Package 'SuessR'

October 20, 2023

Title Suess and Laws Corrections for Marine Stable Carbon Isotope Data

Version 0.1.5

Description Generates region-specific Suess and Laws corrections for
stable carbon isotope data from marine organisms collected between 1850 and 2022. Version
0.1.5 of 'SuessR' contains four built-in regions: the Bering Sea ('Bering Sea'), the
Aleutian archipelago ('Aleutian Islands'), the Gulf of Alaska ('Gulf of Alaska'), and the
subpolar North Atlantic ('Subpolar North Atlantic'). Users can supply their own environmental
data for regions currently not built into the package to generate corrections for those regions.

License MIT + file LICENSE

Depends R (>= 3.5.0)

Imports stats

Encoding UTF-8

LazyData true

RoxygenNote 7.2.0

NeedsCompilation no

Author Casey Clark [cre, aut],
Mattias Cape [aut],
Mark Shapley [aut],
Franz Mueter [aut],
Bruce Finney [aut],
Nicole Misarti [aut]

Maintainer Casey Clark <casey.t.clark@gmail.com>

Repository CRAN

Date/Publication 2023-10-20 04:40:02 UTC

R topics documented:

| reg.uptake | *Calculate a regional carbon dioxide uptake constant from empirical DIC data* |

Description

The reg.uptake() function calculates the regional uptake constant required to modify the global Suess effect curve to be region-specific.

Usage

```
reg.uptake(year1, year2, d13c.change)
```

Arguments

year1	The year in which samples were collected for the first set of DIC δ^{13}C observations.
year2	The year in which samples were collected for the second set of DIC δ^{13}C observations.
d13c.change	The observed change in DIC δ^{13}C between the two years.

Details

This function calculates the regional uptake constant used to modify the global Suess effect curve to make it specific to a region. This method requires δ^{13}C values for DIC from the area of interest from two different time points, ideally separated by at least a decade. The function uses the magnitude (i.e., absolute value) of the observed change in DIC δ^{13}C ('d13c.change'), the year of the first observation ('year1'), and the year of the second observation ('year2') to calculate the regional uptake constant. This value can then be supplied as part of the 'custom.region.data' argument (filling a column titled 'up.con') for the SuessR.custom() function.

Value

Returns a numerical value representing the regional uptake constant. This value can be supplied as part of the 'custom.region.data' (filling a column titled 'up.con') argument for the SuessR.custom() function.

Examples

```
year1 <- 1970
year2 <- 1980
d13c.change <- 0.3

reg.uptake(year1 = year1, year2 = year2, d13c.change = d13c.change)
```

---

| SuessR | *Calculate Suess and Laws corrections for stable carbon isotope data from a built-in region* |
|---|---|

---

### Description

Generates region-specific Suess, Laws, and net (Suess + Laws) corrections for stable carbon isotope data $\delta^{13}$C data input by the user. The net correction is then used to calculate the corrected $\delta^{13}$C data, which are supplied in the output. This function is specifically for data from regions currently built into SuessR ("Bering Sea", "Aleutian Islands","Gulf of Alaska", and "Subpolar North Atlantic", as of Version 0.1.5).
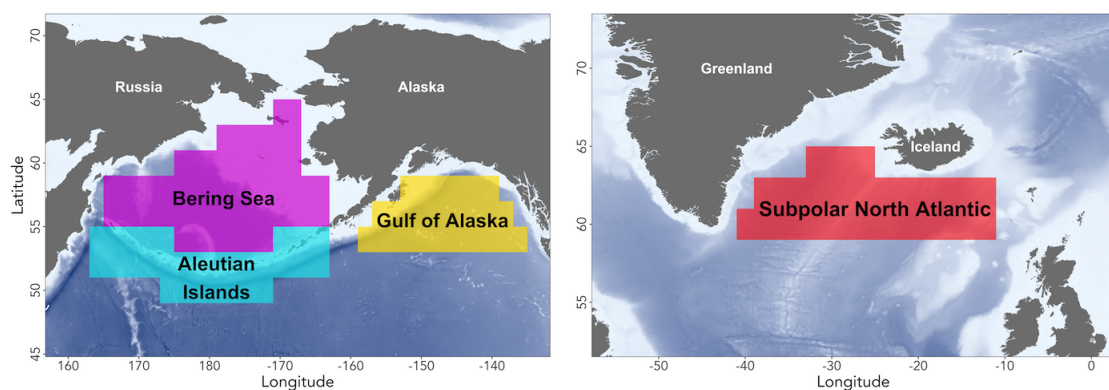


### Usage

```
SuessR(data, correct.to = 1850)
```

Arguments

data	A matrix or data frame including columns containing sample ID ('id'), year of sample collection ('year'), region of sample collection ('region'), and uncorrected δ^{13}C data ('d13c').
correct.to	The year to which the δ^{13}C data will be corrected. Defaults to 1850 (Industrial Revolution).

Details

The SuessR() function uses the year and region of sample collection to calculate Suess, Laws, and net (Suess + Laws) corrections for δ^{13}C data from marine organisms. The Suess Correction represents the change in δ^{13}C values of dissolved inorganic carbon (DIC) in the surface ocean, and is calculated using an exponential function, calibrated to the global decline DIC δ^{13}C values. Surface waters in different regions exhibit varying rates of CO_2 uptake from the atmosphere as a result of differing water mass properties and residence time at the surface. Thus, a region-specific modifier has been calculated from empirical observations of changes in DIC δ^{13}C values through

time and is applied to each region. The Laws correction accounts for changes in stable carbon isotope fractionation during CO_2 uptake and photosynthesis by phytoplankton, and is impacted by changes in aqueous CO_2 concentrations, temperature, and salinity, as well as community growth rates, average cell diameter, average organic carbon content of phytoplankton cells, permeability of the phytoplankton plasmalemma to CO_2, and the ratio of net diffusional loss of CO_2 to carbon fixation. Historic observations and reconstructions of atmospheric CO_2 concentrations, sea surface temperature, and sea surface salinity are used to make these calculations. See references for more details.

This function allows users to correct their data to a specific year, using the 'correct.to' argument. This argument defaults to AD1850, which represents onset of the Industrial Revolution and the initiation of the large-scale combustion of fossil fuels that created the Suess Effect. Correcting data to 1850 allows them to be compared to data from any samples collected during or before 1850 (including archaeological samples), as well as to any other samples Suess corrected to the year 1850. Users examining contemporary datasets may wish to correct their data to another year. For example, a user examining a dataset of δ^{13}C data spanning the years 1970-2010 might choose to correct all their data back to the year 1970, to correct the older samples forward to 2010, or to correct all the samples to 1990, the middle of the time series. In any of these scenarios, corrected data would be comparable to one another. When choosing a value for 'correct.to' consideration should be given to the comparability of the user's data to existing data sets, clarity of presentation of results (i.e., clear statements of the year to which the data were corrected), and reproducibility of results (i.e., presentation of both uncorrected and corrected data so future users can repeat analyses or correct the raw data to another year).

Value

The output of this function is a data frame that includes the sample ID ('id'), year ('year'), uncorrected δ^{13}C ('d13c.uncor'), Laws correction ('Laws.cor'), Suess Correction ('Suess.cor'), net correction ('net.cor'), and corrected δ^{13}C ('d13c.cor') for each sample. The corrected δ^{13}C data is equal to the uncorrected δ^{13}C data plus the net correction. The units for all values are the standard 'per mil' used for δ^{13}C data.

References

Clark, C.T., M.R. Cape, M.D. Shapley, F.J. Mueter, B.P. Finney, and N. Misarti. (In Prep) SuessR: Regional Suess and Laws corrections for δ^{13}C from marine organisms.

Clark, C.T., L. Horstmann, A. de Vernal, A.M. Jensen, and N. Misarti. (2019) Pacific walrus diet across 4000 years of changing sea ice conditions. *Quaternary Research*, 1-17.

Misarti, N., B. Finney, H. Maschner, and M.J. Wooller. (2009) Changes in northeast Pacific marine ecosystems over the last 4500 years: evidence from stable isotope analysis of bone collagen from archaeological middens. *The Holocene*, 19:8. 1139-1151.

Examples

```
example.data <- data.frame(id = c("Sample 1", "Sample 2", "Sample 3", "Sample 4",
                                  "Sample 5", "Sample 6", "Sample 7", "Sample 8"),
                      year = c(2017, 2017, 2017, 2017, 1977, 1977, 1977, 1977),
                      d13c = c(-12, -12, -12, -12, -12, -12, -12, -12),
                      region = c("Bering Sea", "Aleutian Islands",
                                 "Gulf of Alaska", "Subpolar North Atlantic",
```

```
                                            "Bering Sea", "Aleutian Islands",
                                            "Gulf of Alaska", "Subpolar North Atlantic"))

    SuessR(data = example.data)
```

SuessR.custom	*Calculate Suess and Laws corrections for stable carbon isotope data from a custom region*

Description

The SuessR.custom() function generates region-specific Suess, Laws, and net (Suess + Laws) corrections for δ^{13}C data input by the user. The net correction is then used to calculate the corrected δ^{13}C data, which are supplied in the output. This function is specifically for data from regions not currently built into SuessR (i.e., different from "Bering Sea", "Aleutian Islands", "Gulf of Alaska", and "Subpolar North Atlantic", as of Version 0.1.5). Or for scenarios in which users want to change the default parameters used by SuessR for the built-in regions (e.g., averge phytoplankton cell radius).

Usage

```
    SuessR.custom(data, custom.region.data, correct.to = 1850)
```

Arguments

data	A dataframe including sample ID, year of sample collection, uncorrected δ^{13}C data, and region. This function is specifically for data from regions not currently built into SuessR. Columns must be named 'id', 'year', 'd13c', and 'region'.
custom.region.data	
	A data frame containing environmental data for the custom region from which the samples originated. Must contain columns titled 'year', 'region', 'r', 'sst', 'sss', 'CO2atm', 'up.con', and 'Cp'. See details for information on how to supply these parameters appropriately.
correct.to	The year to which the δ^{13}C data will be corrected. Defaults to 1850, pre-Suess effect.

Details

The SuessR.custom() allows users to calculate and apply Suess and Laws corrections to δ^{13}C data from marine organisms collected in a region not currently built into the SuessR package. In Version 0.1.5, the built-in regions are the Bering Sea ('Bering Sea'), the Aleutian archipelago ('Aleutian Islands'), and the Gulf of Alaska ('Gulf of Alaska'). Because the Suess and Laws corrections require region-specific environmental data from 1850-present, users must supply these data using the 'custom.region.data' argument. Once these data have been supplied, this function calculates the corrections exactly like the SuessR() function. See the built-in 'SuessR.reference.data' object for an example template for the data, as well as the references for detailed information on how to compile and supply the appropriate data to the SuessR.custom() function. After compiling these data, please

consider sharing them with the package authors (ctclark 'at' alaska.edu) to be included as built-in regions in future version of this package.

As with the SuessR() function, SuessR.custom() allows users to correct their data to a specific year, using the 'correct.to' argument. This argument defaults to AD1850, which represents onset of the Industrial Revolution and the initiation of the large-scale combusion of fossil fuels that created the Suess Effect. Correcting data to 1850 allows them to be compared to data from any samples collected during or before 1850 (including archaeological samples), as well as to any other samples Suess corrected to the year 1850. Users examining contemporary datasets may wish to correct their data to another time year. For example, a user examining a dataset of δ^{13}C data spanning the years 1970-2010 might choose to correct all their data back to the year 1970, to correct the older samples forward to 2010, or to correct all the samples to 1990, the middle of the time series. In any of these scenarios, corrected data would be comparable to one another. When choosing a value for 'correct.to' consideration should be given to the comparability of the user's data to existing data sets, clarity of presentation of results (i.e., clear statements of the year to which the data were corrected), and reproducibility of results (i.e., presentation of both uncorrected and corrected data so future users can repeat analyses or correct the raw data to another year).

Value

The output of this function is a data frame that includes the sample ID ('id'), year ('year'), uncorrected δ^{13}C ('d13c.uncor'), Laws correction ('Laws.cor'), Suess Correction ('Suess.cor'), net correction ('net.cor'), and corrected δ^{13}C ('d13c.cor') for each sample. The corrected δ^{13}C data is equal to the uncorrected δ^{13}C data plus the net correction. The units for all values are the standard 'per mil' used for δ^{13}C data.

Examples

```
example.region.data <- data.frame(year = seq(from = 1850, to = 2022, by = 1),
                                  region = rep("Example Region", 173),
                                  r = rep(5, 173),
                                  sst = seq(5.9, 6.6, 173),
                                  sss = seq(32.3, 32.7, 173),
                                  CO2atm = SuessR.reference.data$CO2atm[1:173],
                                  up.con = rep(0.014, 173),
                                  Cp = rep(0.41, 173))

example.custom.data <- data.frame(id = c("Sample 1", "Sample 2",
                                         "Sample 3", "Sample 4"),
                                  year = c(1850, 1900, 1950, 2000),
                                  d13c = c(-12, -12, -12, -12),
                                  region = rep("Example Region", 4))

SuessR.custom(data = example.custom.data,
              custom.region.data = example.region.data,
              correct.to = 1850)
```

SuessR.reference.data   *Reference dataset for the SuessR Package*

Description

A dataset containing the information used by SuessR to calculate regional Suess and Laws corrections for δ^{13}C from marine organisms.

Usage

```
SuessR.reference.data
```

Format

A data frame with 692 rows and 8 variables:

year calendar year, 1850-2022

region geographic region, 'Aleutian Islands', 'Bering Sea', 'Gulf of Alaska', or 'Subpolar North Atlantic'

r average cell radius of phytoplankton community, in microns

sst yearly average sea surface temperature, in degrees C

sss yearly average sea surface salinity, in practical salinity units

CO2atm yearly average global atmospheric CO2 concentrations, in parts per million

up.con regional uptake constant for Suess correction, unitless

Cp Proportional change constant of oceanic/atmospheric CO_2 (regional), a proportion

Source

https://psl.noaa.gov/data/gridded/data.noaa.ersst.v5.html

https://iridl.ldeo.columbia.edu/SOURCES/.CARTON-GIESE/.SODA/.v2p2p4/?Set-Language=en

https://coastwatch.noaa.gov/cw/satellite-data-products/sea-surface-salinity/miras-smos.html

https://scrippsco2.ucsd.edu/data/atmospheric_co2/icecore_merged_products.html

References

Clark, C.T., M.R. Cape, M.D. Shapley, F.J. Mueter, B.P. Finney, and N. Misarti. (2021) SuessR: Regional Suess and Laws corrections for δ^{13}C from marine organisms. Methods in Ecology and Evolution. 12(8), 1508-1520.

Huang, B., Thorne, P. W., Banzon, V. F., Boyer, T., Chepurin, G., Lawrimore, J. H., . . . Zhang, H.-M. (2017). NOAA extended reconstructed sea surface temperature (ERSST), version 5. doi:10.7289/V5T72FNM.

Giese, B. S., & Ray, S. (2011). El Niño variability in simple ocean data assimilation (SODA), 1871-2008. Journal of Geophysical Research: Oceans, 116(2), 1–17. doi:10.1029/2010JC006695.

Keeling, C. D., Piper, S. C., Bacastow, R. B., Wahlen, M., Whorf, T. P., Heimann, M., & Meijer, H. A. (2005). Atmospheric CO2 and 13CO2 exchange with the terrestrial biosphere and oceans from 1978 to 2000: Observations and carbon cycle implications. In A history of atmospheric CO2 and its effects on plants, animals, and ecosystems (pp. 83–113). Springer.

MacFarling Meure, C., Etheridge, D., Trudinger, C., Steele, P., Langenfelds, R., Van Ommen, T., . . . Elkins, J. (2006). Law Dome CO2, CH4 and N2O ice core records extended to 2000 years BP. Geophysical Research Letters, 33(14), 2000–2003. doi:10.1029/2006GL026152.

Index