Package 'NEONiso'

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Type Package

Title Tools to Calibrate and Work with NEON Atmospheric Isotope Data

Version 0.9.0

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Depends R (>= 4.1.0)

Description Functions for downloading,
calibrating, and analyzing atmospheric isotope data bundled
into the eddy covariance data products of the National Ecological
Observatory Network (NEON) <https://www.neonscience.org>.
Calibration tools are provided for carbon and water isotope products.
Carbon isotope calibration details are found in Fiorella et al. (2021)
<doi:10.1029/2020JG005862>, and the readme
file at <https://github.com/lanl/NEONiso>. Tools for calibrating water
isotope products have been added as of 0.6.0, but have known deficiencies
and should be considered experimental and unsupported.

License GPL-3

BugReports https://github.com/lanl/NEONiso/issues

URL https://github.com/lanl/NEONiso, https://lanl.github.io/NEONiso/

Encoding UTF-8

Imports dplyr, zoo, httr, lubridate, neonUtilities (>= 2.3.0),
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calculate_12CO2 *Calculate 12C-CO2 Mole Fractions*

Description

This function calculates mole fractions of 12CO2 based on the total CO2 mole fraction, the delta13C value of the mixture, and the assumed fraction of CO2 that does not correspond to 12CO2 or 13CO2 (assumed fixed at 0.00474, e.g., Griffis et al. 2004 Agricultural and Forest Meteorology)

Usage

```
calculate_12CO2(total_co2, delta13c, f = 0.00474)
```

Arguments

total_co2	Vector of CO2 mole fractions.
delta13c	Vector of d13C values.
f	Fraction of CO2 that is not 12CO2 or 13CO2. Assumed fixed at 0.00474

Value

Vector of 12CO2 mole fractions.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

Examples

```
calculate_12CO2(total_co2 = 410, delta13c = -8.5)
```

calculate_13CO2 *Calculate 13C-CO2 Mole Fractions*

Description

This function calculates mole fractions of 13CO2 based on the total CO2 mole fraction, the delta13C value of the mixture, and the assumed fraction of CO2 that does not correspond to 12CO2 or 13CO2 (assumed fixed at 0.00474, e.g., Griffis et al. 2004 Agricultural and Frest Meteorology)

Usage

```
calculate_13CO2(total_co2, delta13c, f = 0.00474)
```

Arguments

total_co2	Vector of CO2 mole fractions.
delta13c	Vector of d13C values.
f	Fraction of CO2 that is not 12CO2 or 13CO2. Assumed fixed at 0.00474

Value

Vector of 13CO2 mole fractions.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

Examples

```
calculate_13CO2(total_co2 = 410, delta13c = -8.5)
```

---

calibrate_ambient_carbon_gainoffset

Calibrate ambient carbon isotope data using gain-and-offset method

---

Description

Function called by `calibrate_carbon_bymonth()` to apply gain and offset parameters to the ambient datasets (000_0x0_09m and 000_0x0_30m). This function should generally not be used independently, but should be used in coordination with `calibrate_carbon_bymonth()`.

Usage

```
calibrate_ambient_carbon_gainoffset(
  amb_data_list,
  caldf,
  site,
  filter_data = TRUE,
  force_to_end = TRUE,
  force_to_beginning = TRUE,
  gap_fill_parameters = FALSE,
  r2_thres = 0.9
)
```

Arguments

amb_data_list	List containing an ambient d13C dataset. Will include all variables in 000_0x0_xxm. (character)
caldf	Calibration data frame containing gain and offset values for 12C and 13C isotopologues.
site	Four-letter NEON code corresponding to site being processed.
filter_data	Apply median absolute deviation filter from Brock 86 to remove impulse spikes?
force_to_end	In given month, calibrate ambient data later than last calibration, using the last calibration? (default true)
force_to_beginning	In given month, calibrate ambient data before than first calibration, using the firs t calibration? (default true)
gap_fill_parameters	Should function attempt to 'gap-fill' across a bad calibration by carrying the last known good calibration forward? Implementation is fairly primitive currently, as it only carries the last known good calibration that's available forward rather than interpolating, etc. Default FALSE.
r2_thres	Minimum r2 value for calibration to be considered "good" and applied to ambient data.

Value

Depends on write_to_file argument. If true, returns nothing to environment; but returns calibrated ambient observations to the output file. If false, returns modified version of amb_data_list that include calibrated ambient data.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

---

calibrate_ambient_carbon_linreg

Calibrate ambient carbon isotope data using linear regression

---

Description

Function called by calibrate_ambient_carbon_linreg to apply gain and offset parameters to the ambient datasets (000_0x0_09m and 000_0x0_30m). This function should generally not be used independently, but should be used with calibrate_ambient_carbon_linreg.

Usage

```
calibrate_ambient_carbon_linreg(
  amb_data_list,
  caldf,
  site,
  filter_data = TRUE,
  force_to_end = TRUE,
  force_to_beginning = TRUE,
  gap_fill_parameters = FALSE,
  r2_thres = 0.9
)
```

Arguments

amb_data_list	List containing an ambient d13C dataset. Will include all variables in 000_0x0_xxm. (character)
caldf	Calibration data frame containing gain and offset values for 12C and 13C isotopologues.
site	Four-letter NEON code corresponding to site being processed.
filter_data	Apply median absolute deviation filter from Brock 86 to remove impulse spikes? Inherited from calibrate_ambient_carbon_linreg
force_to_end	In given month, calibrate ambient data later than last calibration, using the last calibration? (default true)
force_to_beginning	In given month, calibrate ambient data before than first calibration, using the first calibration? (default true)
gap_fill_parameters	Should function attempt to 'gap-fill' across a bad calibration by carrying the last good calibration forward? Implementation is fairly primitive currently, as it only carries the last known good calibration that's available forward rather than interpolating, etc. Default FALSE.
r2_thres	Minimum r2 value for calibration to be considered "good" and applied to ambient data.

Value

Nothing to environment; returns calibrated ambient observations to the function orchestrating calibration (calibrate_carbon). This function is not designed to be called on its own, and is not exported to the namespace.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

calibrate_ambient_water_linreg *calibrate_ambient_water_isotopes*

Description

Function called by `calibrate_ambient_water_linreg` to apply slope and intercept parameters to the ambient datasets (000_0x0_09m and 000_0x0_30m) to correct to the VSMOW scale. This function should generally not be used independently, but should be used with `calibrate_ambient_water_linreg`. Note that in this version *NO CORRECTION FOR HUMIDITY* is performed. Use with caution.

Usage

```
calibrate_ambient_water_linreg(
  amb_data_list,
  caldf,
  outname,
  site,
  filter_data = TRUE,
  force_to_end = TRUE,
  force_to_beginning = TRUE,
  r2_thres = 0.9
)
```

Arguments

`amb_data_list`	List containing ambient d18O/d2H datasets. Will include all variables in 000_0x0_xxm. (character)
`caldf`	Calibration data frame containing slope and intercept values for d18O and d2H values.
`outname`	Output variable name. Inherited from `calibrate_ambient_water_linreg`
`site`	Four-letter NEON code corresponding to site being processed.
`filter_data`	Apply a median filter to output ambient data? inherited.
`force_to_end`	In given month, calibrate ambient data later than last calibration, using the last calibration? (default true)
`force_to_beginning`	In given month, calibrate ambient data before than first calibration, using the first calibration? (default true)
`r2_thres`	Minimum r2 value for calibration to be considered "good" and applied to ambient data.

Value

Nothing to environment; returns calibrated ambient observations to the output file. This function is not designed to be called on its own.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

`calibrate_carbon` *Calibrate NEON carbon isotope data using validation data sets.*

Description

[Experimental] This function drives a workflow that reads in NEON carbon isotope data of atmospheric CO2, calibrates it to the VPDB scale, and (optionally) writes the calibrated data to a new HDF5 file. Two different approaches are possible: a) a calibration on 12CO2 and 13CO2 isotopologues independently, after Bowling et al. 2003 (Agr. For. Met.), or b) a direct calibration of d13C and CO2 values using linear regression. Most of the time the results generated are extremely similar to each other. Wen et al. 2013 compared several different carbon isotope calibration techniques and found this to be the superior method under most circumstances. We also found this to be the case for NEON data (Fiorella et al. 2021; JGR-Biogeosciences).

Usage

```
calibrate_carbon(
  inname,
  outname,
  site,
  method = "Bowling_2003",
  calibration_half_width = 0.5,
  force_cal_to_beginning = TRUE,
  force_cal_to_end = TRUE,
  gap_fill_parameters = FALSE,
  filter_ambient = TRUE,
  r2_thres = 0.95,
  correct_ref_data = TRUE,
  write_to_file = TRUE,
  remove_known_bad_months = TRUE,
  plot_regression_data = FALSE,
  plot_directory = NULL,
  avg = 6,
  min_nobs = NA,
  standards = c("co2Low", "co2Med", "co2High")
)
```

Arguments

`inname`	Input file(s) that are to be calibrated. If a single file is given, output will be a single file per site per month. If a list of files corresponding to a timeseries at a given site is provided, will calibrate the whole time series.
`outname`	Name of the output file. (character)

`site` Four letter NEON site code for site being processed. (character)

`method` Are we using the Bowling et al. 2003 method ("Bowling_2003") or direct linear regression of d13C and CO2 mole fractions ("linreg")?

`calibration_half_width`
Determines the period (in days) from which reference data are selected (period is 2*calibration_half_width).

`force_cal_to_beginning`
Extend first calibration to the beginning of the file? (default true)

`force_cal_to_end`
Extend last calibration to the end of the file? (default true)

`gap_fill_parameters`
Should function attempt to 'gap-fill' across a bad calibration by carrying the last good calibration forward? Implementation is fairly primitive currently, as it only carries the last known good calibration that's available forward rather than interpolating, etc. Default FALSE.

`filter_ambient` Apply the median absolute deviation filter (Brock 86) to remove impulse spikes in output ambient data? (logical; default true)

`r2_thres` Minimum r2 threshold of an "acceptable" calibration. Acts to remove calibration periods where a measurement error makes relationship nonlinear. Default = 0.95

`correct_ref_data`
NEON has indicated there are a few instances where reported d13C or CO2 reference values are wrong. If set to true, correct known incorrect values. This argument will (hopefully, eventually) go away after NEON has fixed the reference database. Users will be warned prior to removal of this argument.

`write_to_file` Write calibrated ambient data to file? (Mostly used for testing)

`remove_known_bad_months`
There are a few site months with known spectral issues where the isotope ratios are likely unrecoverable. This parameter allows removal of these files, but allows them to remain in archive.

`plot_regression_data`
Default false; this is useful for diagnostics.

`plot_directory` Only used if plot_regression_data is TRUE, but specify where to write out diagnostic plot of regression data.

`avg` The averaging interval to extract, in minutes. Default 6.

`min_nobs` Minimum number of high-frequency observations to define a peak.

`standards` Which reference gases (standards) to use? Default is all, but can pass a subset of "co2Low", "co2Med", and "co2High" as a vector to this argument as well.

Details

The 'linreg' method simply takes measured and reference d13C and CO2 values and generates a transfer function between them using `lm()`. For the gain-and-offset method, d13C and CO2 values are converted to 12CO2 and 13CO2 mole fractions. Gain and offset parameters are calculated for each isotopologue independently, and are analogous to regression slope and intercepts, but jointly

correct for CO2 concentration dependence and place d13C values on the VPDB scale. The gain and offset parameters are defined by:

$$G = (X_{2,ref} - X_{1,ref})/(X_{2,meas} - X_{1,meas})$$

$$O = X_{2,ref} - GX_{2,meas}$$

Calibrated ambient isotopologues are then given as:

$$X_{cal} = X_{meas}G + O$$

Measurements of reference materials were considered "good" if the following conditions were met:

- Measured CO2 concentrations were within 10 ppm of known "reference" concentrations.
- Variance of the CO2 concentration in standard peak was < 5 ppm.
- Measured d13C value must be within 5 per mil of known "reference" d13C value.

The first two criteria are intended to filter out periods where there is a clear issue with the gas delivery system (i.e., nearly empty gas tank, problem with a valve in the manifold, etc.); the third criterion was adopted after visual inspection of data timeseries revealed that often the first standard measurement following an instrument issue had higher-than-expected error. This criterion clips clearly poor values. Selection of these criteria will become a function argument, and therefore customizable, in a future release.

The behavior of this function will be a bit different depending on what is supplied as `inname`. If a single file is provided, the output will be monthly. However, a list of files corresponding to a site can also be provided, and then a single output file per site will be generated.

Value

Returns nothing to the environment, but creates a new output HDF5 file containing calibrated carbon isotope values.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

Examples

```
## Not run: fin <- system.file('extdata',
'NEON.D15.ONAQ.DP4.00200.001.nsae.2019-05.basic.20201020T211037Z.packed.h5',
         package = 'NEONiso', mustWork = TRUE)
calibrate_carbon_bymonth(inname = fin, outname = 'out.h5',
         site = 'ONAQ', write_to_file = FALSE)
calibrate_carbon_bymonth(inname = fin, outname = 'out.h5',
         site = 'ONAQ', method = 'linreg', write_to_file = FALSE)
## End(Not run)
```

calibrate_water *Calibrate NEON water isotope ratios using validation data sets.*

Description

[Experimental] This function uses NEON validation data to apply drift corrections to measured ambient water isotope ratios. In brief, ambient water isotope ratios are calibrated by generating regressions using reference water measurements bracketing an ambient period. Three reference waters are measured once per day, with several injections per reference water. Due to memory effects, only the last three are used currently to generate calibration equations. Regressions between measured d18O and d2H values and NEON-provisioned known reference values are generated, and used to calibrate the period of ambient measurements between them if the r2 of the regression is greater than a threshold value (by default, this is 0.95). Most of this function deals with selecting the appropriate calibration data and determining calibration quality. This function also contains a wrapper for `calibrate_ambient_water_linreg`, which calibrates the ambient water data using the calibration parameters generated in this function. This function also copies over data in the qfqm and ucrt hdf5 data groups.

Usage

```
calibrate_water(
  inname,
  outname,
  site,
  calibration_half_width = 14,
  filter_data = TRUE,
  force_cal_to_beginning = FALSE,
  force_cal_to_end = FALSE,
  r2_thres = 0.95,
  slope_tolerance = 9999,
  correct_ref_data = TRUE,
  write_to_file = TRUE
)
```

Arguments

`inname`	Input file(s) that are to be calibrated. If a single file is given, output will be a single file per site per month. If a list of files corresponding to a timeseries at a given site is provided, will calibrate the whole time series.
`outname`	Name of the output file. (character)
`site`	Four-letter NEON code for site being processed.
`calibration_half_width`	Determines the range of standard measurements to use in determining the calibration regression dataset. Creates a moving window that is `2*calibration_half_width` days wide. Default is set to 14 for a 28 day moving window.
`filter_data`	Apply median absolute deviation filter from Brock 86 to remove impulse spikes?

`force_cal_to_beginning`
: Extend first calibration to the beginning of the file?

`force_cal_to_end`
: Extend last calibration to the end of the file?

`r2_thres`
: Minimum r2 threshold of an "acceptable" calibration. Acts to remove calibration periods where a measurement error makes relationship nonlinear. Default = 0.95

`slope_tolerance`
: How different from 1 should we allow 'passing' regression slopes to be? Experimental parameter, off by default (e.g., default slope parameter = 9999)

`correct_ref_data`
: There are a few instances where the reference d18O and d2H values may have been switched, causing very anomalous d-excess values. If TRUE, implement a switch that corrects this issue.

`write_to_file`
: Write calibrated ambient data to file? (Mostly used for testing)

Details

IMPORTANT NOTE Currently this function does not apply a correction for humidity dependence of Picarro isotopic measurements. This is because the data to implement these corrections is not yet publicly available. Caution is suggested when analyzing data at low humidities, below ~5000 ppm, with likely higher biases at lower humidity values.

Additionally, please note that this function is meant to work on *all* files for a given site at the same time. A more flexible version that can handle all files or monthly files will be added to a future release.

Value

nothing to the workspace, but creates a new output file of calibrated water isotope data.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

---

carbon_regression_plots

Make plots of carbon calibration data for debugging

Description

Makes plots of carbon calibration data regressions, primarily for debugging and validation purposes.

Usage

```
carbon_regression_plots(caldata, plot_filename, method, mtitle)
```

Arguments

caldata	Data frame corresponding to a specific calibration period.
plot_filename	What should the output file name for diagnostic plot be?
method	Which method are we using? Currently works for gain/offset.
mtitle	Fed from above routine - what should the plot title be?

Value

Nothing to the environment, but a pdf plot to a file.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

---

convert_NEONhdf5_to_POSIXct_time

Convert NEON HDF5 file time to POSIXct

Description

Converts the date time string in NEON HDF5 files to a POSIXct object for use in R.

Usage

```
convert_NEONhdf5_to_POSIXct_time(intime)
```

Arguments

intime	Vector of datetimes in NEON data files (as string) to convert to POSIXct class

Value

Vector of datetimes from NEON data file now in POSIXct format.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

Examples

```
convert_NEONhdf5_to_POSIXct_time("2019-06-01T12:00:00.000Z")
```

convert_POSIXct_to_NEONhdf5_time *Convert a POSIXct object to the format used in NEON HDF5 files*

Description

Converts a POSIXct object back to the character format used by NEON in their HDF eddy covariance files. Output format, using strptime syntax, is %Y-%m-%dT%H:%M:%OSZ. POSIXct input in any time zone is converted to UTC; fractional seconds are truncated.

Usage

```
convert_POSIXct_to_NEONhdf5_time(intime)
```

Arguments

intime	POSIXct vector to convert to NEON time format.

Value

Returns character version of POSIXct object matching NEON time variable format.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

Examples

```
convert_POSIXct_to_NEONhdf5_time(Sys.time())
```

correct_carbon_ref_cval *correct_carbon_ref_cval*

Description

This ugly function is present out of necessity, and will only exist for as long as it is necessary. It is an internal correction within the NEONiso calibration routines that is required as there are some mismatches between the 'true' isotope reference values and those in the NEON HDF5 files. NEON is working on correcting this, and after it has been corrected, this function has no need to exist and will be immediately deprecated. As a result, this function is fairly messy but there is little incentive to improve it.

Usage

```
correct_carbon_ref_cval(
  std_frame,
  site,
  omit_already_corrected = TRUE,
  co2_tol = 5,
  d13c_tol = 0.25
)
```

Arguments

std_frame	Standard data frame to perform swap on.
site	NEON four letter site code.
omit_already_corrected	Should we attempt correction, if it's already been corrected in the raw files.
co2_tol	Tolerance to use to select co2 values that need to be replaced, in ppm. Default = 5 ppm.
d13c_tol	Tolerance to use to select d13C values that need to be replaced, in ppm. Default = 0.25 per mil.

Details

Current sites and time periods affected:

Value

A data.frame, based on std_frame, where NEON-supplied reference values have been corrected if a mismatch has previously been identified.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

---

correct_carbon_ref_output

Correct carbon ref output

Description

Corrects known mismatches in the database where standard values do not actually match what they should in data files per calVal measurements.

Usage

```
correct_carbon_ref_output(
  std_list,
  site,
  omit_already_corrected = TRUE,
  co2_tol = 5,
  d13c_tol = 0.25,
  ref_gas
)
```

Arguments

std_list	List containing reference/validation gas measurements.
site	Four-letter NEON site code.
omit_already_corrected	Skip correction if the reference gas values have already been corrected in the files (default TRUE) If you have older versions of the files, you may want to set this to FALSE.
co2_tol	Tolerance used to identify a mismatch in CO2 values. Will correct measured CO2 values within +/- co2_tol within time period identified as having incorrect reference values.
d13c_tol	Tolerance used to identify a mismatch in d13C values. Will correct measured d13C values within +/- d13c_tol within time period identified as having incorrect reference values.
ref_gas	Which reference gas is being corrected? Expects "co2High", "co2Med", or "co2Low"

Value

A version of std_list with corrected reference values.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

---

delta_to_R *Converts delta value to heavy-to-light isotope ratio*

Description

Converts a delta value (in per mil) to the heavy-to-light isotope ratio.

Usage

```
delta_to_R(delta_values, element)
```

Arguments

delta_values	A vector of isotope ratios in delta notation.
element	Which element to return R values - carbon, oxygen, or hydrogen.

Value

Vector of isotope ratios (R values).

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

Examples

```
delta_to_R(delta_values = 0, element = 'oxygen') # 2005.2e-6 for VSMOW.
```

---

estimate_calibration_error

Produce estimates of the calibration error.

Description

Estimate calibration error using a 5-fold cross-validation. A 5-fold cross-validation was chosen as each calibration window should have at least 6 data points (e.g., if only daily validation data are used for the calibration) and therefore this ensures that the cross-validation should always run. Model is fit using `lm`, with root-mean-square error (RMSE) and mean-absolute error (MAE) extracted from the cross-validation.

Usage

```
estimate_calibration_error(formula, data)
```

Arguments

formula	Formula to pass to lm for cross validation.
data	Data frame to perform cross-validation on.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

`extract_carbon_cal_data` *Extract only the data corresponding to validation/calibration time periods.*

Description

Extracts data matching a value of "co2Low," "co2Med," or "co2High" which correspond to the validation gases of known CO2, d13C that are fed to the analyzer daily.

Usage

```
extract_carbon_cal_data(
  data_list,
  standards = c("co2Low", "co2Med", "co2High")
)
```

Arguments

`data_list`	List containing data, from the /*/dp01/data/ group in NEON HDF5 file.
`standards`	Which reference gases (standards) to use? Default is all, but can pass a subset of "co2Low", "co2Med", and "co2High" as a vector to this argument as well.

Value

Returns data frame of required variables.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

`extract_water_calibration_data` *Extract only the data corresponding to validation/calibration time periods.*

Description

Extracts data matching a value of "h2oLow," "h2oMed," or "h2oHigh" which correspond to the validation gases of known d18O, d2H that are fed to the analyzer daily.

Usage

```
extract_water_calibration_data(data_list)
```

Arguments

data_list	List containing data, from the /*/dp01/data/ group in NEON HDF5 file.

Value

Returns data frame of required variables.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

---

filter_median_brock86 *Apply a median absolute deviation filter*

Description

Median absolute deviation filter of Brock 1986, with user specified width and magnitude thresholds.

Usage

```
filter_median_brock86(data, width = 7, threshold = 5)
```

Arguments

data	Vector to filter.
width	Width of filter, in rows.
threshold	Only filter values that are abs(threshold) away from median

Value

Returns filtered vector.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

`fit_carbon_regression` *Estimate slope/intercept of carbon isotope calibration regression*

Description

Performs regression between measured and known carbon isotope and mole fractions to generate a transfer function and associated uncertainty estimates using both 5-fold and leave-one-out cross-validation methods. Regression occurs either on 12CO2/13CO2 mole fractions (gainoffset method) or on the CO2 and d13C values (linreg).

Usage

```
fit_carbon_regression(
  ref_data,
  method,
  calibration_half_width,
  plot_regression_data = FALSE,
  plot_dir = "/dev/null",
  site,
  min_nobs = NA
)
```

Arguments

`ref_data`	Reference data.frame from which to estimate calibration parameters.
`method`	Are we using the gain-and-offset method ("gainoffset"), formerly called the Bowling et al. 2003 method in this package, or direct linear regression of d13C and CO2 mole fractions ("linreg")?
`calibration_half_width`	Determines the period (in days) from which reference data are selected (period is 2*calibration_half_width).
`plot_regression_data`	True or false - should we plot the data used in the regression? Useful for debugging.
`plot_dir`	If plot_regression_data is true, where should the plots be saved?
`site`	Needed for regression plots.
`min_nobs`	Minimum number of high-frequency observations to define a peak.

Value

Returns a data.frame of calibration parameters. If `method == "gainoffset"`, then data.frame includes gain and offset parameters for 12CO2 and 13CO2, and r^2 values for each regression. If `method == "linreg"`, then data.frame includes slope, intercept, and r^2 values for d13C and CO2 values.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

`fit_water_regression` *Estimate slope/intercept of water isotope calibration regression*

Description

Performs regression between measured and known carbon isotope and mole fractions to generate a transfer function and associated uncertainty estimates using both 5-fold and leave-one-out cross-validation methods. Regression occurs on d18O and d2H values.

Usage

```
fit_water_regression(
  ref_data,
  calibration_half_width,
  slope_tolerance,
  r2_thres,
  plot_regression_data = FALSE,
  plot_dir = "/dev/null",
  site,
  min_nobs = NA
)
```

Arguments

`ref_data`	Reference data.frame from which to estimate calibration parameters.
`calibration_half_width`	Determines the period (in days) from which reference data are selected (period is 2*calibration_half_width).
`slope_tolerance`	Allows for filtering of slopes that deviate from 1 by slope_tolerance.
`r2_thres`	What is the minimum r2 value permitted in a 'useful' calibration relationship.
`plot_regression_data`	True or false - should we plot the data used in the regression? Useful for debugging.
`plot_dir`	If plot_regression_data is true, where should the plots be saved?
`site`	Needed for regression plots.
`min_nobs`	Minimum number of high-frequency observations to define a peak.

Value

Returns a data.frame of calibration parameters. Output data.frame includes slope, intercept, and r^2 values for d13C and CO2 values.

get_Rstd *Return heavy-to-light isotope ratio of primary standard.*

Description

Returns the heavy-to-light isotope ratio of the dominant standard for that element. Vienna Standard Mean Ocean Water (VSMOW) for oxygen and hydrogen isotopes, Vienna Pee Dee Belemnite (VPDB) for carbon stable isotopes.

Usage

```
get_Rstd(element)
```

Arguments

element	Which element to return standard ratio - carbon, oxygen, or hydrogen.

Value

Heavy-to-light isotope ratio of most common stable isotope standard. VSMOW for water, VPDB for carbon.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

Examples

```
get_Rstd("carbon") # returns 0.0111797
get_Rstd("oxygen") # returns 2005.20e-6
```

ingest_data *Ingest and stack variables needed in calibration.*

Description

Opens and stacks isotope ratio and water/carbon dioxide mole fraction variables from monthly HDF5 files. If a new enough version of neonUtilities is available, this function will try to use fasttime in order to accelerate data stacking.

Usage

```
ingest_data(inname, analyte, name_fix = TRUE, amb_avg, ref_avg)
```

Arguments

inname	A file (or list of files) to extract data from for calibration.
analyte	Carbon (Co2) or water (H2o)?
name_fix	Fix to data frame required for next-generation calibration functions, but breaks old 'by_month()' functions. This parameter provides a necessary work around until these functions are removed.
amb_avg	The averaging interval of the ambient data to extract.
ref_avg	The averaging interval of the reference data to extract.

Value

List of data frames, taken from files specified in inname

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

---

loocv *Leave-one-out cross validation*

Description

Calculate analytic leave-one-out cross variance error estimate

Usage

```
loocv(mod)
```

Arguments

mod	Fitted model to estimate leave-one-out CV on.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

`manage_local_EC_archive` *Manage a local eddy covariance (EC) data archive.*

Description

Utility function to help retrieve new EC data and/or prune duplicates, as NEON provisions new data or re-provisions data for an existing site and month.

Usage

```
manage_local_EC_archive(
  file_dir,
  get = TRUE,
  unzip_files = TRUE,
  trim = FALSE,
  dry_run = TRUE,
  sites = "all",
  release = "RELEASE-2024"
)
```

Arguments

`file_dir`	Specify the root directory where the local EC store is kept.
`get`	Pull down data from NEON API that does not exist locally?
`unzip_files`	NEON gzips the hdf5 files, should we unzip any gzipped files within file_dir? (Searches recursively)
`trim`	Search through local holdings, and remove older file where there are duplicates?
`dry_run`	List files identified as duplicates, but do not actually delete them? Default true to prevent unintended data loss.
`sites`	Which sites to retrieve data from? Default will be all sites with available data, but can specify a single site or a vector here.
`release`	Download data corresponding to a specific release? Defaults to "RELEASE-2024." To download all data, including provisional data, set to NULL.

Value

Returns nothing to the environment, but will download new NEON HDF5 files for selected sites (if `get = TRUE`), unzip them in the local file directory (if `unzip_files = TRUE`), and identify and remove suspected duplicate files (if `trim = TRUE` and `dry_run = FALSE`).

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

`restructure_carbon_variables` *Restructure ingested variables for the carbon isotope system.*

Description

Restructures carbon isotope measurement system variables and shortens names to simplify referencing variables elsewhere in calibration code.

Usage

```
restructure_carbon_variables(dataframe, varname, mode, group)
```

Arguments

`dataframe`	Input data.frame, from `neonUtilities::stackEddy`
`varname`	Which variable are we applying this function to? There's a list of ~10 common ones to write to the hdf5 file.
`mode`	Are we fixing a reference data frame or an ambient data frame?
`group`	Data, ucrt, or qfqm?

Value

data.frame formatted for output to hdf5 file.

`restructure_variables` *Restructures data.frames imported by ingest_data to shorten variable names and Wrapper function around restructure_carbon_variables and restructure_water_variables.*

Description

Restructures data.frames imported by ingest_data to shorten variable names and Wrapper function around restructure_carbon_variables and restructure_water_variables.

Usage

```
restructure_variables(dataframe, varname, mode, group, species)
```

Arguments

`dataframe`	Input data.frame, from `neonUtilities::stackEddy`
`varname`	Which variable are we applying this function to? There's a list of ~10 common ones to write to the hdf5 file.
`mode`	Are we fixing a reference data frame or an ambient data frame?
`group`	Data, ucrt, or qfqm?
`species`	Set to 'Co2' for carbon; 'H2o' for water

Value

data.frame formatted for output to hdf5 file.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

`restructure_water_variables` *Restructure ingested variables for the water isotope system.*

Description

Restructures water isotope measurement system variables and shortens names to simplify referencing variables elsewhere in calibration code.

Usage

```
restructure_water_variables(dataframe, varname, mode, group)
```

Arguments

`dataframe`	Input data.frame, from `neonUtilities::stackEddy`
`varname`	Which variable are we applying this function to? There's a list of ~10 common ones to write to the hdf5 file.
`mode`	Are we fixing a reference data frame or an ambient data frame?
`group`	Data, ucrt, or qfqm?

Value

data.frame formatted for output to hdf5 file.

`R_to_delta` *Convert heavy-to-light isotope ratio to delta values.*

Description

Converts a heavy-to-light stable isotope ratio to a corresponding delta value, in per mil values.

Usage

```
R_to_delta(R_values, element)
```

Arguments

R_values	A vector of isotope ratios (e.g., R values).
element	Which element to return delta values - carbon, oxygen, or hydrogen.

Value

Vector of isotope ratios in delta notation.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

Examples

```
R_to_delta(R_values = 2005.20e-6, element = 'oxygen') # returns 0.
```

---

select_daily_reference_data

Select validation data corresponding to a particular day

Description

Select validation data corresponding to a particular day

Usage

```
select_daily_reference_data(standard_df, analyte, min_nobs = NA)
```

Arguments

standard_df	Input reference data.frame.
analyte	Are we calibrating CO2 and H2O? (Use argument 'co2' or 'h2o', or else function will throw error)
min_nobs	Minimum number of high-frequency observations to define a peak. If not supplied, defaults are 200 for `analyte = 'co2'` or 30 for `analyte = 'h2o'`

Value

Smaller data.frame where only the reference data selected to use in the calibration routines is returned. Assumes that we are calibrating on a daily basis, and not on a longer time scale. Data are selected based on two criteria: cannot be missing, and must be at least a certain number of high-frequency observations in order to qualify as a valid measurement. For the water system, this function also keeps only the last three injections for each reference water per day.

`setup_output_file` *Structure a new HDF5 file*

Description

Creates a skeleton HDF5 file for the calibrated data, essentially setting up the HDF5 groups at the /site/dp01/{data,ucrt,qfqm} level.

Usage

```
setup_output_file(
  inname,
  outname,
  site,
  analyte,
  attrs = NULL,
  keep_open = FALSE
)
```

Arguments

`inname`	Input file name.
`outname`	Output file name.
`site`	NEON 4-letter site code.
`analyte`	Carbon ('Co2') or water ('H2o') system?
`attrs`	Pre-read attributes list from the input file. If NULL (default), attributes are read from `inname`.
`keep_open`	If TRUE, return the open file handle instead of closing it. The caller is responsible for closing via `h5_close()`.

Value

If `keep_open = TRUE`, returns the open HDF5 file handle. Otherwise nothing (creates a new data file with basic HDF5 structure consistent with NEON's data files).

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

swap_standard_isotoperatios *swap_standard_isotoperatios*

Description

There are a few suspected instances where the water isotope ratios for oxygen and hydrogen have been flipped in the reference data. This function corrects them until they are corrected in the NEON database using a d-excess filter.

Usage

```
swap_standard_isotoperatios(std_frame, dxs_thres = 500)
```

Arguments

std_frame	Standard data frame to perform swap on.
dxs_thres	d-excess threshold to indicate when to swap.

Value

A data.frame based on std_frame, where d18O and d2H values have been swapped from NEON input files if determined to have a reference value mismatch. Mismatch is determined based on the d-excess of the standard (= d2H - 8*d18O), using a value of 500 by default.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

terrestrial_core_sites *List terrestrial core sites*

Description

Returns a vector of four-letter NEON site codes for the core terrestrial sites that have TIS instrumentation.

Usage

```
terrestrial_core_sites()
```

Value

A vector listing NEON core terrestrial sites.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

Examples

```
terrestrial_core_sites()
```

---

terrestrial_gradient_sites *List terrestrial gradient sites*

Description

Returns a vector of four-letter NEON site codes for the gradient terrestrial sites that have TIS instrumentation.

Usage

```
terrestrial_gradient_sites()
```

Value

A vector listing NEON gradient terrestrial sites.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

Examples

```
terrestrial_gradient_sites()
```

---

validate_analyte *Standardize analyte names*

Description

Enforces standard capitalization and formatting of H2o and Co2 analyte names across calibration functions.

Usage

```
validate_analyte(analyte)
```

Arguments

analyte	Co2 or H2o?

Value

Standardized string for the water ('H2o') or carbon ('Co2') systems to make sure strings are standardized across package functions.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

`validate_output_file` *Validate output file.*

Description

Function ensures that the output file has the correct groups in it, as a check to ensure proper file structure at the end of the calibration routines.

Usage

```
validate_output_file(inname, outname, site, analyte, avg_suffix = NULL)
```

Arguments

`inname`	Input file name.
`outname`	Output file name.
`site`	NEON 4-letter site code.
`analyte`	Carbon ('Co2') or water ('H2o') system?
`avg_suffix`	Averaging-interval suffix(es) of the input groups that were calibrated, e.g. "06m". Input groups with other suffixes are not expected in the output. If NULL, "09m" for carbon and c("03m", "09m") for water.

Value

Nothing to environment, simply checks to make sure expected groups are in output.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

water_isotope_sites *List sites with water vapor isotope ratios.*

Description

Returns a vector of four-letter NEON site codes for the terrestrial sites that have water vapor isotope ratio instrumentation.

Usage

```
water_isotope_sites()
```

Value

A vector listing NEON sites measuring water vapor isotope ratios.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

Examples

```
water_isotope_sites()
```

write_carbon_ambient_data *Write calibrated carbon ambient data to file*

Description

Write out ambient observations from the NEON EC towers where the isotope data (either H2O or CO2) have been calibrated using this package.

Usage

```
write_carbon_ambient_data(
  outname,
  site,
  amb_data_list,
  to_file = TRUE,
  fid = NULL
)
```

Arguments

outname	Output file name.
site	NEON 4-letter site code.
amb_data_list	Calibrated list of ambient data - this is the output from one of the calibrate_ambient_carbon* functions.
to_file	Write to file (TRUE) or to environment (FALSE).
fid	Optional open HDF5 file handle. If NULL, the file is opened and closed internally.

Value

Nothing to the environment, but writes data in amb_data_list to file.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

---

write_carbon_calibration_data
Write carbon calibrations to file

Description

Write a data.frame with slope, intercepts, and error estimates of calibrations for carbon isotope system. If gainoffset method was used the slopes/intercepts are called gain/offsets for each isotopologue.

Usage

```
write_carbon_calibration_data(
  outname,
  site,
  cal_df,
  method,
  to_file = TRUE,
  fid = NULL
)
```

Arguments

outname	Output file name.
site	NEON 4-letter site code.
cal_df	Calibration data frame - this is the output from fit_carbon_regression
method	Was the Bowling et al. 2003 or the linear regression method used in fit_carbon_regression?
to_file	Write to file (TRUE) or to environment (FALSE).
fid	Optional open HDF5 file handle. If NULL, the file is opened and closed internally.

Value

Nothing to the environment, but writes out the calibration parameters (e.g., gain and offset or regression slopes and intercepts) to the output hdf5 file.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

`write_water_ambient_data` *Write calibrated ambient water isotope ratio observations to file.*

Description

Write out ambient observations from the NEON EC towers where the isotope data have been calibrated using this package.

Usage

```
write_water_ambient_data(outname, site, amb_data_list, fid = NULL)
```

Arguments

`outname`	Output file name.
`site`	NEON 4-letter site code.
`amb_data_list`	Calibrated list of ambient data - this is the output from one of the calibrate_ambient_water* functions.
`fid`	Optional open HDF5 file handle. If NULL, the file is opened and closed internally.

Value

Nothing to the environment, but writes data in amb_data_list to file.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

write_water_calibration_data *Write water calibration parameters to file*

Description

Write a data.frame with slope, intercepts, and error estimates of calibrations for water isotope system.

Usage

```
write_water_calibration_data(outname, site, cal_df, fid = NULL)
```

Arguments

outname	Output file name.
site	NEON 4-letter site code.
cal_df	Calibration data frame - this is the output from fit_water_regression
fid	Optional open HDF5 file handle. If NULL, the file is opened and closed internally.

Value

Nothing to the environment, but writes out the calibration parameters (e.g., regression slopes and intercepts) to the output hdf5 file.

Author(s)

Rich Fiorella <rfiorella@lanl.gov>

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