Package 'snvecR'

June 9, 2023

Title Calculate Earth's Obliquity and Precession in the Past

Version 3.7.7

Description Easily calculate precession and obliquity from an orbital solution (defaults to ZB18a from Zeebe and Lourens (2019) <doi:10.1126/science.aax0612>) and assumed or reconstructed values for tidal dissipation (Td) and dynamical ellipticity (Ed). This is a translation and adaptation of the C-code in the supplementary material to Zeebe and Lourens (2022) <doi:10.1029/2021PA004349>, with further details on the methodology described in Zeebe (2022) <doi:10.3847/1538-3881/ac80f8>. The name of the C-routine is snvec, which refers to the key units of computation: spin vector s and orbit normal vector n.

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Encoding UTF-8

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Suggests ggplot2, testthat, roxygen2, knitr, rmarkdown

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VignetteBuilder knitr

URL https://japhir.github.io/snvecR/

NeedsCompilation no

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R topics documented:

`get_solution` *Get an Orbital Solution*

Description

Get an Orbital Solution

Usage

```
get_solution(orbital_solution = "ZB18a", quiet = FALSE, force = FALSE)
```

Arguments

`orbital_solution`	Character vector with the name of the orbital solution to use. One of `"ZB18a"` (default) from Zeebe and Lourens (2019), or `"La11"` (not yet implemented!).
`quiet`	Be quiet? • If `TRUE`, hide info messages. • If `FALSE` (the default) print info messages and timing.
`force`	Force re-downloading the results, even if the solution is saved to the cache.

Value

`get_solution()` returns a tibble with the orbital solution input and some preprocessed new columns.

References

Zeebe, R. E., & Lourens, L. J. (2019). Solar System chaos and the Paleocene–Eocene boundary age constrained by geology and astronomy. *Science*, 365(6456), 926–929. doi:10.1126/science.aax0612.

See Also

`get_ZB18a()`

Examples

```
get_solution()
```

`prepare_solution` *Prepare Orbital Solution*

Description

Calculates helper columns from an orbital solution input.

Usage

```
prepare_solution(data, quiet = FALSE)
```

Arguments

`data`	The output of `get_solution()`. It needs to contain columns: • `t` Time t (days). • `lph` Longitude of perihelion ϖ (degrees). • `lan` Longitude of the ascending node Ω (degrees). • `inc` Inclination I (degrees).
`quiet`	Be quiet? • If `TRUE`, hide info messages. • If `FALSE` (the default) print info messages and timing.

Details

New columns include:

- `lphu` Unwrapped longitude of perihelion ϖ (degrees without jumps).
- `lanu` Unwrapped longitude of the ascending node Ω (degrees without jumps).
- `hh` Variable: $e \sin(\varpi)$.
- `kk` Variable: $e \cos(\varpi)$.
- `pp` Variable: $2 \sin(0.5I) \sin(\Omega)$.
- `qq` Variable: $2 \sin(0.5I) \cos(\Omega)$.
- `cc` Helper: $\cos(I)$.
- `dd` Helper: $\cos(I)/2$.
- `nnx`, `nny`, `nnz` The x, y, and z-components of the Earth's orbit unit normal vector $\vec{n}$, normal to Earth's instantaneous orbital plane.

Value

A tibble with the new columns added.

See Also

`get_ZB18a()` `get_solution()`

snvec *Calculate Earth's Obliquity and Precession in the Past*

Description

`snvec()` computes climatic precession and obliquity (or tilt) from an orbital solution (OS) input and input values for dynamical ellipticity (E_d) and tidal dissipation (T_d). It solves a set of ordinary differential equations.

Usage

```
snvec(
  tend = -1000,
  ed = 1,
  td = 0,
  orbital_solution = "ZB18a",
  tres = 0.4,
  atol = 1e-05,
  rtol = 0,
  solver = "vode",
  quiet = FALSE,
  output = "nice"
)
```

Arguments

`tend`	Final timestep in thousands of years before present (ka). Defaults to `-1000` ka.
`ed`	Dynamical ellipticity E_d, normalized to modern. Defaults to `1.0`.
`td`	Tidal dissipation T_d, normalized to modern. Defaults to `0.0`.
`orbital_solution`	Character vector with the name of the orbital solution to use. One of `"ZB18a"` (default) from Zeebe and Lourens (2019), or `"La11"` (not yet implemented!).
`tres`	Output timestep resolution in thousands of years (kyr). Defaults to `0.4`.
`atol`	Numerical absolute tolerance passed to `deSolve::ode()`'s `atol`. Defaults to `1e-5`.
`rtol`	Numerical relative tolerance passed to `deSolve::ode()`'s `rtol`. Defaults to `0`.
`solver`	Character vector specifying the method passed to `deSolve::ode()`'s `method`. Defaults to `"vode"` for stiff problems with a variable timestep.
`quiet`	Be quiet? • If `TRUE`, hide info messages. • If `FALSE` (the default) print info messages and timing.
`output`	Character vector with name of desired output. One of: • `"nice"` (the default) A tibble with the columns `time`, `age`, `eei`, `epl`, `phi`, `cp`. • `"full"` A tibble with all the computed and interpolated columns. • `"ode"` A matrix with the output of the ODE solver.

Details

This is a re-implementation of the C-code in the supplementary information of Zeebe & Lourens (2022). The terms are explained in detail in Zeebe (2022).

Note that the different ODE solver algorithm we use (Soetaert et al., 2010) means that the R routine returns an evenly-spaced time grid, whereas the C-routine has a variable time-step.

Value

`snvec()` returns different output depending on the `outputs` argument.

If `output = "nice"` (the default), returns a tibble with the following columns:

- `time` Time t (days).
- `age` Age in thousands of years ago (ka).
- `eei` Orbital solution's eccentricity e, interpolated to output timescale (-).
- `epl` Calculated Obliquity ϵ (radians).
- `phi` Calculated Precession ϕ (radians) from ECLIPJ2000.
- `cp` Calculated Climatic precession (-) as $e \sin(\varpi)$.

where ϖ is the longitude of perihelion relative to the moving equinox.

If `output = "all"` (for developers), additional columns are included, typically interpolated to output timescale.

- `sx`, `sy`, `sz` The x, y, and z-components of Earth's spin axis unit vector $\vec{s}$ in the heliocentric inertial reference frame.

See the source code for descriptions of all the intermediate computational steps.

If `output = "ode"`, it will return the raw output of the ODE solver, which is an object of class `deSolve` and `matrix`, with columns `time`, `sx`, `sy`, and `sz` (see above). This can be useful for i.e. `deSolve::diagnostics()`.

References

Zeebe, R. E., & Lourens, L. J. (2019). Solar System chaos and the Paleocene–Eocene boundary age constrained by geology and astronomy. *Science*, 365(6456), 926–929. doi:10.1126/science.aax0612.

Zeebe, R. E., & Lourens, L. J. (2022). A deep-time dating tool for paleo-applications utilizing obliquity and precession cycles: The role of dynamical ellipticity and tidal dissipation. *Paleoceanography and Paleoclimatology*, e2021PA004349. doi:10.1029/2021PA004349.

Zeebe, R. E. (2022). Reduced Variations in Earth's and Mars' Orbital Inclination and Earth's Obliquity from 58 to 48 Myr ago due to Solar System Chaos. *The Astronomical Journal*, 164(3), doi:10.3847/15383881/ac80f8.

Wikipedia page on Orbital Elements: `https://en.wikipedia.org/wiki/Orbital_elements`

Karline Soetaert, Thomas Petzoldt, R. Woodrow Setzer (2010). Solving Differential Equations in R: Package deSolve. Journal of Statistical Software, 33(9), 1–25. doi:10.18637/jss.v033.i09.

See Also

- deSolve::ode() from Soetaert et al., (2010) for the ODE solver that we use.
- get_ZB18a() Documents the default orbital solution input.
- get_solution() A general function that in the future may be used to get other orbital solutions.

Examples

```
# default call

snvec()
# remove the directory with the cached orbital solution to clean up
unlink(tools::R_user_dir("snvecR", which = "cache"), recursive = TRUE)
```

ZB18a *Orbital Solution ZB18a*

Description

The HNBody output of Zeebe & Lourens (2019).

Usage

```
get_ZB18a(quiet = FALSE, force = FALSE)
```

Arguments

quiet	Be quiet? • If TRUE, hide info messages. • If FALSE (the default) print info messages and timing.
force	Force re-downloading the results, even if the solution is saved to the cache.

Format

ZB18a**:**

A data frame with 250,001 rows and 20 columns:

t Time t (days).

age Age in thousands of years before present (ka).

aa Semimajor axis a in astronomical units (au).

ee Eccentricity e (unitless).

inc Inclination I (degrees).

lph Longitude of perihelion ϖ (degrees).

lan Longitude of the ascending node Ω (degrees).

arp Argument of perihelion ω (degrees).

mna Mean anomaly M (degrees).

The following columns were computed from the above input:

lphu Unwrapped longitude of perihelion ϖ (degrees without jumps).

lanu Unwrapped longitude of the ascending node Ω (degrees without jumps).

hh Variable: $e\sin(\varpi)$.

kk Variable: $e\cos(\varpi)$.

pp Variable: $2\sin(0.5I)\sin(\Omega)$.

qq Variable: $2\sin(0.5I)\cos(\Omega)$.

cc Helper: $\cos(I)$.

dd Helper: $\cos(I)/2$.

nnx, nny, nnz The x, y, and z-components of the Eart's orbit unit normal vector $\vec{n}$, normal to Earth's instantaneous orbital plane.

Details

The wikipedia page on Orbital elements describes what the components relate to in order to uniquely specify an orbital plane. The function asks to download the files to the user's cache directory so that they can be accessed more quickly in the future.

Value

`get_ZB18a()` returns a tibble with the orbital solution input and some preprocessed new columns.

Source

- All orbital solutions by Zeebe can be found on `http://www.soest.hawaii.edu/oceanography/faculty/zeebe_files/Astro.html`.
- The specific one we use here is available at `http://www.soest.hawaii.edu/oceanography/faculty/zeebe_files/Astro/PrecTilt/OS/ZB18a/ems-plan3.dat`.

References

Zeebe, R. E., & Lourens, L. J. (2019). Solar System chaos and the Paleocene–Eocene boundary age constrained by geology and astronomy. *Science*, 365(6456), 926–929. doi:10.1126/science.aax0612.

See Also

`prepare_solution()` Processes orbital solution input to include helper columns.

Examples

```
get_ZB18a()
```

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