Streamflow data analysis with *fasstr* : : CHEAT SHEET

Getting Started

fasstr, Flow Analysis Summary Statistics Tool for R, is a package for cleaning, summarizing, performing hydrologic analyses, and visualizing daily streamflow data.

Install **fasstr** using the following code:

```
remotes::install_github('bcgov/fasstr')
```

To use the **station_number** argument, a HYDAT database must be downloaded using:

```
tidyhydat::download_hydat()
```

Function Usage

fasstr functions can be generally categorized into the following groups:

- **Cleaning** - preparing data for analyses; add_* and fill_* functions.
- **Screening** - to look for outliers and missing data; screen_* functions.
- **Calculating summary statistics** - long-term, annual, monthly and daily statistics; calc_* functions.
- **Visualizing summary statistics** - plotting the various statistics; plot_* functions.
- **Computing** analyses - volume frequency analyses and trending; compute_* functions.
- **Writing** data and plots - to save your data and plots; write_* functions.

Getting Data

There are two argument options in most functions to choose a data source:

1. **data** Data frame of daily data with dates (YYYY-MM-DD), flow values, and optional groupings. 'data' is the first argument listed to allow for piping (%>%). Arguments for selecting columns in **data** data frame:
   - **dates** Dates column, default 'Date'.
   - **values** Flow values column, default 'Value'.
   - **groups** Groupings columns (optional), default 'STATION_NUMBER'.
2. **station_number** Extracts daily data from a HYDAT database using a vector of HYDAT station numbers (ex. '08NM116' or c('08NM116', '08FA002')); downloaded HYDAT required.

Example data with default column names:

STATION_NUMBER	Date	Value
08NM116	1987-04-06	6.230
08NM116	1987-04-07	6.440

Function Outputs

All outputs from are one, or lists, of the following:

- All **data tables /** data frames produced as **tibbles**.
- All **plots** are produced as lists of **ggplot2** objects.

Data Cleaning

These functions add rows and columns to daily streamflow data frames to prepare for custom analyses.

fill_missing_dates()
Fill dates with missing flow values with NA.

add_date_variables(water_year=FALSE**)**
Add 'Year', 'Month', 'MonthName' and 'DayofYear' columns. If water_year = TRUE also adds 'WaterYear' and 'WaterDayofYear' columns.

add_seasons(seasons_length**)**
Adds column of season identifiers called 'Season' with the length of seasons in months chosen with seasons_length argument, seasons start in first month of year.

add_rolling_means(roll_days, roll_align**)**
Add columns of rolling daily flow means (ex. 7-day means).

add_basin_area(basin_area**)**
Add a basin area column, in square kilometres. See basin_area argument on reverse of cheat sheet.

add_daily_volume()
Add daily volumetric flows, converted from daily mean to cubic metres.

add_daily_yield(basin_area**)**
Add daily yields, converted from daily mean to millimetres based on upstream basin area.

add_cumulative_volume()
Add daily cumulative volumetric flows on an annual basis, in cubic metres.

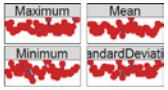
add_cumulative_yield()
Add daily cumulative runoff yield flows on an annual basis, in millimetres based on upstream basin area.

Data Screening

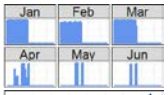
These functions calculate and plot statistics to screen data for outliers, gaps, and missing dates.

screen_flow_data()
Calculate annual mean, maximum, minimum, standard deviation, and missing dates.

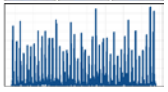
plot_data_screening()
Plot annual mean, maximum, minimum, and standard deviation.



plot_missing_dates()
Plot the number of missing dates for each month and year.



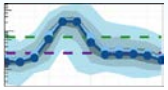
plot_flow_data(plot_by_year = FALSE, one_plot = TRUE**)**
Plot the daily mean data set.



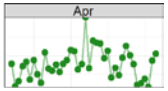
Basic Summary Statistics

These functions calculate and plot the mean, median, maximum, minimum, and selected percentiles using the 'percentiles' argument. Can select duration of statistics (ex. 7-day) using 'roll_days' and 'roll_align' arguments.

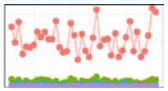
calc_longterm_stats()
plot_longterm_stats()
Statistics for all data and for each month over all years.



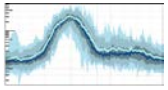
calc_monthly_stats()
plot_monthly_stats()
Statistics for each month of each year.



calc_annual_stats()
plot_annual_stats()
Statistics for each year.



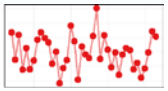
calc_daily_stats()
plot_daily_stats(include_year= NULL**)**
Statistics for each day of the year over all years.



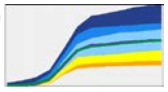
Cumulative Statistics

These functions calculate and plot the total flows for years by volume (m^3) or by area-based yield (mm) using the 'use_yield' and 'basin_area' area arguments.

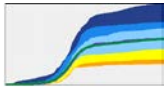
calc_annual_cumulative_stats(include_seasons = TRUE**)**
plot_annual_cumulative_stats(include_seasons = TRUE**)**
Total annual cumulative discharge for each year (option to include seasonal totals).



calc_monthly_cumulative_stats()
plot_monthly_cumulative_stats(include_year = NULL**)**
Cumulative monthly statistics for each month over all years.



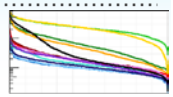
calc_daily_cumulative_stats()
plot_daily_cumulative_stats(include_year = NULL**)**
Cumulative daily statistics for each day of year over all years



Long-term Statistics

These functions calculate and plot various long-term statistics outside of the basic summary statistics.

plot_flow_duration()
Plot flow durations curves for each month and annually over all years.



calc_longterm_mad(percent_MAD = NULL**)**
Calculate the mean discharge over all years with options to include percentages of the long-term mean.

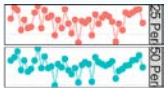
calc_longterm_percentile(percentiles = NULL**)**
Calculate percentile flow values over all years.

calc_flow_percentile(flow_value = NULL**)**
Calculate the percentile rank of a specific flow value from flows over all years.

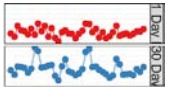
Annual Statistics

These functions calculate and plot various annual statistics beyond the basic summary statistics.

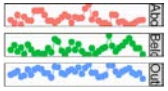
calc_annual_flow_timing(percent_total = c(25,33.3,25,75)**)**
plot_annual_flow_timing(percent_total = c(25,33.3,25,75)**)**
Calculate the day of year when portions of total annual flows have occurred (ex timing of half flows).



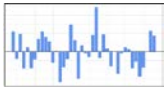
calc_annual_lowflows(roll_days = c(1,3,7,30)**)**
plot_annual_lowflows(roll_days = c(1,3,7,30)**)**
Calculate the values and day of occurrence for annual minimum flow values. Multiple 'roll_days' allowed.



calc_annual_outside_normal(normal_percentiles = c(25,75)**)**
plot_annual_outside_normal(normal_percentiles = c(25,75)**)**
Calculate the number of days per year that occur above or below "normal", "normal" period based on values provided.



plot_annual_means()
Plot annual mean flows with the x-axis centred on the long-term mean



calc_all_annual_stats(annual_percentiles = c(10,90), monthly_percentiles = c(10,20), stats_days = 1, lowflow_days = c(1,3,7,30), timing_percent = c(25,33.3,50,75), normal_percentiles = c(25,75)**)**
Calculate all statistics from all calc_annual_* and calc_monthly_stats() functions.

Arguments and Options

These arguments are used to customize many of the functions. Not all are listed; see function documentation for more specific argument information.

Date Filtering and Options

ignore_missing Logical value indicating whether dates with missing values should be included in the analysis. If TRUE then a statistic will be calculated regardless of missing dates. If FALSE then only statistics with no missing dates will be returned. Default FALSE.

water_year Logical value indicating use of water years to filter/group data instead of calendar years; designated by calendar year in which year ends. Default FALSE.

water_year_start Numeric value indicating the first month of water year; default 10 if water_year = TRUE.

start_years and **end_years** Numeric values of the first and last year to consider for analysis. Leave blank to include all years of data provided.

exclude_years Numeric vector of years to exclude from analysis; ex. c(1991:1993, 1995). Leave blank to include all years of data provided.

complete_years Logical value indicating whether to only include years with complete data in analysis. Only in selected analyses; default FALSE.

months Numeric vector of months to include in analysis; default c(1:12).

Data Analysis Options

roll_days Numeric value (or values for some functions) of the number of days to apply a rolling mean; default 1.

roll_align Character string identifying the direction of the rolling mean from the specified date, either by the first ('left'), last ('right), or middle ('center') day of the rolling n-day group of observations; default 'right'.

use_yield Logical value indicating to use area-based yield, in mm, instead of volumetric for cumulative analysis functions; default FALSE. Requires basin_area.

basin_area Drainage basin area, in square km, to use when use_yield = TRUE. Three options: 1) leave blank if column of HYDAT station numbers; 2) single numeric value to apply to all observations.; 3) list each basin area for each station c("08NM116" = 795, "08NM242" = 10). Stations not listed will result in NA basin area.

percentiles Numeric vector of percentiles to calculate, ex. c(5,25,75,95). Set to NA if none required.

Table/Tibble Options

transpose Logical value indicating if the results rows and columns are to be switched; default FALSE.

Plotting Options

log_discharge Logical value to indicate plotting the discharge axis on a logarithmic scale; default FALSE.

include_title Logical value to indicate adding the group/station number to the plot, if provided.

include_year Numeric value indicating a year of daily flows to add to the daily statistics plot.

Writing Functions

These functions help save the outputted objects (tibbles and lists of plots) from the **fasstr** functions.

write_flow_data()
Write a streamflow dataset as a .xlsx, .xls, or .csv file. Can extract and save HYDAT data with this function.

write_results(digits = 10**)**
Write a data frame as a .xlsx, .xls, or .csv file. Can save a data frame and round digits of all numeric columns.

write_plots(plots, foldername, plot_filetype, combined_pdf**)**
Write plots from a list object into a directory or PDF document. By default will save all plots in a folder. To create a PDF of all plots, set combined_pdf = TRUE.

write_objects_list(list, foldername, table_filetype, plot_filetype**)**
Write all tables and plots contained in a list object into a folder. Saves only data frames and ggplot2 objects.

Annual Trending Analysis

This function computes and plots prewhitened, non-parametric annual trends on streamflow data.

This function calculates prewhitened, non-parametric annual trends using the 'zyp' package. It calculates various annual metrics using the calc_all_annual_stats() function and then calculates and plots the trends. See the zyp package, function documentation, and the trending vignette for more information on the analysis.

Function

compute_annual_trends()
Calculate prewhitened nonlinear annual trends on streamflow data.

Arguments

zyp_method Prewhitening method, either 'yuepilon' or 'zhang'. See zyp methodology for more information.

include_plots Logical value indicating if annual trending plots should be included. Default TRUE.

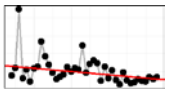
zyp_alpha Numeric value of the significance level (ex. 0.05) of when to plot a trend line. Leave blank for no line.

Outputs

$Annual_Trends_Data A tibble of annual data from the `calc_all_annual_stats()` function used for trending

$Annual_Trends_Results A tibble of annual trending results, including significance, confidence intervals, trend values, etc.

$Annual_* A ggplot2 object for each annual statistic trended, with the slope plotted if significance is greater than 'zyp_alpha' provided.



Volume Frequency Analyses

These functions compute and plot volume frequency analyses on annual low or high streamflow data.

These functions perform volume frequency analyses on annual low or high flow data. These functions plot probabilities of data using chosen plotting methods and calculates frequency quantiles (ex. 7Q10) based on fitting data to selected distributions and fitting methods. See function documentation for more information.

Functions

compute_annual_frequencies()
Annual frequency analysis from daily streamflow data; calculates minimums or maximums of selected roll_days.

compute_frequency_quantile()
Annual frequency analysis from daily streamflow data; calculates minimums or maximums of selected roll_days and return_period. Quantile value is returned.

compute_hydat_peak_frequencies()
Annual frequency analysis from instantaneous peak data (minimum or maximum) for stations from HYDAT. Data selected using station_number argument.

compute_frequency_analysis()
Conduct a frequency analysis with custom data.

Arguments

use_max Rank data from high to low rather than low to high (for peak analyses); default FALSE.

use_log Log-transform event data; default TRUE.

prob_plot_positions Plotting positions used to plot the probabilities; 'weibull' (default), 'hazen', or 'median'.

prob_scale_points Probabilities to be plotted on the x-axis; default c(.9999, .999, .99, .9, .5, .2, .1, .02, .01, .001, .0001).

fit_distr Distribution used to fit the data; one of 'PIII' (default) or 'weibull'.

fit_dist_method Method used to fit the data to the distribution; one of 'MOM' (default) or 'MLE'.

fit_quantiles Quantiles to be estimated from the fitted distribution (event probabilities); default c(.975, .99, .98, .95, .90, .80, .50, .20, .10, .05, .01).

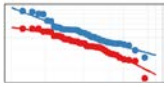
plot_curve Plot the computed curve on the plot; default TRUE.

Outputs

$Freq_Analysis_Data Tibble of computed or extracted data used in analysis.

$Freq_Plot_Data Tibble of plotting coordinates used in the frequency plot.

$Freq_Plot ggplot2 object of the frequency plot with return periods and probabilities.



$Freq_Fitting fitdisplus::fitdist object of fitting parameters.

$Freq_Fitted_Quantiles Tibble of fitted quantiles with probabilities and return periods.

Computing Full Analysis

This function calculates a suite of data a plots from many of the **fasstr** functions into organized lists.

This function calculates many of the data and plot analyses from the fasstr functions, producing lists of tables and plots organized in lists by time periods and analysis types. See the function documentation for more information.

Function

compute_full_analysis()
Computes a suite of analyses from fasstr functions and produces assorted tables and plots.

Arguments

sections Numeric vector of the sections of the analysis to include; default is all (1:7). Include those sections with which stats are desired: 1: Screening, 2: Long-term, 3: Annual, 4: Monthly, 5: Daily, 6: Trending, 7: Low-flow Frequencies.

write_to_dir Logical value indicating if all results are to also be written into a directory; default FALSE.

foldername Name of folder to create (if it does not exist) to create all folders and save tables and plots if write_to_dir = TRUE.

table_filetype Table type to write if write_to_dir = TRUE. One of "csv", "xls", or "xlsx" (default).

plot_filetype Image type to write if write_to_dir = TRUE. One of "png" (default), "eps", "ps", "tex", "pdf", "jpeg", "tiff", "bmp", or "svg".

Outputs

$Screening List of table and plot objects to review and screen data.

$Longterm List of table and plot objects from long-term statistics, including summary statistics and flow duration.

$Annual List of table and plot objects from annual statistics, including summary and cumulative statistics, and other annual metrics.

$Monthly List of table and plot objects from monthly statistics, including summary and cumulative statistics.

$Daily List of table and plot objects from daily statistics, including summary and cumulative statistics.

$Trending List of table and plot objects from an annual trending analysis.

$Lowflow_Frequencies List of table and plot objects from a low-flow frequency analysis.