</code>	data generated by <code>detrended.flow</code> . Default = NA.
<code>salinity.detrended</code>	data generated by <code>detrended.flow</code> . Default = NA.
<code>gamSeasonPlot</code>	Character vector for evaluating and displaying seasonal model (see details for further information).

## Details

gamSeasonPlot is an additional argument (relative to the arguments used in the gamTest function) that is used to target a specific season for the focus of output and can be a 2- or 3-element vector. While the GAM is fit to all data as in the function gamTest, the output figure will only show the model corresponding to the gamSeasonPlot specifications. The first element of gamSeasonPlot can be a single date (e.g., '8/28') or a date range (e.g., '7/1-9/30'). The second element specifies the color of the line to be plotted. If a date range is specified as the first element and an optional third element is provided as 'range', then the plot will show the season minimum and maximum as well as the mean; otherwise, only the mean is plotted. If the first element of gamSeasonPlot is a single date then observations within a +/- 15-day window of the date are plotted; otherwise, only observations within the date range are plotted. Estimates of difference are computed with baytrends::gamDiff by setting the argument doy.set to either the single date provided from gamSeasonPlot or the same doys used to compute the season mean. The option to specify seasons that "wrap" around end of year, i.e., 12/1-1/30, has not been implemented.

## Value

Returns a list with results

## See Also

[gamTest](#)

## Examples

```
## Not run:
# Specify parameter and station to analyze
dep      <- 'do'
stat     <- 'CB5.4'
layer    <- 'B'

# Prepare data and set up specifications for analysis
dfr <- analysisOrganizeData (dataCensored)
df   <- dfr[[1]]
analySpec <- dfr[[2]]

# Apply gamTest
gamResult <- gamTest(df, dep, stat, layer, analySpec=analySpec)
gamPlotDisp(gamResult = gamResult, analySpec = analySpec,
            fullModel = 2, seasAvgModel = 2, seasonalModel = 2,
            diffType = "regular", obserPlot = TRUE, interventionPlot = TRUE,
            seasAvgPlot = TRUE, seasAvgConfIntPlot = FALSE,
            seasAvgSigPlot = FALSE, fullModelPlot = TRUE, seasModelPlot = TRUE,
            BaseCurrentMeanPlot = FALSE, adjustedPlot = FALSE)

# Apply gamTestSeason
gamResult2 <- gamTestSeason(df, dep, stat, layer, analySpec=analySpec,
                           gamSeasonPlot = c("7/15-8/15", "purple", "range"))
gamPlotDispSeason(gamResult = gamResult2, analySpec = analySpec,
                  fullModel = 2, seasAvgModel = 2, seasonalModel = 2,
                  diffType = "regular", obserPlot = TRUE, interventionPlot = TRUE,
```



```
seasAvgPlot = TRUE, seasAvgConfIntPlot = FALSE,  
seasAvgSigPlot = FALSE, fullModelPlot = FALSE, seasModelPlot = FALSE,  
BaseCurrentMeanPlot = TRUE, adjustedPlot = FALSE, gamSeasonFocus = TRUE)  
  
## End(Not run)
```

---

impute	<i>Impute Censored Values</i>
--------	-------------------------------

---

## Description

Impute value for multiply censored data.

## Usage

```
impute(x, imputeOption = "mid")
```

## Arguments

x	vector of type baytrends::qw
imputeOption	imputation method [default= "mid"], valid impute options are "lower", "upper", "mid", "norm", "lnorm"

## Details

The imputeOption values of lower, upper and mid impute the lower limit, upper limit, and midpoint between the lower and upper limit. In the context of typical water quality data, these options would be equivalent to zero, detection limit and 1/2 detection limit substitution. Options for substituting the normal ["norm"] or lognormal ["lnorm"] expectation can also be used.

## Value

vector where x is transformed into a simple numeric variable

## Examples

```
x <- dataCensored[1:20,"tdp"]  
x.lower <- impute(x,'lower')  
x.mid <- impute(x,'mid')  
x.upper <- impute(x,'upper')  
x.norm <- impute(x,'norm')  
x.lnorm <- impute(x,'lnorm')
```

---

layerLukup	<i>Layer List</i>
------------	-------------------

---

**Description**

A lookup table of layer abbreviations and the corresponding names.

**Usage**

```
layerLukup
```

**Format**

A data frame with 10 rows and 3 variables:

**layers** Layer codes

**order** Analysis order

**name** Layer name

---

loadData	<i>Load/Clean CSV and TXT Data File</i>
----------	---

---

**Description**

Load and clean comma delimited (\*.csv) or tab delimited (\*.txt) file and perform some rudimentary data cleaning.

**Usage**

```
loadData(  
  file = NA,  
  folder = NA,  
  pk = NA,  
  remDup = TRUE,  
  remNAcol = TRUE,  
  remNArow = TRUE,  
  convDates = TRUE,  
  tzSel = "America/New_York",  
  commChar = "#",  
  naChar = NA  
)
```

**Arguments**

file	file (can use wildcards, e.g., "*.csv")
folder	folder (i.e., directory to look in, can use relative path )
pk	vector of columns that form the primary key for data set
remDup	logical field indicating whether duplicate rows are deleted
remNAcol	logical field indicating whether columns with all NA are deleted
remNArow	logical field indicating whether rows with all NA are deleted
convDates	vector or logical field indicating whether date-like columns should be converted to POSIXct format (see details)
tzSel	time zone to use for date conversions (default: "America/New_York")
commChar	character for comment line to be skipped
naChar	characters to treat as NA

**Details**

This function reads in a single comma delimited (\*.csv) or tab delimited (\*.txt) file using either `utils::read.table` or `utils::read.csv` based on the file extension. The user can use the wildcard feature for the file argument (e.g., `file='*.csv'`) and the function will identify the most recently modified csv or txt file in the folder for importing.

Some specific features of this function include the following:

1. Leading '0's in character strings that would otherwise be trimmed and treated as numeric variables (e.g., USGS flow gages, state and county FIPS codes) are preserved. To effectively use this functionality, data maintained in a spreadsheet would be enclosed in quotes (e.g., "01578310"). When exported to csv or txt files the field would be in triple quotes (e.g., ""01578310"""). Any column read in as integer is converted to numeric.
2. Rows and columns with no data (i.e., all NA) are deleted unless default settings for `remNAcol` and `remNArow` are changed to `FALSE`.
3. Completely duplicate rows are deleted unless default setting for `remDup` is changed to `FALSE`.
4. Rows beginning with '#' are skipped unless `commChar` set to ""
5. If a primary key (either single or multiple columns) is selected, the function enforces the primary key by deleting duplicate entries based on the primary key. Columns corresponding to the primary key (when specified) are moved to the first columns.
6. If `convDates` is a vector (i.e., `c('beginDate', 'endDate')`), then a date conversion is attempted for the corresponding columns found in the input file. If `TRUE`, then a date conversion is attempted for all columns found in the input file with 'date' in the name, If `FALSE`, no date conversion is attempted.

Some other common time zones include the following: `America/New_York`, `America/Chicago`, `America/Denver`, `America/Los_Angeles`, `America/Anchorage`, `America/Honolulu`, `America/Jamaica`, `America/Managua`, `America/Phoenix`, `America/Metlakatla`

A brief table reporting the results of the import are printed.

Note that columns containing just F, T, `FALSE`, `TRUE` are stored as logical fields

**Value**

Returns data frame

---

loadExcel	<i>Load/Clean Excel sheet</i>
-----------	-------------------------------

---

**Description**

Load and clean one sheet from an Excel file

**Usage**

```
loadExcel(
  folder = NA,
  file = NA,
  sheet = 1,
  pk = NA,
  remDup = TRUE,
  remNAcol = TRUE,
  remNArow = TRUE,
  convDates = TRUE,
  tzSel = "America/New_York"
)
```

**Arguments**

folder	folder (i.e., directory to look in, can use relative path )
file	file (can use wildcards, e.g., "*.csv")
sheet	worksheet name to load from Excel file
pk	vector of columns that form the primary key for data set
remDup	logical field indicating whether duplicate rows are deleted
remNAcol	logical field indicating whether columns with all NA are deleted
remNArow	logical field indicating whether rows with all NA are deleted
convDates	vector or logical field indicating whether date-like columns should be converted to POSIXct format (see details)
tzSel	time zone to use for date conversions (default: "America/New_York")

**Details**

This function reads in a single sheet from an Excel file using `readxl::read_excel` to load the data

After reading data in with `readxl::read_excel`, some specific additional steps are implemented:

1. Double quotes are removed from beginning and ending of all fields. The purpose is to maintain leading zeroes (e.g., USGS flow gages). To effectively use this functionality, data maintained in a spreadsheet would be enclosed in quotes (e.g., "01578310"). If exported to csv or txt files the field

would be in triple quotes (e.g., ""01578310"""). Any column read in as integer is converted to numeric.

2. Rows and columns with no data (i.e., all NA) are deleted unless default settings for remNAcol and remNArow are changed to FALSE.

3. Completely duplicate rows are deleted unless default setting for remDup is changed to FALSE.

4. If a primary key (either single or multiple columns) is selected, the function enforces the primary key by deleting duplicate entries based on the primary key. Columns corresponding to the primary key (when specified) are moved to the first columns.

5. If convDates is a vector (i.e., c('beginDate', 'endDate')), then a date conversion is attempted for the corresponding columns found in the input file. If TRUE, then a date conversion is attempted for all columns found in the input file with 'date' in the name, If FALSE, no date conversion is attempted.

Some other common time zones include the following: America/New\_York, America/Chicago, America/Denver, America/Los\_Angeles, America/Anchorage, America/Honolulu, America/Jamaica, America/Managua, America/Phoenix, America/Metlakatla

A brief table reporting the results of the import are printed.

Note that columns containing just F, T, FALSE, TRUE are stored as logical fields

## Value

Returns data frame

---

loadModels	<i>Load Built-in GAM formulas</i>
------------	-----------------------------------

---

## Description

Returns built-in GAM formulas

## Usage

```
loadModels(gamSelect = "gam4")
```

## Arguments

gamSelect	character vector of models (Current options include gam0, gam1, gam2, gam3, gam4, gam5)
-----------	---

## Details

By default, the function analysisOrganizeData will store the formulas for gam0-gam4 in the variable analySpec\$gamModels as a list. The user can customize this list with the function loadModels (see example).

**Value**

Returns a list with GAM formulas

**Examples**

```
# run analysisOrganizeData function to create the list analySpec
dfr <- analysisOrganizeData (dataCensored, report=NA)
df      <- dfr[["df"]]
analySpec <- dfr[["analySpec"]]

# current models in analySpec
analySpec$gamModels

# set models in analySpec to gam0, gam1, and gam2 only
analySpec$gamModels <- loadModels(c('gam0','gam1','gam2'))
```

---

loadModelsResid	<i>Load Built-in GAM formulas for calculating residuals</i>
-----------------	---

---

**Description**

Load Built-in GAM formulas for calculating residuals

**Usage**

```
loadModelsResid(gamSelect = "doy_flw_sal")
```

**Arguments**

gamSelect      character vector of models (Current options include 'doy', 'doy\_flw\_sal', 'doy\_flw\_sal\_int')

**Value**

Returns a list with GAM formulas

---

parameterList	<i>Parameter List</i>
---------------	-----------------------

---

**Description**

A lookup table of water quality parameters

**Usage**

```
parameterList
```

**Format**

A data frame with 82 rows and 13 variables:

**parm** "preferred" parameter ID

**parmSource** parmamter field as may be found in sample data sets

**parmCat** Parameter Group Header

**parmName** Full parameter name

**parmCalc** indicator if parameter is calculated

**parmNameLc** parameter name in lower case

**parmUnits** units

**parmRecensor** numerical value used in log plots if data are reported as  $\leq 0$

**parmRO1** Parameter sort order level 1

**parmRO2** Parameter sort order level 2

**parmTrend** TRUE/FALSE for whether parameter should be analyzed for trend

**logTrans** TRUE/FALSE for whether parameter should be analyzed in log transposed

**trendIncrease** Should an increase in concentration be interpreted as 'improving', 'degrading', 'increasing', or 'decreasing'

---

pcodeColData

*Selected USGS parameter Codes*

---

**Description**

Selected U.S. Geological Survey (USGS) parameter codes to create column names and data type conversion when importing data from NWISweb.

From swmrQW

**Usage**

pcodeColData

**Format**

Data frame with 1178 rows and 3 columns

Name	Type	Description
parm_cd	character	The 5-digit parameter code
col_name	character	The column name to use when importing data from NWISweb
data_type	character	The data type to convert the imported data

**Note**

This data set can be copied and modified by the user to add or change column names. The `data_type` must be either "qw" or "numeric" any other value will be ignored.

**References**

Lorenz, D.L., 2016, smwrQW—An R Package for Managing and Analyzing Water-Quality Data, Version 0.7.3

**Examples**

```
data(pcodeColData)
# just print some rows
head(pcodeColData)
tail(pcodeColData)
```

---

Q05078470

*Daily Streamflow*


---

**Description**

Daily mean flow for Judicial Ditch 64 near Mentor, Minnesota (SW4), USGS station number 05078470 for calendar year 2003.

From smwrData.

**Usage**

Q05078470

**Format**

Data frame with 365 rows and 2 columns

Name	Type	Description
DATES	Date	Day
FLOW	numeric	Daily mean streamflow

Note: the daily mean streamflow rates are in cubic feet per second.

**Source**

Data retrieved from NWISWeb (<https://nwis.waterdata.usgs.gov/mn/nwis/sw>) on 2005-01-05.



**Examples**

```
data(Q05078470)
# Plot the data for station 05078470
with(Q05078470, plot(DATES, FLOW, type='l'))
```

---

qw.export

*qw.export*


---

**Description**

Export the contents of a QW object to comma delimited file (csv).

**Usage**

```
qw.export(df.qw, dir.output = getwd(), fn.output = NULL)
```

**Arguments**

df.qw	Data frame with qw fields to be exported.
dir.output	Directory where output files will be saved. Default is working directory.
fn.output	Name of output file.

**Details**

This internal function will export each qw field of a given data frame to separate columns in a single comma separated file (csv). The left header information will be used "as is" but the data fields will be named with the qw column name and the qw slot names .Data.values, .Data.value2, and remark.codes (e.g., secchi..Data.values). These slots names will be renamed \_lo, \_hi, \_symbol (e.g., secchi\_lo). The remaining qw slot values will not be exported.

The exported file will be in a directory specified by the user (defaults to working directory). The file will be named as specified by the user.

**Value**

Returns a user named tab delimited files to the user defined directory with all of the qw slot data.

**Examples**

```
## Not run:
# define data frame with qw column classes
myDF <- dataCensored

# directory to save output
dir.save <- getwd()

# prefix for file names ()
fn.out <- "data_censored_test.csv"
```

```
# run function
qw.export(myDF, dir.save, fn.out)

## End(Not run)
```

---

qw.import

*qw.import*

---

## Description

Import the contents of tab delimited text files to a QW object.

## Usage

```
qw.import(fn.import, qw.names, rounding = c(3, 4))
```

## Arguments

fn.import	Filename (with path) containing data. Comma separated (CSV) format only.
qw.names	Names of parameters for QW columns.
rounding	OPTIONAL. Rounding values for QW columns. Default is c(3,4) but can be changed.

## Details

This internal function will import data from a comma delimited (CSV) file to create a data frame with columns of the qw class.

Only three slots are recognized by this function; ".Data" and "remark.codes" The slot name ".Data" includes ".Data.values" and ".Data.value2".

These three slots are marked as "\_lo", "\_hi", and "\_symbol" in the import file the prefix of the parameter name to be used in the qw object; e.g., secchi\_lo, secchi\_hi, and secchi\_symbol.

To view all qw slot names use the command slotNames("qw").

The function returns a data frame with QW enabled columns. The user must save the file. Any modification of column classes needs to be handled by the user (e.g., character to date or POSIXct).

## Value

Returns a QW enabled data frame.

## Examples

```
## Not run:
# Use internal function to export dataCensored as example for import
qw.export(dataCensored, getwd(), "data_censored_test.csv")

# Import Test file as a qw object

# Define function parameters
fn.import <- file.path(".", "data_censored_test.csv")
qw.names <- c("secchi", "chla", "do", "tn", "tp", "po4", "tdp"
             , "no23", "nh4", "tdn", "tss")
rounding <- c(3, 4)

# Import
dataCensored.test<- qw.import(fn.import, qw.names, rounding)

# Check for qw class
str(dataCensored.test)

# Save
save(dataCensored.test, file="data_censored_test.rda")

# Show slot names for a qw object.
slotNames("qw")

####
# convert date field to POSIXct
#dataCensored.test[,"date"] <- as.POSIXct(dataCensored.test[,"date"])
# str(dataCensored.test)
# as.numeric() and as.integer() can be used to convert columns of those types.

## End(Not run)
```

---

QW05078470

*Stream Water Quality*

---

## Description

Selected water-quality data for Judicial Ditch 64 near Mentor, Minnesota (SW4), USGS station number 05078470 for calendar year 2003.

## Usage

QW05078470

**Format**

Data frame with 11 rows and 4 columns

Name	Type	Description
DATES	Date	Sample date
TIMES	character	Sample time
R00665	character	Remark code for total phosphorus concentration
P00665	numeric	Total phosphorus concentration

Note: all concentrations are in milligrams per liter as phosphorus.

### Source

Data retrieved from NWISWeb (<https://nwis.waterdata.usgs.gov/mn/nwis/qw>) on 2005-01-05.

### Examples

```
data(QW05078470)
# Plot the data
with(QW05078470, plot(DATES, P00665, log='y'))
```

---

QWstacked

*Stream Water Quality*

---

### Description

Selected water-quality data for Judicial Ditch 64 near Mentor, Minnesota (SW4), USGS station number 05078470 for calendar year 2003.

From smwrData.

### Usage

QWstacked

### Format

Data frame with 46 rows and 22 columns

Name	Type	Description
agency_cd	character	Agency code
site_no	character	USGS station number
sample_dt	Date	Sample date

sample_tm	character	Sample time
sample_end_dt	Date	Sample end date
sample_end_tm	character	Sample end time
sample_start_time_datum_cd	character	Time zone datum
tm_datum_rlby_cd	character	Time datum reliability code
coll_ent_cd	character	Collecting agency code
medium_cd	character	Sample medium code
tu_id	character	Taxonomic unit code
body_part_id	character	Body part code
parm_cd	character	Analyte parameter code
remark_cd	character	Remark code for the result
result_va	character	Numeric value of the result
val_qual_tx	character	Result value qualifier code
meth_cd	character	Lab method code
dqi_cd	character	Data-quality indicator code
rpt_lev_va	character	Reporting level
rpt_lev_cd	character	Reporting level type
lab_std_va	character	Lab standard deviation
anl_ent_cd	character	Analyzing agency code

Note: all concentrations in the column result\_va are in milligrams per liter as phosphorus.

### Source

Data retrieved from NWISWeb (<https://nwis.waterdata.usgs.gov/mn/nwis/qwdata>) on 2012-04-06. The format of water-quality data is often retrieved by result—each row represents the data for a single analyte. Note that many columns are part of the generic data retrieval and do not pertain specifically to these data.

### Examples

```
data(QWstacked)
# Plot the data for whole-water phosphorus
with(subset(QWstacked, parm_cd == "00665"), plot(sample_dt, result_va))
# Overlay the data for dissolved phosphorus (should be smaller values)
with(subset(QWstacked, parm_cd == "00666"), points(sample_dt, result_va, col='red'))
```

---

rbindQW

*Combine Data by Rows*


---

### Description

Combines a sequence of data frame arguments and combine by rows. This is a specialized version of rbind that works for data frames that contain columns of class "qw."

**Usage**

```
rbindQW(...)
```

**Arguments**

... any number of data frames with identical columns. The missing value NA is permitted as a special case to allow the addition of missing values.

**Value**

A data frame with all columns combined in the order specified in ...

**See Also**

[rbind](#)

---

sal	<i>Salinity data</i>
-----	----------------------

---

**Description**

Salinity data, 1984 to 2016, for 8 stations.

**Usage**

```
sal
```

**Format**

A data frame with 51,092 rows and 4 variables:

**station** CBP Station ID

**date** date, YYYY-MM-DD

**layer** sample layer

**salinity** Measured salinity

---

`saveDF`*Save R object to disk*

---

**Description**

Saves R object to disk using csv and/or Rdata format.

**Usage**

```
saveDF(  
  rObj,  
  note = NULL,  
  rData = FALSE,  
  csv = TRUE,  
  attr = FALSE,  
  timeStamp = TRUE,  
  folder = "_save_df"  
)
```

**Arguments**

<code>rObj</code>	Name of R object to save.
<code>note</code>	Suffix to include in file name.
<code>rData</code>	Logical field to save <code>rObj</code> as an <code>rData</code> file (FALSE [default]).
<code>csv</code>	Logical field to save <code>rObj</code> as an a <code>csv</code> file (TRUE [default]).
<code>attr</code>	Logical field to save data frame attributes as a text file (FALSE [default]).
<code>timeStamp</code>	Logical field to include date/time stamp in file name (TRUE [default]).
<code>folder</code>	Subdirectory for saving file ('_save_df' is default)

**Details**

Output files are saved with an "rObj\_note\_YYYY\_MM\_DD\_HHMMSS" naming convention. By default, files are saved as `csv` files to a `'_save_df'` subdirectory relative to the working directory and include a time stamp in the file name using `utils::write.csv`. The default folder can be changed with the `folder` argument. Inclusion of a time stamp in the file name enables saving the same object at multiple steps through an R script, but can be turned off with the `timeStamp` argument. To also save object as `rData` file, set `rData=TRUE`.

**Value**

Nothing returned. Saves R object to disk using `csv` and/or `Rdata` format.



**Examples**

```
## Not run:  
df <- data.frame(x=c(1:100))  
saveDF(df, 'test_note')  
  
## End(Not run)
```

---

selectData	<i>Select data for analysis from a larger data frame</i>
------------	--

---

**Description**

Select data for analysis from a larger data frame based on dependent variable, station, and layer. Removing records with missing values, performing log-transformations, and adding a centering date are performed based on settings.

**Usage**

```
selectData(  
  df,  
  dep,  
  stat,  
  layer = NA,  
  transform = TRUE,  
  remMiss = TRUE,  
  analySpec  
)
```

**Arguments**

df	data frame
dep	dependent variable
stat	station
layer	layer (optional)
transform	logical field to return log-transformed value (TRUE [default])
remMiss	logical field to remove records where dependent variable, dep, is a missing value (TRUE [default])
analySpec	analytical specifications

## Details

The returned data frame will include `dyear` and `cyear`. `dyear` is the decimal year computed using `smwrBase::baseDay2decimal` and `smwrBase::baseDay`. From this, the minimum and maximum 'dyear' are averaged. This averaged value, `centerYear`, is used to compute the centering date, `cyear`, using `cyear = dyear - centerYear`.

The variable identified by `dep` is copied to the variable name `dep+".orig"` (e.g., `chla.orig`) allowing the user to track the original concentrations. A new column, `recensor`, is added. The value of `recensor` is `FALSE` unless the value of `dep.orig` was  $\leq 0$ . In the cases where `dep.orig` is  $\leq 0$ , `recensor` is set to `TRUE` and the value of `dep` is set to "less-than" a small positive value which is stored as `iSpec$recensor`. If `transform=TRUE`, the returned data frame will also include a variable `"ln"+dep` (i.e., `"lnchla"` for log transformed `chla`).

The data frame will include a column, `intervention`, which is a factor identifying different periods of record such as when different laboratory methods were used and is based on the data frame `methodsList` that is loaded into the global environment. This column is set to "A" with only 1 level if the data frame `methodsList` has not been loaded into the global environment.

The data frame will include a column, `lowCensor`, to indicate whether the data record occurs in a year with a low level of censoring over that particular year. The function `gamTest` uses this column to identify years of record (i.e., when `lowCensor==FALSE`) that should not be used in analyses.

If `remMiss=TRUE`, then the returned data frame will be down selected by removing records where the variable identified in 'dep' is missing; otherwise, no down selection is performed.

`iSpec` contains a large list of information

`dep` - name of column where dependent variable is stored, could be `"ln"+dep` for variables that will be analyzed after natural log transformation

`depOrig` - name of original dependent variable, could be same as `dep` if no transformation is used

`stat` - name of station

`stationMethodGroup` - name of station group that the station belongs to, derived from station list (`stationMasterList`) and used to identify interventions specified in `methodsList` table

`intervenNum` - number of interventions found for this station and dependent variable as derived from `methodsList` table, a value of 1 is assigned if no `methodsList` entry is found

`intervenList` - data frame of interventions identified by beginning and ending date and labeled consecutively starting with "A"

`layer` - layer

`layerName` - layer name derived from `layerLukup`

`transform` - `TRUE/FALSE` indicating whether log transformations were taken

`trendIncrease` - an indicator for interpretation of an increasing concentration

`logConst` - not currently used

`recensor` - small value that observations  $\leq 0$  are recensored to as "less than" the small value

`censorFrac` - data frame indicating the yearly number of observations and fraction of observations reported as less than, uncensored, interval censored, less than zero, and recensored; also includes a 'lowCensor' field indicating which years will be dropped by `gamTest` due to high yearly censoring

`yearRangeDropped` - year range of data that will be dropped due to censoring

`censorFracSum` - censoring overall summary

centerYear - centering year  
 parmName - parameter name  
 parmNameLc - parameter name in lower case  
 parmUnits - parameter units  
 statLayer - station/layer label, e.g., "LE3.1 (S)"  
 usgsGageID - USGS gage used for flow adjustments  
 usgsGageName - USGS gage used for flow adjustments  
 numObservations - number of observations  
 dyearBegin - begin date in decimal form  
 dyearEnd - end date in decimal form  
 dyearLength - period of record length  
 yearBegin - period of record begin year  
 yearend - period of record end year  
 dateBegin - begin date  
 dateEnd - end date

The baseDay and baseDay2decimal functions have been added to this package from the smwrBase package.

### Value

A nest list is returned. The first element of the nest list is the down-selected data frame. The second element is the list, iSpec, contains specifications for data extraction. See examples for usage and details for further discussion of the data processing and components of each element.

---

stationMasterList	<i>Chesapeake Bay Program long-term tidal monitoring stations</i>
-------------------	---

---

### Description

Chesapeake Bay Program long-term tidal monitoring stations

### Usage

```
stationMasterList
```

### Format

A data frame with 145 rows and 19 variables:

**station** Water quality station code

**state** State location

**locationType** As identified in the state trend reports, whether this station is in the mainstem or tributary monitoring

- waterbody** Location as identified in the CBP CIMS database
- latitude** From the CBP CIMS database, and verified in a GIS map
- longitude** From the CBP CIMS database, and verified in a GIS map
- cbSeg92** Match to CB 92 Segmentation scheme (for 303d list)
- usgsGageName** Manual match to a USGS fall-line monitoring station (See usgsGages\$siteName)
- usgsGageID** USGS station code (See usgsGages\$siteNumber)
- usgsGageMatch** Identifies how the USGS-to-TribStation match was made. Direct: If the station falls within a tributary with a USGS station, or in the mainstem. Indirect: If the station is in a small sub-tributary of one of the major tributaries. The USGS station may not be that representative, but it is better than matching to the Susquehanna. SusDefault: If there was no clear match, the tidal station was matched to the Susquehanna River.
- stationRO1** Station sort order level 1
- stationRO2** Station sort order level 2
- stationGrpName** Station group header
- stationMethodGroup** Foreign key to methodsList table
- hydroTerm** "flow" or "salinity" to indicate whether to model flow or salinity effects (if missing, "flow" assumed)
- flwAvgWin** list of averaging windows if flow is selected in hydroTerm (options are: 1, 5, 10, 15, 20, 30, 40, 50, 60, 90, 120, 150, 180, 210)
- flwParms** list of parameters to model with flow (regardless of hydroTerm value), each parameter separated by a space
- salParms** list of parameters to model with salinity (regardless of hydroTerm value), each parameter separated by a space
- notes** Optional note to track updates

---

 usgsGages

*USGS Gages*


---

### Description

List of core USGS gages for CBP trend analyses

### Usage

usgsGages

### Format

A data frame with 9 rows and 2 variables:

**usgsGageID** USGS Gage ID

**siteName** USGS Site Name

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