ExoPlaSim

Release 2.0.4

Adiv Paradise

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Created by Adiv Paradise

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This API was written with Python 3 in mind, but should work with Python 2 and outdated versions of NumPy.

REQUIREMENTS

- netCDF4
- numpy
- a Fortran compiler
- a C compiler
- (optionally) MPI libraries for those compilers

INSTALLATION

```
pip install exoplasim
```

OR:

```
python setup.py install
```

The first time you import the module and try to create a model after either installing or updating, ExoPlaSim will run a configuration script, write the install directory into its source code, and compile the burn7 NetCDF postprocessor. You must have NetCDF libraries available in the path when this happens. The burn7 compilation process will build and compile a patched version of the NetCDF libraries necessary for burn7–burn7 makes use of features anachronistic to a particular version of NetCDF that no longer exists.

You may also configure and compile the model manually if you wish to not use the Python API, by entering the exoplasim/ directory and running first configure.sh, then compile.sh (compilation flags are shown by running `./compile.sh -h`). The postprocessor and its libraries can be compiled by entering `exoplasim/postprocessor/` and running `./build_init.sh`.

PLASIM DOCUMENTATION

Original PlaSim documentation is available in the exoplasim/docs/ folder.

USAGE

To use the ExoPlaSim Python API, you must import the module, create a Model or one of its subclasses, call its configure method and/or modify method, and then run it.

Basic example::

```python
import exoplasim as exo
mymodel = exo.Model(workdir="mymodel_testrun",modelname="mymodel",resolution="T21",
→layers=10,ncpus=8)
mymodel.configure()
mymodel.exportcfg()
mymodel.run(years=100,crashifbroken=True)
mymodel.finalize("mymodel_output")
```

In this example, we initialize a model that will run in the directory "mymodel_testrun", and has the name "mymodel", which will be used to label output and error logs. The model has T21 resolution, or 32x64, 10 layers, and will run on 8 CPUs. By default, the compiler will use 8-byte precision. 4-byte may run slightly faster, but possibly at the cost of reduced stability. If there are machine-specific optimization flags you would like to use when compiling, you may specify them as a string to the optimization argument, e.g. `optimization='mavx'`. ExoPlaSim will check to see if an appropriate executable has already been created, and if not (or if flags indicating special compiler behavior such as debug=True or an optimization flag are set) it will compile one. We then configure the model with all the default parameter choices, which means we will get a model of Earth. We then export the model configurations to a `.cfg` file (named automatically after the model), which will allow the model configuration to be recreated exactly by other users. We run the model for 100 years, with error-handling enabled. Finally, we tell the model to clean up after itself. It will take the most recent output files and rename them after the model name we chose, and delete all the intermediate output and configuration files.

4.1 Package Contents

4.1.1 exoplasim package

Submodules

exoplasim.gcmt module

exception exoplasim.gcmt.**DatafileError**
    Bases: Exception

exception exoplasim.gcmt.**DimensionError**
    Bases: Exception

exception exoplasim.gcmt.**UnitError**
     Bases: Exception

exoplasim.gcmt.**cspatialmath**(*variable*, *lat=None*, *lon=None*, *file=None*, *mean=True*, *time=None*,
                                   ignoreNaNs=True, *lev=None*, *radius=6371000.0*, *poles=False*)
     Compute spatial means or sums of data, but optionally don't go all the way to the poles.

     Sometimes, saying that the latitudes covered go all the way to $\pm 90°$ results in errors, and accurate accounting
     requires excluding the poles themselves. This function is identical to spatialmath, except that it provides that
     option.

     Parameters

   - **variable** (*str, numpy.ndarray*) – The variable to operate on. Can either be a data
     array, or the name of a variable. If the latter, file must be specified.

   - **lat** (*numpy.ndarray, optional*) – Latitude and longitude arrays. If file is provided
     and lat and lon are not, they will be extracted from the file.

   - **lon** (*numpy.ndarray, optional*) – Latitude and longitude arrays. If file is provided
     and lat and lon are not, they will be extracted from the file.

   - **file** (*str, optional*) – Path to a NetCDF output file to open and extract data from.

   - **mean** (*bool, optional*) – If True, compute a global mean. If False, compute a global
     sum.

   - **time** (*int, optional*) – The time index on which to slice. If unspecified, a time
     average will be returned.

   - **ignoreNaNs** (*bool, optional*) – If True, use NaN-safe numpy operators.

   - **lev** (*int, optional*) – If set, slice a 3D spatial array at the specified level.

   - **radius** (*float, optional*) – Radius of the planet in meters. Only used if
     mean=False.

   - **poles** (*bool, optional*) – If False (default), exclude the poles.

     Returns

     Return type float

exoplasim.gcmt.**make2d**(*variable*, *lat=None*, *lon=None*, *time=None*, *lev=None*, *ignoreNaNs=True*)
     Compress a variable in two dimensions by slicing or averaging.

     Parameters

   - **variable** (*numpy.ndarray*) – The variable to operate on

   - **lat** (*int, str, optional*) – Either an index on which to slice, or either of "sum" or
     "mean", indicating what should be done along that axis.

   - **lon** (*int, str, optional*) – Either an index on which to slice, or either of "sum" or
     "mean", indicating what should be done along that axis.

   - **lev** (*int, str, optional*) – Either an index on which to slice, or either of "sum" or
     "mean", indicating what should be done along that axis.

   - **time** (*int, optional*) – The time index on which to slice. If unspecified, a time
     average will be returned.

   - **ignoreNaNs** (*bool, optional*) – If set, will use NaN-safe numpy operators.

     Returns A 2-D array

     Return type numpy.ndarray

exoplasim.gcmt.**parse**(*file*, *variable*, *lat=None*, *lon=None*)

 Retrieve a variable from a NetCDF file

  Parameters

- **file** (*str*) – Path to a NetCDF file

- **variable** (*str*) – Name of the variable to extract

- **lat** (*str, optional*) – If the latitude and longitude arrays have non-standard names, specify them here.

- **lon** (*str, optional*) – If the latitude and longitude arrays have non-standard names, specify them here.

  Returns Requested output field

  Return type numpy.ndarray

exoplasim.gcmt.**spatialmath**(*variable*, *lat=None*, *lon=None*, *file=None*, *mean=True*, *time=None*, *ignoreNaNs=True*, *lev=None*, *radius=6371000.0*)

 Compute spatial means or sums of data

  Parameters

- **variable** (*str, numpy.ndarray*) – The variable to operate on. Can either be a data array, or the name of a variable. If the latter, file must be specified.

- **lat** (*numpy.ndarray, optional*) – Latitude and longitude arrays. If file is provided and lat and lon are not, they will be extracted from the file.

- **lon** (*numpy.ndarray, optional*) – Latitude and longitude arrays. If file is provided and lat and lon are not, they will be extracted from the file.

- **file** (*str, optional*) – Path to a NetCDF output file to open and extract data from.

- **mean** (*bool, optional*) – If True, compute a global mean. If False, compute a global sum.

- **time** (*int, optional*) – The time index on which to slice. If unspecified, a time average will be returned.

- **ignoreNaNs** (*bool, optional*) – If True, use NaN-safe numpy operators.

- **lev** (*int, optional*) – If set, slice a 3D spatial array at the specified level.

- **radius** (*float, optional*) – Radius of the planet in meters. Only used if mean=False.

  Returns

  Return type float

exoplasim.gcmt.**streamfxn**(*file*, *time=None*)

 Return the streamfunction

  Parameters **file** (*str*) – Path to an ExoPlaSim NetCDF output file.

  Returns The streamfunction for the given file.

  Return type numpy.ndarray

exoplasim.gcmt.**wrap2d**(*var*)

 Add one element to the longitude axis to allow for wrapping

Module contents

class exoplasim.**Earthlike**(*resolution='T21'*, *layers=10*, *ncpus=4*, *precision=8*, *debug=False*, *inityear=0*, *recompile=False*, *optimization=None*, *mars=False*, *workdir='most'*, *source=None*, *modelname='MOST_EXP'*)

Bases: *exoplasim.Model*

Create an Earth-like model, but more flexible.

Identical to Model, except configuration options common for Earth-like models requiring slightly more flexibility are the default when configure is called–specifically, 45-minute timestep, snapshot output reporting every 480 timesteps, and a model top pinned to 50 mbar. All these defaults can be overridden.

configure(*timestep=45.0*, *snapshots=480*, ***kwargs*)

Configure the model's namelists and boundary conditions.

The defaults here are appropriate for an Earth model.

Model Operation

noutput [bool, optional] True/False. Whether or not model output should be written. restartfile: Path to a restart file to use for initial conditions. Can be None.

writefrequency [int, optional] How many times per day ExoPlaSim should write output. Ignored by default–default is to write time-averaged output once every 5 days.

timestep [float, optional] Model timestep. Defaults to 45 minutes.

runscript [function , optional] A Python function that accepts a Model object as its first argument. This is the routine that will be run when you issue the Model.run() command. Any keyword arguments passed to run() will be forwarded to the specified function. If not set, the default internal routine will be used.

snapshots [int, optional] How many timesteps should elapse between snapshot outputs. If not set, no snapshots will be written.

highcadence [dict, optional] A dictionary containing the following arguments:

'toggle' [{0,1}] Whether or not high-cadence output should be written (1=yes).

'start' [int] Timestep at which high-cadence output should begin.

'end' [int] Timestep at which high-cadence output should end.

'interval' [int] How many timesteps should elapse between high-cadence outputs.

threshold [float, optional] Energy balance threshold model should run to, if using runtobalance(). Default is <0.05 W/m^2/yr average drift in TOA and surface energy balance over 45-year timescales.

resources [list, optional] A list of paths to any additional files that should be available in the run directory.

otherargs [dict, optional] Any namelist parameters not included by default in the configuration options. These should be passed as a dictionary, with "PARAMETER@namelist" as the form of the dictionary key, and the parameter value passed as a string. e.g. otherargs={"N_RUN_MONTHS@plasim_namelist":'4', "NGUI@plasim_namelist:'1'}

Model Dynamics

columnmode [{None,"-","clear","static","static|clear","clear|static"}, optional] The inclusion of 'static' will disable horizontal advection, forcing ExoPlaSim into a column-only mode of operation. The inclusion of 'clear' will disable the radiative effects of clouds.

drycore [bool, optional] True/False. If True, evaporation is turned off, and a dry atmosphere will be used.

physicsfilter [str, optional] If not an empty string, specifies the physics filter(s) to be used. Filters can be used during the transform from gridpoint to spectral (`"gp"`), and/or during the transform from spectral to gridpoint (`"sp"`). Filter types are "none", "cesaro", "exp", or "lh" (see the Notes for more details). Combinations of filter types and times should be combined with a `|`, e.g. `physicsfilter="gp|exp|sp"` or `physicsfilter="gp|cesaro"`.

filterkappa [float, optional] A constant to be used with the exponential filter. Default is 8.0.

filterpower [int, optional] A constant integer to be used with the exponential filter. Default is 8.

filterLHN0 [float, optional] The constant used in the denominator of the Lander-Hoskins Filter. Default is 15; typically chosen so f(N)=0.1.

diffusionwaven [int, optional] The critical wavenumber beyond which hyperdiffusion is applied. Default is 15 for T21.

qdiffusion [float, optional] Timescale for humidity hyperdiffusion in days. Default for T21 is 0.1.

tdiffusion [float, optional] Timescale for temperature hyperdiffusion in days. Default for T21 is 5.6.

zdiffusion [float, optional] Timescale for vorticity hyperdiffusion in days. Default for T21 is 1.1.

ddiffusion [float, optional] Timescale for divergence hyperdiffusion in days.. Default for T21 is 0.2.

diffusionpower [int, optional] integer exponent used in hyperdiffusion. Default is 2 for T21.

Radiation

flux [float, optional] Incident stellar flux in W/m^2. Default 1367 for Earth.

startemp [float, optional] Effective blackbody temperature for the star. Not used if not set.

starspec [str, optional] Spectral file for the stellar spectrum. Should have two columns and 965 rows, with wavelength in the first column and radiance or intensity in the second. A similarly-named file with the "_hr.dat" suffix must also exist and have 2048 wavelengths.

twobandalbedo [bool, optional] True/False. If True, separate albedos will be calculated for each of the two shortwave bands. If False (default), a single broadband albedo will be computed and used for both.

synchronous [bool, optional] True/False. If True, the Sun is fixed to one longitude in the sky.

substellarlon [float, optional] The longitude of the substellar point, if synchronous==True. Default 180°

pressurebroaden [bool, optional] True/False. If False, pressure-broadening of absorbers no longer depends on surface pressure. Default is True

ozone [bool, optional] True/False. Whether or not forcing from stratospheric ozone should be included.

snowicealbedo [float, optional] A uniform albedo to use for all snow and ice.

soilalbedo [float, optional] A uniform albedo to use for all land.

wetsoil [bool, optional] True/False. If True, land albedo depends on soil moisture (wet=darker).

oceanalbedo [float, optional] A uniform albedo to use for the ocean.

oceanzenith [{"ECHAM-3","ECHAM-6","Lambertian}, optional] The zenith-angle dependence to use for blue-light reflectance from the ocean. Can be `'Lambertian'`/`'uniform'`, `'ECHAM-3'`/`'plasim'`/`'default'`, or `'ECHAM-6'`. The default is `'ECHAM-3'` (synonymous with `'plasim'` and `'default'`), which is the dependence used in the ECHAM-3 model.

Orbital Parameters

year [float, optional] Number of 24-hour days in a sidereal year. Not necessary if eccentricity and obliquity are zero. Defaults if not set to ~365.25 days

rotationperiod [float, optional] Planetary rotation period, in days. Default is 1.0.

eccentricity [float, optional] Orbital eccentricity. If not set, defaults to Earth's (0.016715)

obliquity [float, optional] Axial tilt, in degrees. If not set, defaults to Earth's obliquity (23.441°).

lonvernaleq [float, optional] Longitude of periapse, measured from vernal equinox, in degrees. If not set, defaults to Earth's (102.7°).

fixedorbit [bool, optional] True/False. If True, orbital parameters do not vary over time. If False, variations such as Milankovich cycles will be computed by PlaSim.

Planet Parameters

gravity [float, optional] Surface gravity, in m/s^2. Defaults to 9.80665 m/s^2.

radius [float, optional] Planet radius in Earth radii. Default is 1.0.

orography [float, optional] If set, a scaling factor for topographic relief. If `orography=0.0`, topography will be zeroed-out.

aquaplanet [bool, optional] True/False. If True, the surface will be entirely ocean-covered.

desertplanet [bool, optional] True/False. If True, the surface will be entirely land-covered.

seaice [bool, optional] True/False. If False, disables radiative effects of sea ice (although sea ice itself is still computed).

landmap [str, optional] Path to a `.sra` file containing a land mask for the chosen resolution.

topomap [str, optional] Path to a `.sra` file containing geopotential height map. Must include landmap.

Atmosphere

gascon [float, optional] Effective gas constant. Defaults to 287.0 (Earth), or the gas constant corresponding to the composition specified by partial pressures.

vtype [{0,1,2,3,4,5}, optional] Type of vertical discretization. Can be: 0 Pseudolinear scaling with pressure that maintains resolution near the ground. 1 Linear scaling with pressure. 2 Logarithmic scaling with pressure (resolves high altitudes) 3 Pseudologarithmic scaling with pressure that preserves resolution near the ground. 4 Pseudolinear scaling with pressure, pinned to a specified top pressure. 5 If >10 layers, bottom 10 as if `vtype=4`, and upper layers as if `vtype=2`.

modeltop [float, optional] Pressure of the top layer

tropopause [float, optional] If stratosphere is being included, pressure of the 10th layer (where scheme switches from linear to logarithmic).

stratosphere [bool, optional] True/False. If True, vtype=5 is used, and model is discretized to include a stratosphere.

pressure: float, optional Surface pressure in bars, if not specified through partial pressures.

Gas Partial Pressures

Partial pressures of individual gases can be specified. If pressure and gascon are not explicitly set, these will determine surface pressure, mean molecular weight, and effective gas constant. Note however that Rayleigh scattering assumes an Earth-like composition, and the only absorbers explicitly included in the radiation scheme are CO_2 and H_2O.

pH2 [float, optional] H2 partial pressure in bars.

pHe [float, optional] He partial pressure in bars.

pN2 [float, optional] N2 partial pressure in bars.

pO2 [float, optional] O2 partial pressure in bars.

pH2 [float, optional] H2 partial pressure in bars.

pAr [float, optional] Ar partial pressure in bars.

pNe [float, optional] Ne partial pressure in bars.

pKr [float, optional] Kr partial pressure in bars.

pCO2 [float, optional] CO2 partial pressure in bars. This gets translated into a ppmv concentration, so if you want to specify/vary CO2 but don't need the other gases, specifying pCO2, pressure, and gascon will do the trick. In most use cases, however, just specifying pN2 and pCO2 will give good enough behavior.

pH2O [float, optional] H2O partial pressure in bars. This is only useful in setting the gas constant and surface pressure; it will have no effect on actual moist processes.

Surface Parameters

mldepth [float, optional] Depth of the mixed-layer ocean. Default is 50 meters.

soildepth [float, optional] Scaling factor for the depth of soil layers (default total of 12.4 meters)

cpsoil [float, optional] Heat capacity of the soil, in J/m^3/K. Default is 2.4*10^6.

soilwatercap [float, optional] Water capacity of the soil, in meters. Defaults to 0.5 meters

soilsaturation [float, optional] Initial fractional saturation of the soil. Default is 0.0 (dry).

maxsnow [float, optional] Maximum snow depth (Default is 5 meters; set to -1 to have no limit).

Additional Physics

Carbon-Silicate Weathering

co2weathering [bool, optional] True/False. Toggles whether or not carbon-silicate weathering should be computed. Default is False.

evolveco2 [bool, optional] True/False. If co2weathering==True, toggles whether or not the CO2 partial pressure should be updated every year. Usually the change in pCO2 will be extremely small, so this is not necessary, and weathering experiments try to estimate the average weathering rate for a given climate in order to interpolate timescales between climates, rather than modelling changes in CO2 over time directly.

outgassing [float, optional] The assumed CO2 outgassing rate in units of Earth outgassing. Default is 1.0.

erosionsupplylimit [float, optional] If set, the maximum CO2 weathering rate per year permitted by erosion, in ubars/year. This is not simply a hard cutoff, but follows Foley 2015 so high weathering below the cutoff is also reduced.

See [1]_ for details on the implementation of supply-limited weathering.

Glaciology

glaciers [dict, optional] A dictionary containing the following arguments: toggle : bool

True/False. Whether or not glaciers should be allowed to grow or shrink in thickness, or be formed from persistent snow on land.

mindepth [float] The minimum snow depth in meters of liquid water equivalent that must persist year-round before the grid cell is considered glaciated. Default is 2 meters.

initialh [float] If >=0, covers the land surface with ice sheets of a height given in meterss. If -1, no initial ice sheets are assumed.

Storm Climatology

stormclim [bool, optional] True/False. Toggles whether or not storm climatology (convective available potential energy, maximum potential intensity, ventilation index, etc) should be computed. If True, output fields related to storm climatology will be added to standard output files. Enabling this mode currently roughly doubles the computational cost of the model. This may improve in future updates. Refer to Paradise, et al 2021 for implementation description.

stormcapture [dict, optional] A dictionary containing arguments controlling when high-cadence output is triggered by storm activity. This dictionary must contain 'toggle', which can be either 1 or 0 (yes or no). It may also contain any namelist parameters accepted by hurricanemod.f90, including the following:

toggle [{0,1}] Whether (1) or not (0) to write high-cadence output when storms occur

NKTRIGGER [{0,1}, optional] (0/1=no/yes). Whether or not to use the Komacek, et al 2020 conditions for hurricane cyclogenesis as the output trigger. Default is no.

VITHRESH [float, optional] (nktrigger) Ventilation index threshold for nktrigger output. Default 0.145

VMXTHRESH [float, optional] (nktrigger) Max potential intensity threshold for nktrigger output.Default 33 m/s

LAVTHRESH [float, optional] (nktrigger) Lower-atmosphere vorticity threshold for nktrigger output. Default 1.2*10^-5 s^-1

VRMTHRESH [float, optional] (unused) Ventilation-reduced maximum intensity threshold. Default 0.577

GPITHRESH [float, optional] (default) Genesis Potential Index threshold. Default 0.37.

MINSURFTEMP [float, optional] (default) Min. surface temperature for storm activity. Default 25C

MAXSURFTEMP [float, optional] (default) Max. surface temperature for storm activity. Default 100C

WINDTHRESH [float, optional] (default) Lower-atmosphere maximum wind threshold for storm activity. Default 33 m/s

SWINDTHRESH [float, optional] (default) Minimum surface windspeed for storm activity. Default 20.5 m/s

SIZETHRESH [float, optional] (default) Minimum number of cells that must trigger to start outputDefault 30

ENDTHRESH [float, optional] (default) Minimum number of cells at which point storm output ends.Default 16

MINSTORMLEN [float, optional] (default) Minimum number of timesteps to write output. Default 256

MAXSTORMLEN [float, optional] (default) Maximum number of timesteps to write output. Default 1024

Note that actual number of writes will be stormlen/interval, as set in highcadence. This interval defaults to 4, so 64 writes minimum, 256 max. For more details on the storm climatology factors considered here, see **[5]_**.

Notes

In some cases, it may be necessary to include physics filters. This typically becomes necessary when sharp features are projected on the model's smallest spectral modes, causing Gibbs "ripples". Earth-like models typically do not require filtering, but tidally-locked models do. Filtering may be beneficial for Earth-like models at very high resolutions as well, or if there is sharp topography.

Three filter functional forms are included in ExoPlaSim: Cesaro, exponential, and Lander-Hoskins. Their functional forms are given below, where n is the wavenumber, and N is the truncation wavenumber (e.g. 21 for T21):

Cesaro: $f(n) = 1 - \frac{n}{N+1}$ **[2]_**

Exponential: $f(n) = \exp\left[-\kappa \left(\frac{n}{N}\right)^\gamma\right]$ **[3]_**

Lander-Hoskins: $f(n) = \exp\left[-\left(\frac{n(n+1)}{n_0(n_0+1)}\right)^2\right]$ **[3]_ [4]_**

κ is exposed to the user through `filterkappa`, γ is exposed through `filterpower`, and n_0 is exposed through `filterLHN0`.

Physics filters can be applied at two different points; either at the transform from gridpoint to spectral, or the reverse. We find that in most cases, the ideal usage is to use both. Generally, a filter at the gridpoint->spectral transform is good for dealing with oscillations caused by sharp jumps and small features in the gridpoint tendencies. Conversely, a filter at the spectral->gridpoint transform is good for dealing with oscillations that come from small-scale features in the spectral fields causing small-scale features to appear in the gridpoint tendencies **[3]_**. Since we deal with climate systems where everything is coupled, any oscillations not removed by one filter will be amplified through physical feedbacks if not suppressed by the other filter.

See also:

modify Change model configuration after it has been initialized

References

class exoplasim.**Model**(*resolution='T21'*, *layers=10*, *ncpus=4*, *precision=8*, *debug=False*, *inityear=0*, *recompile=False*, *optimization=None*, *mars=False*, *workdir='most'*, *source=None*, *modelname='MOST_EXP'*)

Bases: `object`

Create an ExoPlaSim model in a particular directory.

Initialize an ExoPlaSim model in a particular directory. If the necessary executable does not yet exist, compile it.

Parameters

- **resolution** (`str, optional`) – The resolution of the model. Options are T21, T42, T63, T85, T106, T127, and T170, corresponding to 32, 64, 96, 128, 160, 192, and 256 latitudes respectively, and twice as many longitudes. ExoPlaSim has been tested and validated most extensively at T21 and T42. Higher resolutions will take considerable time to run.

- **layers** (`int, optional`) – The number of vertical layers in the model atmosphere. The default is 10, but PlaSim has been used with 5 layers in many studies. More layers are supported, but not recommended except at higher resolutions.

- **ncpus** (`int, optional`) – The number of MPI processes to use, typically the number of cores available. If ncpus=1, MPI will not be used.

- **precision** (`int, optional`) – Either 4 or 8–specifies the number of bytes for a Fortran real.

- **debug** (`bool, optional`) – If True, compiler optimizations are disabled and the code is compiled with debugging flags enabled that will allow line-by-line tracebacks if ExoPlaSim crashes. Only use for development purposes.

- **inityear** (`int, optional`) – The number to use for the initial model year (default 0).

- **recompile** (`bool, optional`) – True/False flag used to force a recompile. Cannot force the model to skip compilation if the executable does not exist or compilation-inducing flags are set.

- **optimization** (*str, optional*) – Fortran compiler arguments for optimization. ANY compiler flags can be passed here, but it's intended for optimization flags. Setting this will trigger a recompile.

- **mars** (*bool, optional*) – True/False. If True, will use Mars-specific routines.

- **workdir** (*str, optional*) – The directory in which to construct the model.

- **source** (*str, optional*) – The directory in which to look for executables, namelists, boundary conditions, etc. If not set, will default to exoplasim/plasim/run/.

- **modelname** (*str, optional*) – The name to use for the model and its output files when finished.

Returns An instantiated Model object that resides in a directory with the namelists and executable necessary to run ExoPlaSim.

Return type *Model*

Examples

```
>>> import exoplasim as exo
>>> mymodel = exo.Model(workdir="mymodel_testrun",modelname="mymodel",resolution=
↪"T21",layers=10,ncpus=8)
>>> mymodel.configure()
>>> mymodel.exportcfg()
>>> mymodel.run(years=100,crashifbroken=True)
>>> mymodel.finalize("mymodel_output")
```

In this example, we initialize a model that will run in the directory "mymodel_testrun", and has the name "mymodel", which will be used to label output and error logs. The model has T21 resolution, or 32x64, 10 layers, and will run on 8 CPUs. By default, the compiler will use 8-byte precision. 4-byte may run slightly faster, but possibly at the cost of reduced stability. If there are machine-specific optimization flags you would like to use when compiling, you may specify them as a string to the optimization argument, e.g. optimization='mavx'. ExoPlaSim will check to see if an appropriate executable has already been created, and if not (or if flags indicating special compiler behavior such as debug=True or an optimization flag are set) it will compile one. We then configure the model with all the default parameter choices, which means we will get a model of Earth. We then export the model configurations to a .cfg file (named automatically after the model), which will allow the model configuration to be recreated exactly by other users. We run the model for 100 years, with error-handling enabled. Finally, we tell the model to clean up after itself. It will take the most recent output files and rename them after the model name we chose, and delete all the intermediate output and configuration files.

configure (*noutput=True, flux=1367.0, startemp=None, starspec=None, pH2=None, pHe=None, pN2=None, pO2=None, pCO2=None, pAr=None, pNe=None, pKr=None, pH2O=None, gascon=None, pressure=None, pressurebroaden=True, vtype=0, rotationperiod=24.0, synchronous=False, substellarlon=180.0, year=None, glaciers={'initialh': - 1.0, 'mindepth': 2.0, 'toggle': False}, restartfile=None, gravity=9.80665, radius=1.0, eccentricity=None, obliquity=None, lonvernaleq=None, fixedorbit=False, orography=None, seaice=True, co2weathering=False, evolveco2=False, physicsfilter=None, filterkappa=8.0, filterpower=8, filterLHN0=15.0, diffusionwaven=None, qdiffusion=None, tdiffusion=None, zdiffusion=None, ddiffusion=None, diffusionpower=None, erosionsupplylimit=None, outgassing=50.0, snowicealbedo=None, twobandalbedo=False, maxsnow=None, soilalbedo=None, oceanalbedo=None, oceanzenith='ECHAM-3', wetsoil=False, soilwatercap=None, aquaplanet=False, desertplanet=False, soilsaturation=None, drycore=False, ozone=True, cpsoil=None, soildepth=1.0, mldepth=50.0, writefrequency=None, modeltop=None, stratosphere=False, tropopause=None, timestep=45.0, runscript=None, columnmode=None, highcadence={'end': 576, 'interval': 4, 'start': 320, 'toggle': 0}, snapshots=None, resources=[], landmap=None, stormclim=False, nstorms=4, stormcapture={'ENDTHRESH': 16, 'GPITHRESH': 0.37, 'LAVTHRESH': 1.2e-05, 'MAXSTORMLEN': 1024, 'MAXSURFTEMP': 373.15, 'MINSTORMLEN': 256, 'MINSURFTEMP': 298.15, 'NKTRIGGER': 0, 'SIZETHRESH': 30, 'SWINDTHRESH': 20.5, 'VITHRESH': 0.145, 'VMXTHRESH': 33.0, 'VRMTHRESH': 0.577, 'WINDTHRESH': 33.0, 'toggle': 0}, topomap=None, threshold=0.0005, otherargs={})*

Configure the model's namelists and boundary conditions.

> The defaults here are appropriate for an Earth model.

> ### Model Operation

>> **noutput** [bool, optional] True/False. Whether or not model output should be written. restartfile: Path to a restart file to use for initial conditions. Can be None.

>> **writefrequency** [int, optional] How many times per day ExoPlaSim should write output. Ignored by default–default is to write time-averaged output once every 5 days.

>> **timestep** [float, optional] Model timestep. Defaults to 45 minutes.

>> **runscript** [function , optional] A Python function that accepts a Model object as its first argument. This is the routine that will be run when you issue the Model.run() command. Any keyword arguments passed to run() will be forwarded to the specified function. If not set, the default internal routine will be used.

>> **snapshots** [int, optional] How many timesteps should elapse between snapshot outputs. If not set, no snapshots will be written.

>> **highcadence** [dict, optional] A dictionary containing the following arguments:

>>> **'toggle'** [{0,1}] Whether or not high-cadence output should be written (1=yes).

>>> **'start'** [int] Timestep at which high-cadence output should begin.

>>> **'end'** [int] Timestep at which high-cadence output should end.

>>> **'interval'** [int] How many timesteps should elapse between high-cadence outputs.

>> **threshold** [float, optional] Energy balance threshold model should run to, if using runtobalance(). Default is <0.05 W/m^2/yr average drift in TOA and surface energy balance over 45-year timescales.

resources [list, optional] A list of paths to any additional files that should be available in the run directory.

otherargs [dict, optional] Any namelist parameters not included by default in the configuration options. These should be passed as a dictionary, with "PARAMETER@namelist" as the form of the dictionary key, and the parameter value passed as a string. e.g. `otherargs={"N_RUN_MONTHS@plasim_namelist":'4', "NGUI@plasim_namelist:'1'}`

Model Dynamics

columnmode [{None,"-","clear","static","static|clear","clear|static"}, optional] The inclusion of 'static' will disable horizontal advection, forcing ExoPlaSim into a column-only mode of operation. The inclusion of 'clear' will disable the radiative effects of clouds.

drycore [bool, optional] True/False. If True, evaporation is turned off, and a dry atmosphere will be used.

physicsfilter [str, optional] If not an empty string, specifies the physics filter(s) to be used. Filters can be used during the transform from gridpoint to spectral (`"gp"`), and/or during the transform from spectral to gridpoint (`"sp"`). Filter types are "none", "cesaro", "exp", or "lh" (see the Notes for more details). Combinations of filter types and times should be combined with a `|`, e.g. `physicsfilter="gp|exp|sp"` or `physicsfilter="gp|cesaro"`.

filterkappa [float, optional] A constant to be used with the exponential filter. Default is 8.0.

filterpower [int, optional] A constant integer to be used with the exponential filter. Default is 8.

filterLHN0 [float, optional] The constant used in the denominator of the Lander-Hoskins Filter. Default is 15; typically chosen so f(N)=0.1.

diffusionwaven [int, optional] The critical wavenumber beyond which hyperdiffusion is applied. Default is 15 for T21.

qdiffusion [float, optional] Timescale for humidity hyperdiffusion in days. Default for T21 is 0.1.

tdiffusion [float, optional] Timescale for temperature hyperdiffusion in days. Default for T21 is 5.6.

zdiffusion [float, optional] Timescale for vorticity hyperdiffusion in days. Default for T21 is 1.1.

ddiffusion [float, optional] Timescale for divergence hyperdiffusion in days.. Default for T21 is 0.2.

diffusionpower [int, optional] integer exponent used in hyperdiffusion. Default is 2 for T21.

Radiation

flux [float, optional] Incident stellar flux in W/m^2. Default 1367 for Earth.

startemp [float, optional] Effective blackbody temperature for the star. Not used if not set.

starspec [str, optional] Spectral file for the stellar spectrum. Should have two columns and 965 rows, with wavelength in the first column and radiance or intensity in the second. A similarly-named file with the "_hr.dat" suffix must also exist and have 2048 wavelengths.

twobandalbedo [bool, optional] True/False. If True, separate albedos will be calculated for each of the two shortwave bands. If False (default), a single broadband albedo will be computed and used for both.

synchronous [bool, optional] True/False. If True, the Sun is fixed to one longitude in the sky.

substellarlon [float, optional] The longitude of the substellar point, if synchronous==True. Default 180°

pressurebroaden [bool, optional] True/False. If False, pressure-broadening of absorbers no longer depends on surface pressure. Default is True

ozone [bool, optional] True/False. Whether or not forcing from stratospheric ozone should be included.

snowicealbedo [float, optional] A uniform albedo to use for all snow and ice.

soilalbedo [float, optional] A uniform albedo to use for all land.

wetsoil [bool, optional] True/False. If True, land albedo depends on soil moisture (wet=darker).

oceanalbedo [float, optional] A uniform albedo to use for the ocean.

oceanzenith [{"ECHAM-3","ECHAM-6","Lambertian}, optional] The zenith-angle dependence to use for blue-light reflectance from the ocean. Can be `'Lambertian'`/`'uniform'`, `'ECHAM-3'`/`'plasim'`/`'default'`, or `'ECHAM-6'`. The default is `'ECHAM-3'` (synonymous with `'plasim'` and `'default'`), which is the dependence used in the ECHAM-3 model.

Orbital Parameters

year [float, optional] Number of 24-hour days in a sidereal year. Not necessary if eccentricity and obliquity are zero. Defaults if not set to ~365.25 days

rotationperiod [float, optional] Planetary rotation period, in days. Default is 1.0.

eccentricity [float, optional] Orbital eccentricity. If not set, defaults to Earth's (0.016715)

obliquity [float, optional] Axial tilt, in degrees. If not set, defaults to Earth's obliquity (23.441°).

lonvernaleq [float, optional] Longitude of periapse, measured from vernal equinox, in degrees. If not set, defaults to Earth's (102.7°).

fixedorbit [bool, optional] True/False. If True, orbital parameters do not vary over time. If False, variations such as Milankovich cycles will be computed by PlaSim.

Planet Parameters

gravity [float, optional] Surface gravity, in m/s^2. Defaults to 9.80665 m/s^2.

radius [float, optional] Planet radius in Earth radii. Default is 1.0.

orography [float, optional] If set, a scaling factor for topographic relief. If `orography=0.0`, topography will be zeroed-out.

aquaplanet [bool, optional] True/False. If True, the surface will be entirely ocean-covered.

desertplanet [bool, optional] True/False. If True, the surface will be entirely land-covered.

seaice [bool, optional] True/False. If False, disables radiative effects of sea ice (although sea ice itself is still computed).

landmap [str, optional] Path to a `.sra` file containing a land mask for the chosen resolution.

topomap [str, optional] Path to a `.sra` file containing geopotential height map. Must include landmap.

Atmosphere

gascon [float, optional] Effective gas constant. Defaults to 287.0 (Earth), or the gas constant corresponding to the composition specified by partial pressures.

vtype [{0,1,2,3,4,5}, optional] Type of vertical discretization. Can be: 0 Pseudo-linear scaling with pressure that maintains resolution near the ground. 1 Linear scaling with pressure. 2 Logarithmic scaling with pressure (resolves high altitudes) 3 Pseudologarithmic scaling with pressure that preserves resolution near the ground. 4 Pseudolinear scaling with pressure, pinned to a specified top pressure. 5 If >10 layers, bottom 10 as if `vtype=4`, and upper layers as if `vtype=2`.

modeltop [float, optional] Pressure of the top layer

tropopause [float, optional] If stratosphere is being included, pressure of the 10th layer (where scheme switches from linear to logarithmic).

stratosphere [bool, optional] True/False. If True, vtype=5 is used, and model is discretized to include a stratosphere.

pressure: float, optional Surface pressure in bars, if not specified through partial pressures.

Gas Partial Pressures

Partial pressures of individual gases can be specified. If pressure and gascon are not explicitly set, these will determine surface pressure, mean molecular weight, and effective gas constant. Note however that Rayleigh scattering assumes an Earth-like composition, and the only absorbers explicitly included in the radiation scheme are CO_2 and H_2O.

pH2 [float, optional] H2 partial pressure in bars.

pHe [float, optional] He partial pressure in bars.

pN2 [float, optional] N2 partial pressure in bars.

pO2 [float, optional] O2 partial pressure in bars.

pH2 [float, optional] H2 partial pressure in bars.

pAr [float, optional] Ar partial pressure in bars.

pNe [float, optional] Ne partial pressure in bars.

pKr [float, optional] Kr partial pressure in bars.

pCO2 [float, optional] CO2 partial pressure in bars. This gets translated into a ppmv concentration, so if you want to specify/vary CO2 but don't need the other gases, specifying pCO2, pressure, and gascon will do the trick. In most use cases, however, just specifying pN2 and pCO2 will give good enough behavior.

pH2O [float, optional] H2O partial pressure in bars. This is only useful in setting the gas constant and surface pressure; it will have no effect on actual moist processes.

Surface Parameters

mldepth [float, optional] Depth of the mixed-layer ocean. Default is 50 meters.

soildepth [float, optional] Scaling factor for the depth of soil layers (default total of 12.4 meters)

cpsoil [float, optional] Heat capacity of the soil, in J/m^3/K. Default is 2.4*10^6.

soilwatercap [float, optional] Water capacity of the soil, in meters. Defaults to 0.5 meters

soilsaturation [float, optional] Initial fractional saturation of the soil. Default is 0.0 (dry).

maxsnow [float, optional] Maximum snow depth (Default is 5 meters; set to -1 to have no limit).

Additional Physics

Carbon-Silicate Weathering

co2weathering [bool, optional] True/False. Toggles whether or not carbon-silicate weathering should be computed. Default is False.

evolveco2 [bool, optional] True/False. If co2weathering==True, toggles whether or not the CO2 partial pressure should be updated every year. Usually the change in pCO2 will be extremely small, so this is not necessary, and weathering experiments try to estimate the average weathering rate for a given climate in order to interpolate timescales between climates, rather than modelling changes in CO2 over time directly.

outgassing [float, optional] The assumed CO2 outgassing rate in units of Earth outgassing. Default is 1.0.

erosionsupplylimit [float, optional] If set, the maximum CO2 weathering rate per year permitted by erosion, in ubars/year. This is not simply a hard cutoff, but follows Foley 2015 so high weathering below the cutoff is also reduced.

See [1]_ for details on the implementation of supply-limited weathering.

Glaciology

glaciers [dict, optional] A dictionary containing the following arguments: toggle : bool

> True/False. Whether or not glaciers should be allowed to grow or shrink in thickness, or be formed from persistent snow on land.

mindepth [float] The minimum snow depth in meters of liquid water equivalent that must persist year-round before the grid cell is considered glaciated. Default is 2 meters.

initialh [float] If >=0, covers the land surface with ice sheets of a height given in meterss. If -1, no initial ice sheets are assumed.

Storm Climatology

stormclim [bool, optional] True/False. Toggles whether or not storm climatology (convective available potential energy, maximum potential intensity, ventilation index, etc) should be computed. If True, output fields related to storm climatology will be added to standard output files. Enabling this mode currently roughly doubles the computational cost of the model. This may improve in future updates. Refer to Paradise, et al 2021 for implementation description.

stormcapture [dict, optional] A dictionary containing arguments controlling when high-cadence output is triggered by storm activity. This dictionary must contain 'toggle', which can be either 1 or 0 (yes or no). It may also contain any namelist parameters accepted by hurricanemod.f90, including the following:

toggle [{0,1}] Whether (1) or not (0) to write high-cadence output when storms occur

NKTRIGGER [{0,1}, optional] (0/1=no/yes). Whether or not to use the Komacek, et al 2020 conditions for hurricane cyclogenesis as the output trigger. Default is no.

VITHRESH [float, optional] (nktrigger) Ventilation index threshold for nktrigger output. Default 0.145

VMXTHRESH [float, optional] (nktrigger) Max potential intensity threshold for nktrigger output.Default 33 m/s

LAVTHRESH [float, optional] (nktrigger) Lower-atmosphere vorticity threshold for nktrigger output. Default 1.2*10^-5 s^-1

VRMTHRESH [float, optional] (unused) Ventilation-reduced maximum intensity threshold. Default 0.577

GPITHRESH [float, optional] (default) Genesis Potential Index threshold. Default 0.37.

MINSURFTEMP [float, optional] (default) Min. surface temperature for storm activity. Default 25C

MAXSURFTEMP [float, optional] (default) Max. surface temperature for storm activity. Default 100C

WINDTHRESH [float, optional] (default) Lower-atmosphere maximum wind threshold for storm activity. Default 33 m/s

SWINDTHRESH [float, optional] (default) Minimum surface windspeed for storm activity. Default 20.5 m/s

SIZETHRESH [float, optional] (default) Minimum number of cells that must trigger to start outputDefault 30

ENDTHRESH [float, optional] (default) Minimum number of cells at which point storm output ends.Default 16

MINSTORMLEN [float, optional] (default) Minimum number of timesteps to write output. Default 256

MAXSTORMLEN [float, optional] (default) Maximum number of timesteps to write output. Default 1024

Note that actual number of writes will be stormlen/interval, as set in highcadence. This interval defaults to 4, so 64 writes minimum, 256 max. For more details on the storm climatology factors considered here, see **[5]**_.

Notes

In some cases, it may be necessary to include physics filters. This typically becomes necessary when sharp features are projected on the model's smallest spectral modes, causing Gibbs "ripples". Earth-like models typically do not require filtering, but tidally-locked models do. Filtering may be beneficial for Earth-like models at very high resolutions as well, or if there is sharp topography.

Three filter functional forms are included in ExoPlaSim: Cesaro, exponential, and Lander-Hoskins. Their functional forms are given below, where n is the wavenumber, and N is the truncation wavenumber (e.g. 21 for T21):

Cesaro: $f(n) = 1 - \frac{n}{N+1}$ **[2]_**

Exponential: $f(n) = \exp\left[-\kappa\left(\frac{n}{N}\right)^\gamma\right]$ **[3]_**

Lander-Hoskins: $f(n) = \exp\left[-\left(\frac{n(n+1)}{n_0(n_0+1)}\right)^2\right]$ **[3]_ [4]_**

κ is exposed to the user through `filterkappa`, γ is exposed through `filterpower`, and n_0 is exposed through `filterLHN0`.

Physics filters can be applied at two different points; either at the transform from gridpoint to spectral, or the reverse. We find that in most cases, the ideal usage is to use both. Generally, a filter at the gridpoint->spectral transform is good for dealing with oscillations caused by sharp jumps and small features in the gridpoint tendencies. Conversely, a filter at the spectral->gridpoint transform is good for dealing with oscillations that come from small-scale features in the spectral fields causing small-scale features to appear in the gridpoint tendencies **[3]_**. Since we deal with climate systems where everything is coupled, any oscillations not removed by one filter will be amplified through physical feedbacks if not suppressed by the other filter.

See also:

modify Change model configuration after it has been initialized

References

exportcfg (*filename=None*)

Export model configuration to a text file that can be used as configuration input

Write the current model configuration to a text file. This file can be shared and used by other users to recreate your model configuration.

> **Parameters filename** (*str, optional*) – Path to the file that should be written. If None (default), <modelname>.cfg will be created in the working directory.

See also:

loadconfig Load a saved configuration.

finalize (*outputdir*, *allyears=False*, *keeprestarts=False*, *clean=True*)

Move outputs and optionally restarts to a specified output directory.

If more than the final year of output is being kept, a folder will be created in the output directory using the model name. Otherwise, finalized files will be renamed using the model name.

> **Parameters**
>
> - **outputdir** (*str*) – Directory in which to put output.

- **allyears** (*bool, optional*) – True/False. If True, output from all years will be kept, in a directory in outputdir named with the model name. Otherwise, the most recent year will be kept in outputdir, using the model name. Default False.

- **keeprestarts** (*bool, optional*) – True/False: If True, restart files will be kept as well as output files. Default False.

- **clean** (*bool, optional*) – True/False. If True, the original working directory will be deleted after files are moved. Default True.

get (*year*, *snapshot=False*, *highcadence=False*)

    Return an open NetCDF data object for the given year. Defaults is to return time-averaged output.

    Parameters

- **year** (*int*) – Integer year of output to return

- **snapshot** (*bool, optional*) – True/False. If True, return the snapshot version.

- **highcadence** (*bool, optional*) – True/False. If True, return the high-cadence version.

    Returns An open netCDF4 data opject

    Return type netCDF4.Dataset

getbalance (*key*, *year=- 1*)

    Return the global annual mean of a given variable for a given year

    Parameters

- **key** (*str*) – The output variable string to return

- **year** (*int, optional*) – Which year to go to for output

    Returns Global annual mean of requested quantity

    Return type float

gethistory (*key='ts'*, *mean=True*, *layer=- 1*)

    Return the an array of global annual means of a given variable for each year

    Parameters

- **key** (*str, optional*) – The output variable string to return

- **mean** (*bool, optional*) – Toggle whether we return the mean or the sum

- **year** (*int, optional*) – Which year to go to for output

    Returns 1-D Array of global annual means

    Return type numpy.ndarray

inspect (*variable*, *year=- 1*, *ignoreNaNs=True*, *snapshot=False*, *highcadence=False*, *savg=False*, *tavg=False*, *layer=None*)

    Return a given output variable from a given year, with optional averaging parameters.

    Parameters

- **variable** (*str*) – The name of the variable to return.

- **year** (*int, optional*) – Which year of output to return. Year indexing follows Pythonic rules. If the model has been finalized, only the final year of output will be returned.

- **ignoreNaNs** (*bool, optional*) – True/False. If True, use NaN-tolerant numpy functions.

- **snapshot** (*bool, optional*) – True/False. If True, use snapshot output instead of time-averaged.

- **highcadence** (*bool, optional*) – True/False. If True, use high-cadednce output instead of time-averaged.

- **savg** (*bool, optional*) – True/False. If True, compute the spatial average. Default False

- **tavg** (*bool, optional*) – True/False. If True, compute the annual average. Default False

- **layer** (*int, optional*) – If specified and data has 3 spatial dimensions, extract the specified layer. If unspecified and data has 3 spatial dimensions, the vertical dimension will be preserved (even if spatial averages are being computed).

   Returns The requested data, averaged if that was requested.

   Return type float or numpy.ndarray

integritycheck (*ncfile*)
   Check an output file to see it contains the expected variables and isn't full of NaNs.

   If the file does not exist, exoplasim will attempt to create it using the postprocessor. If the file does not have the expected variables or is full of trash, an exception will be raised. If the file is fine, this function returns a 1. If the file did not exist and cannot be created, this function will return a 0.

      Parameters **ncfile** (*str*) – The output file to check.

      Returns 0 or 1 depending on failure or success respectively

      Return type int

loadconfig (*configfile*)
   Load a previously-exported configuration file and configure the model accordingly.

      Parameters **configfile** (*str*) – Path to the configuration file to load

   See also:

   exportcfg Export model configuration to a text file.

modify (***kwargs*)
   Modify any already-configured parameters. All parameters accepted by configure() can be passed as arguments.

   See also:

   configure Set model parameters and boundary conditions

postprocess (*inputfile*, *namelist*, *log='postprocess.log'*, *crashifbroken=False*)
   Produce NetCDF output from an input file, using a specified postprocessing namelist.

      Parameters

         - **inputfile** (*str*) – The raw output file to be processed

         - **namelist** (*str*) – The burn7 namelist to use

         - **log** (*str, optional*) – The log file to which burn7 should output standard output and errors

         - **crashifbroken** (*bool, optional*) – True/False. If True, exoplasim will run .integritycheck() on the file.

> > **Returns** 1 if successful, 0 if not
>
> > **Return type** int

run(***kwargs*)

> Run the Model's designated run routine.
>
> This may have been passed as runscript when the model was created, or it could be the model's internal ._run() routine. That method takes the following arguments:
>
> > **Parameters**
> >
> > - **years** (*int, optional*) – Number of years to run
> >
> > - **postprocess** (*bool, optional*) – True/False. Whether or not NetCDF files should be produced on-the-fly
> >
> > - **crashifbroken** (*bool, optional*) – True/False. If True, use Pythonic error handling
> >
> > - **clean** (*bool, optional*) – True/False. If True, delete raw output files once NetCDF files are made

runtobalance(*threshold=None*, *baseline=50*, *maxyears=300*, *minyears=75*, *timelimit=None*, *crashifbroken=True*, *clean=True*)

> Run the model until energy balance equilibrium is reached at the top and surface.
>
> > **Parameters**
> >
> > - **threshold** (*float, optional*) – If specified, overrides the threshold set by `.config()`. The model will run until the energy balance at the top and surface drifts by less than this amount per year over a given baseline.
> >
> > - **baseline** (*int, optional*) – The number of years over which to evaluate energy balance drift. Default 50
> >
> > - **maxyears** (*int, optional*) – The maximum number of years to run before returning. Default 300. This is useful if you are running on a scratch disk with limited space.
> >
> > - **minyears** (*int, optional*) – The minimum number of years to run before determining that the model is in equilibrium.
> >
> > - **timelimit** (*float, optional*) – If set, maxyears will be revised each year based on the average minutes per year thus far, to try to avoid going over the time limit, which should be given in minutes.
> >
> > - **crashifbroken** (*bool, optional*) – True/False. If True, Pythonic error handling is enabled. Default True.
> >
> > - **clean** (*bool, optional*) – True/False. If True, raw output is deleted once postprocessed. Default True.
> >
> > **Returns** True if the model reached equilibrium, False if not.
> >
> > **Return type** bool

save(*filename=None*)

> Save the current Model object to a NumPy save file.
>
> The model object can then be reinstantiated using `numpy.load(savefile).item()`.
>
> > **Parameters** **filename** (*str, optional*) – Filename to save to. If unspecified, will default to <modelname>.npy.

Notes

Note that these files are often not portable between versions of Python or machine architectures, so their use is only recommended internally. For sharing with other users, it is recommended that you use the `.exportcfg()` function.

See also:

exportcfg Export model configuration to a portable text file.

class exoplasim.**TLaquaplanet**(*resolution='T21'*, *layers=10*, *ncpus=4*, *precision=8*, *debug=False*, *inityear=0*, *recompile=False*, *optimization=None*, *mars=False*, *workdir='most'*, *source=None*, *modelname='MOST_EXP'*)

Bases: *exoplasim.Model*

Create a tidally-locked planet with no land.

Identical to Model, except configuration options suitable for tidally-locked models are the default when configure() is called, and the surface is entirely ocean-covered. Specifically, a 30-minute timestep, snapshot outputs every 720 timesteps, eccentricity=0.0, 0-degree obliquity, exponential physics filtering, fixed orbital parameters, and no ozone. All these defaults can be overridden.

configure(*timestep=30.0*, *snapshots=720*, *eccentricity=0.0*, *ozone=False*, *obliquity=0.0*, *physicsfilter='gp|exp|sp'*, ***kwargs*)

Configure the model's namelists and boundary conditions.

> The defaults here are appropriate for an Earth model.

> **Model Operation**

> > **noutput** [bool, optional] True/False. Whether or not model output should be written. restartfile: Path to a restart file to use for initial conditions. Can be None.

> > **writefrequency** [int, optional] How many times per day ExoPlaSim should write output. Ignored by default–default is to write time-averaged output once every 5 days.

> > **timestep** [float, optional] Model timestep. Defaults to 45 minutes.

> > **runscript** [function , optional] A Python function that accepts a Model object as its first argument. This is the routine that will be run when you issue the Model.run() command. Any keyword arguments passed to run() will be forwarded to the specified function. If not set, the default internal routine will be used.

> > **snapshots** [int, optional] How many timesteps should elapse between snapshot outputs. If not set, no snapshots will be written.

> > **highcadence** [dict, optional] A dictionary containing the following arguments:

> > > **'toggle'** [{0,1}] Whether or not high-cadence output should be written (1=yes).

> > > **'start'** [int] Timestep at which high-cadence output should begin.

> > > **'end'** [int] Timestep at which high-cadence output should end.

> > > **'interval'** [int] How many timesteps should elapse between high-cadence outputs.

> > **threshold** [float, optional] Energy balance threshold model should run to, if using runtobalance(). Default is <0.05 W/m^2/yr average drift in TOA and surface energy balance over 45-year timescales.

resources [list, optional] A list of paths to any additional files that should be available in the run directory.

otherargs [dict, optional] Any namelist parameters not included by default in the configuration options. These should be passed as a dictionary, with "PARAMETER@namelist" as the form of the dictionary key, and the parameter value passed as a string. e.g. `otherargs={"N_RUN_MONTHS@plasim_namelist":'4', "NGUI@plasim_namelist:'1'}`

Model Dynamics

columnmode [{None,"-","clear","static","static|clear","clear|static"}, optional] The inclusion of 'static' will disable horizontal advection, forcing ExoPlaSim into a column-only mode of operation. The inclusion of 'clear' will disable the radiative effects of clouds.

drycore [bool, optional] True/False. If True, evaporation is turned off, and a dry atmosphere will be used.

physicsfilter [str, optional] If not an empty string, specifies the physics filter(s) to be used. Filters can be used during the transform from gridpoint to spectral (`"gp"`), and/or during the transform from spectral to gridpoint (`"sp"`). Filter types are "none", "cesaro", "exp", or "lh" (see the Notes for more details). Combinations of filter types and times should be combined with a `|`, e.g. `physicsfilter="gp|exp|sp"` or `physicsfilter="gp|cesaro"`.

filterkappa [float, optional] A constant to be used with the exponential filter. Default is 8.0.

filterpower [int, optional] A constant integer to be used with the exponential filter. Default is 8.

filterLHN0 [float, optional] The constant used in the denominator of the Lander-Hoskins Filter. Default is 15; typically chosen so f(N)=0.1.

diffusionwaven [int, optional] The critical wavenumber beyond which hyperdiffusion is applied. Default is 15 for T21.

qdiffusion [float, optional] Timescale for humidity hyperdiffusion in days. Default for T21 is 0.1.

tdiffusion [float, optional] Timescale for temperature hyperdiffusion in days. Default for T21 is 5.6.

zdiffusion [float, optional] Timescale for vorticity hyperdiffusion in days. Default for T21 is 1.1.

ddiffusion [float, optional] Timescale for divergence hyperdiffusion in days.. Default for T21 is 0.2.

diffusionpower [int, optional] integer exponent used in hyperdiffusion. Default is 2 for T21.

Radiation

flux [float, optional] Incident stellar flux in W/m^2. Default 1367 for Earth.

startemp [float, optional] Effective blackbody temperature for the star. Not used if not set.

---

starspec [str, optional] Spectral file for the stellar spectrum. Should have two columns and 965 rows, with wavelength in the first column and radiance or intensity in the second. A similarly-named file with the "_hr.dat" suffix must also exist and have 2048 wavelengths.

twobandalbedo [bool, optional] True/False. If True, separate albedos will be calculated for each of the two shortwave bands. If False (default), a single broadband albedo will be computed and used for both.

synchronous [bool, optional] True/False. If True, the Sun is fixed to one longitude in the sky.

substellarlon [float, optional] The longitude of the substellar point, if synchronous==True. Default 180°

pressurebroaden [bool, optional] True/False. If False, pressure-broadening of absorbers no longer depends on surface pressure. Default is True

ozone [bool, optional] True/False. Whether or not forcing from stratospheric ozone should be included.

snowicealbedo [float, optional] A uniform albedo to use for all snow and ice.

soilalbedo [float, optional] A uniform albedo to use for all land.

wetsoil [bool, optional] True/False. If True, land albedo depends on soil moisture (wet=darker).

oceanalbedo [float, optional] A uniform albedo to use for the ocean.

oceanzenith [{"ECHAM-3","ECHAM-6","Lambertian}, optional] The zenith-angle dependence to use for blue-light reflectance from the ocean. Can be `'Lambertian'`/`'uniform'`, `'ECHAM-3'`/`'plasim'`/`'default'`, or `'ECHAM-6'`. The default is `'ECHAM-3'` (synonymous with `'plasim'` and `'default'`), which is the dependence used in the ECHAM-3 model.

Orbital Parameters

year [float, optional] Number of 24-hour days in a sidereal year. Not necessary if eccentricity and obliquity are zero. Defaults if not set to ~365.25 days

rotationperiod [float, optional] Planetary rotation period, in days. Default is 1.0.

eccentricity [float, optional] Orbital eccentricity. If not set, defaults to Earth's (0.016715)

obliquity [float, optional] Axial tilt, in degrees. If not set, defaults to Earth's obliquity (23.441°).

lonvernaleq [float, optional] Longitude of periapse, measured from vernal equinox, in degrees. If not set, defaults to Earth's (102.7°).

fixedorbit [bool, optional] True/False. If True, orbital parameters do not vary over time. If False, variations such as Milankovich cycles will be computed by PlaSim.

Planet Parameters

gravity [float, optional] Surface gravity, in m/s^2. Defaults to 9.80665 m/s^2.

radius [float, optional] Planet radius in Earth radii. Default is 1.0.

orography [float, optional] If set, a scaling factor for topographic relief. If `orography=0.0`, topography will be zeroed-out.

aquaplanet [bool, optional] True/False. If True, the surface will be entirely ocean-covered.

desertplanet [bool, optional] True/False. If True, the surface will be entirely land-covered.

seaice [bool, optional] True/False. If False, disables radiative effects of sea ice (although sea ice itself is still computed).

landmap [str, optional] Path to a `.sra` file containing a land mask for the chosen resolution.

topomap [str, optional] Path to a `.sra` file containing geopotential height map. Must include landmap.

Atmosphere

gascon [float, optional] Effective gas constant. Defaults to 287.0 (Earth), or the gas constant corresponding to the composition specified by partial pressures.

vtype [{0,1,2,3,4,5}, optional] Type of vertical discretization. Can be: 0 Pseudo-linear scaling with pressure that maintains resolution near the ground. 1 Linear scaling with pressure. 2 Logarithmic scaling with pressure (resolves high altitudes) 3 Pseudologarithmic scaling with pressure that preserves resolution near the ground. 4 Pseudolinear scaling with pressure, pinned to a specified top pressure. 5 If >10 layers, bottom 10 as if `vtype=4`, and upper layers as if `vtype=2`.

modeltop [float, optional] Pressure of the top layer

tropopause [float, optional] If stratosphere is being included, pressure of the 10th layer (where scheme switches from linear to logarithmic).

stratosphere [bool, optional] True/False. If True, vtype=5 is used, and model is discretized to include a stratosphere.

pressure: float, optional Surface pressure in bars, if not specified through partial pressures.

Gas Partial Pressures

Partial pressures of individual gases can be specified. If pressure and gascon are not explicitly set, these will determine surface pressure, mean molecular weight, and effective gas constant. Note however that Rayleigh scattering assumes an Earth-like composition, and the only absorbers explicitly included in the radiation scheme are CO_2 and H_2O.

pH2 [float, optional] H2 partial pressure in bars.

pHe [float, optional] He partial pressure in bars.

pN2 [float, optional] N2 partial pressure in bars.

pO2 [float, optional] O2 partial pressure in bars.

pH2 [float, optional] H2 partial pressure in bars.

pAr [float, optional] Ar partial pressure in bars.

pNe [float, optional] Ne partial pressure in bars.

pKr [float, optional] Kr partial pressure in bars.

pCO2 [float, optional] CO2 partial pressure in bars. This gets translated into a ppmv concentration, so if you want to specify/vary CO2 but don't need the other gases, specifying pCO2, pressure, and gascon will do the trick. In most use cases, however, just specifying pN2 and pCO2 will give good enough behavior.

pH2O [float, optional] H2O partial pressure in bars. This is only useful in setting the gas constant and surface pressure; it will have no effect on actual moist processes.

Surface Parameters

mldepth [float, optional] Depth of the mixed-layer ocean. Default is 50 meters.

soildepth [float, optional] Scaling factor for the depth of soil layers (default total of 12.4 meters)

cpsoil [float, optional] Heat capacity of the soil, in J/m^3/K. Default is 2.4*10^6.

soilwatercap [float, optional] Water capacity of the soil, in meters. Defaults to 0.5 meters

soilsaturation [float, optional] Initial fractional saturation of the soil. Default is 0.0 (dry).

maxsnow [float, optional] Maximum snow depth (Default is 5 meters; set to -1 to have no limit).

Additional Physics

Carbon-Silicate Weathering

co2weathering [bool, optional] True/False. Toggles whether or not carbon-silicate weathering should be computed. Default is False.

evolveco2 [bool, optional] True/False. If co2weathering==True, toggles whether or not the CO2 partial pressure should be updated every year. Usually the change in pCO2 will be extremely small, so this is not necessary, and weathering experiments try to estimate the average weathering rate for a given climate in order to interpolate timescales between climates, rather than modelling changes in CO2 over time directly.

outgassing [float, optional] The assumed CO2 outgassing rate in units of Earth outgassing. Default is 1.0.

erosionsupplylimit [float, optional] If set, the maximum CO2 weathering rate per year permitted by erosion, in ubars/year. This is not simply a hard cutoff, but follows Foley 2015 so high weathering below the cutoff is also reduced.

See **[1]_** for details on the implementation of supply-limited weathering.

Glaciology

glaciers [dict, optional] A dictionary containing the following arguments: toggle : bool

True/False. Whether or not glaciers should be allowed to grow or shrink in thickness, or be formed from persistent snow on land.

mindepth [float] The minimum snow depth in meters of liquid water equivalent that must persist year-round before the grid cell is considered glaciated. Default is 2 meters.

initialh [float] If >=0, covers the land surface with ice sheets of a height given in meterss. If -1, no initial ice sheets are assumed.

Storm Climatology

stormclim [bool, optional] True/False. Toggles whether or not storm climatology (convective available potential energy, maximum potential intensity, ventilation index, etc) should be computed. If True, output fields related to storm climatology will be added to standard output files. Enabling this mode currently roughly doubles the computational cost of the model. This may improve in future updates. Refer to Paradise, et al 2021 for implementation description.

stormcapture [dict, optional] A dictionary containing arguments controlling when high-cadence output is triggered by storm activity. This dictionary must contain 'toggle', which can be either 1 or 0 (yes or no). It may also contain any namelist parameters accepted by hurricanemod.f90, including the following:

toggle [{0,1}] Whether (1) or not (0) to write high-cadence output when storms occur

NKTRIGGER [{0,1}, optional] (0/1=no/yes). Whether or not to use the Komacek, et al 2020 conditions for hurricane cyclogenesis as the output trigger. Default is no.

VITHRESH [float, optional] (nktrigger) Ventilation index threshold for nktrigger output. Default 0.145

VMXTHRESH [float, optional] (nktrigger) Max potential intensity threshold for nktrigger output.Default 33 m/s

LAVTHRESH [float, optional] (nktrigger) Lower-atmosphere vorticity threshold for nktrigger output. Default 1.2*10^-5 s^-1

VRMTHRESH [float, optional] (unused) Ventilation-reduced maximum intensity threshold. Default 0.577

GPITHRESH [float, optional] (default) Genesis Potential Index threshold. Default 0.37.

MINSURFTEMP [float, optional] (default) Min. surface temperature for storm activity. Default 25C

MAXSURFTEMP [float, optional] (default) Max. surface temperature for storm activity. Default 100C

WINDTHRESH [float, optional] (default) Lower-atmosphere maximum wind threshold for storm activity. Default 33 m/s

SWINDTHRESH [float, optional] (default) Minimum surface windspeed for storm activity. Default 20.5 m/s

SIZETHRESH [float, optional] (default) Minimum number of cells that must trigger to start outputDefault 30

ENDTHRESH [float, optional] (default) Minimum number of cells at which point storm output ends.Default 16

MINSTORMLEN [float, optional] (default) Minimum number of timesteps to write output. Default 256

MAXSTORMLEN [float, optional] (default) Maximum number of timesteps to write output. Default 1024

Note that actual number of writes will be stormlen/interval, as set in highcadence. This interval defaults to 4, so 64 writes minimum, 256 max. For more details on the storm climatology factors considered here, see [5]_.

Notes

In some cases, it may be necessary to include physics filters. This typically becomes necessary when sharp features are projected on the model's smallest spectral modes, causing Gibbs "ripples". Earth-like models typically do not require filtering, but tidally-locked models do. Filtering may be beneficial for Earth-like models at very high resolutions as well, or if there is sharp topography.

Three filter functional forms are included in ExoPlaSim: Cesaro, exponential, and Lander-Hoskins. Their functional forms are given below, where n is the wavenumber, and N is the truncation wavenumber (e.g. 21 for T21):

Cesaro: $f(n) = 1 - \frac{n}{N+1}$ **[2]_**

Exponential: $f(n) = \exp\left[-\kappa\left(\frac{n}{N}\right)^{\gamma}\right]$ **[3]_**

Lander-Hoskins: $f(n) = \exp\left[-\left(\frac{n(n+1)}{n_0(n_0+1)}\right)^2\right]$ **[3]_ [4]_**

κ is exposed to the user through `filterkappa`, γ is exposed through `filterpower`, and n_0 is exposed through `filterLHN0`.

Physics filters can be applied at two different points; either at the transform from gridpoint to spectral, or the reverse. We find that in most cases, the ideal usage is to use both. Generally, a filter at the gridpoint->spectral transform is good for dealing with oscillations caused by sharp jumps and small features in the gridpoint tendencies. Conversely, a filter at the spectral->gridpoint transform is good for dealing with oscillations that come from small-scale features in the spectral fields causing small-scale features to appear in the gridpoint tendencies **[3]_**. Since we deal with climate systems where everything is coupled, any oscillations not removed by one filter will be amplified through physical feedbacks if not suppressed by the other filter.

See also:

modify Change model configuration after it has been initialized

References

class exoplasim.**TLlandplanet**(*resolution='T21'*, *layers=10*, *ncpus=4*, *precision=8*, *debug=False*, *inityear=0*, *recompile=False*, *optimization=None*, *mars=False*, *workdir='most'*, *source=None*, *modelname='MOST_EXP'*)

Bases: *exoplasim.Model*

Create a tidally-locked model with no oceans.

Identical to Model, except configuration options suitable for tidally-locked models are the default when configure() is called, and the surface is entirely land-covered. Specifically, a 30-minute timestep, snapshot outputs every 720 timesteps, eccentricity=0.0, 0-degree obliquity, exponential physics filtering, fixed orbital parameters, and no ozone. All these defaults can be overridden.

Notes

The default is to include zero soil water initially. This will result in a completely dry model. Set soilsaturation to something nonzero if you want groundwater.

configure(*timestep=30.0*, *snapshots=720*, *eccentricity=0.0*, *ozone=False*, *obliquity=0.0*, *physicsfilter='gp|exp|sp'*, ***kwargs*)
Configure the model's namelists and boundary conditions.

The defaults here are appropriate for an Earth model.

Model Operation

noutput [bool, optional] True/False. Whether or not model output should be written. restartfile: Path to a restart file to use for initial conditions. Can be None.

writefrequency [int, optional] How many times per day ExoPlaSim should write output. Ignored by default–default is to write time-averaged output once every 5 days.

timestep [float, optional] Model timestep. Defaults to 45 minutes.

runscript [function , optional] A Python function that accepts a Model object as its first argument. This is the routine that will be run when you issue the Model.run() command. Any keyword arguments passed to run() will be forwarded to the specified function. If not set, the default internal routine will be used.

snapshots [int, optional] How many timesteps should elapse between snapshot outputs. If not set, no snapshots will be written.

highcadence [dict, optional] A dictionary containing the following arguments:

'toggle' [{0,1}] Whether or not high-cadence output should be written (1=yes).

'start' [int] Timestep at which high-cadence output should begin.

'end' [int] Timestep at which high-cadence output should end.

'interval' [int] How many timesteps should elapse between high-cadence outputs.

threshold [float, optional] Energy balance threshold model should run to, if using runtobalance(). Default is <0.05 W/m^2/yr average drift in TOA and surface energy balance over 45-year timescales.

resources [list, optional] A list of paths to any additional files that should be available in the run directory.

otherargs [dict, optional] Any namelist parameters not included by default in the configuration options. These should be passed as a dictionary, with "PARAMETER@namelist" as the form of the dictionary key, and the parameter value passed as a string. e.g. `otherargs={"N_RUN_MONTHS@plasim_namelist":'4', "NGUI@plasim_namelist:'1'}`

Model Dynamics

columnmode [{None,"-","clear","static","static|clear","clear|static"}, optional] The inclusion of 'static' will disable horizontal advection, forcing ExoPlaSim into a column-only mode of operation. The inclusion of 'clear' will disable the radiative effects of clouds.

drycore [bool, optional] True/False. If True, evaporation is turned off, and a dry atmosphere will be used.

physicsfilter [str, optional] If not an empty string, specifies the physics filter(s) to be used. Filters can be used during the transform from gridpoint to spectral (`"gp"`), and/or during the transform from spectral to gridpoint (`"sp"`). Filter types are "none", "cesaro", "exp", or "lh" (see the Notes for more details). Combinations of filter types and times should be combined with a `|`, e.g. `physicsfilter="gp|exp|sp"` or `physicsfilter="gp|cesaro"`.

filterkappa [float, optional] A constant to be used with the exponential filter. Default is 8.0.

filterpower [int, optional] A constant integer to be used with the exponential filter. Default is 8.

filterLHN0 [float, optional] The constant used in the denominator of the Lander-Hoskins Filter. Default is 15; typically chosen so f(N)=0.1.

diffusionwaven [int, optional] The critical wavenumber beyond which hyperdiffusion is applied. Default is 15 for T21.

qdiffusion [float, optional] Timescale for humidity hyperdiffusion in days. Default for T21 is 0.1.

tdiffusion [float, optional] Timescale for temperature hyperdiffusion in days. Default for T21 is 5.6.

zdiffusion [float, optional] Timescale for vorticity hyperdiffusion in days. Default for T21 is 1.1.

ddiffusion [float, optional] Timescale for divergence hyperdiffusion in days.. Default for T21 is 0.2.

diffusionpower [int, optional] integer exponent used in hyperdiffusion. Default is 2 for T21.

Radiation

flux [float, optional] Incident stellar flux in W/m^2. Default 1367 for Earth.

startemp [float, optional] Effective blackbody temperature for the star. Not used if not set.

starspec [str, optional] Spectral file for the stellar spectrum. Should have two columns and 965 rows, with wavelength in the first column and radiance or intensity in the second. A similarly-named file with the "_hr.dat" suffix must also exist and have 2048 wavelengths.

twobandalbedo [bool, optional] True/False. If True, separate albedos will be calculated for each of the two shortwave bands. If False (default), a single broadband albedo will be computed and used for both.

synchronous [bool, optional] True/False. If True, the Sun is fixed to one longitude in the sky.

substellarlon [float, optional] The longitude of the substellar point, if synchronous==True. Default 180°

pressurebroaden [bool, optional] True/False. If False, pressure-broadening of absorbers no longer depends on surface pressure. Default is True

ozone [bool, optional] True/False. Whether or not forcing from stratospheric ozone should be included.

snowicealbedo [float, optional] A uniform albedo to use for all snow and ice.

soilalbedo [float, optional] A uniform albedo to use for all land.

wetsoil [bool, optional] True/False. If True, land albedo depends on soil moisture (wet=darker).

oceanalbedo [float, optional] A uniform albedo to use for the ocean.

oceanzenith [{"ECHAM-3","ECHAM-6","Lambertian}, optional] The zenith-angle dependence to use for blue-light reflectance from the ocean. Can be `'Lambertian'`/`'uniform'`, `'ECHAM-3'`/`'plasim'`/`'default'`, or `'ECHAM-6'`. The default is `'ECHAM-3'` (synonymous with `'plasim'` and `'default'`), which is the dependence used in the ECHAM-3 model.

Orbital Parameters

year [float, optional] Number of 24-hour days in a sidereal year. Not necessary if eccentricity and obliquity are zero. Defaults if not set to ~365.25 days

rotationperiod [float, optional] Planetary rotation period, in days. Default is 1.0.

eccentricity [float, optional] Orbital eccentricity. If not set, defaults to Earth's (0.016715)

obliquity [float, optional] Axial tilt, in degrees. If not set, defaults to Earth's obliquity (23.441°).

lonvernaleq [float, optional] Longitude of periapse, measured from vernal equinox, in degrees. If not set, defaults to Earth's (102.7°).

fixedorbit [bool, optional] True/False. If True, orbital parameters do not vary over time. If False, variations such as Milankovich cycles will be computed by PlaSim.

Planet Parameters

gravity [float, optional] Surface gravity, in m/s^2. Defaults to 9.80665 m/s^2.

radius [float, optional] Planet radius in Earth radii. Default is 1.0.

orography [float, optional] If set, a scaling factor for topographic relief. If `orography=0.0`, topography will be zeroed-out.

aquaplanet [bool, optional] True/False. If True, the surface will be entirely ocean-covered.

desertplanet [bool, optional] True/False. If True, the surface will be entirely land-covered.

seaice [bool, optional] True/False. If False, disables radiative effects of sea ice (although sea ice itself is still computed).

landmap [str, optional] Path to a `.sra` file containing a land mask for the chosen resolution.

topomap [str, optional] Path to a `.sra` file containing geopotential height map. Must include landmap.

Atmosphere

gascon [float, optional] Effective gas constant. Defaults to 287.0 (Earth), or the gas constant corresponding to the composition specified by partial pressures.

vtype [{0,1,2,3,4,5}, optional] Type of vertical discretization. Can be: 0 Pseudo-linear scaling with pressure that maintains resolution near the ground. 1 Linear scaling with pressure. 2 Logarithmic scaling with pressure (resolves high altitudes) 3 Pseudologarithmic scaling with pressure that preserves resolution near the ground. 4 Pseudolinear scaling with pressure, pinned to a specified top pressure. 5 If >10 layers, bottom 10 as if `vtype=4`, and upper layers as if `vtype=2`.

modeltop [float, optional] Pressure of the top layer

tropopause [float, optional] If stratosphere is being included, pressure of the 10th layer (where scheme switches from linear to logarithmic).

stratosphere [bool, optional] True/False. If True, vtype=5 is used, and model is discretized to include a stratosphere.

pressure: float, optional Surface pressure in bars, if not specified through partial pressures.

Gas Partial Pressures

Partial pressures of individual gases can be specified. If pressure and gascon are not explicitly set, these will determine surface pressure, mean molecular weight, and effective gas constant. Note however that Rayleigh scattering assumes an Earth-like composition, and the only absorbers explicitly included in the radiation scheme are CO_2 and H_2O.

pH2 [float, optional] H2 partial pressure in bars.

pHe [float, optional] He partial pressure in bars.

pN2 [float, optional] N2 partial pressure in bars.

pO2 [float, optional] O2 partial pressure in bars.

pH2 [float, optional] H2 partial pressure in bars.

pAr [float, optional] Ar partial pressure in bars.

pNe [float, optional] Ne partial pressure in bars.

pKr [float, optional] Kr partial pressure in bars.

pCO2 [float, optional] CO2 partial pressure in bars. This gets translated into a ppmv concentration, so if you want to specify/vary CO2 but don't need the other gases, specifying pCO2, pressure, and gascon will do the trick. In most use cases, however, just specifying pN2 and pCO2 will give good enough behavior.

pH2O [float, optional] H2O partial pressure in bars. This is only useful in setting the gas constant and surface pressure; it will have no effect on actual moist processes.

Surface Parameters

mldepth [float, optional] Depth of the mixed-layer ocean. Default is 50 meters.

soildepth [float, optional] Scaling factor for the depth of soil layers (default total of 12.4 meters)

cpsoil [float, optional] Heat capacity of the soil, in J/m^3/K. Default is 2.4*10^6.

soilwatercap [float, optional] Water capacity of the soil, in meters. Defaults to 0.5 meters

soilsaturation [float, optional] Initial fractional saturation of the soil. Default is 0.0 (dry).

maxsnow [float, optional] Maximum snow depth (Default is 5 meters; set to -1 to have no limit).

Additional Physics

Carbon-Silicate Weathering

co2weathering [bool, optional] True/False. Toggles whether or not carbon-silicate weathering should be computed. Default is False.

evolveco2 [bool, optional] True/False. If co2weathering==True, toggles whether or not the CO2 partial pressure should be updated every year. Usually the change in pCO2 will be extremely small, so this is not necessary, and weathering experiments try to estimate the average weathering rate for a given climate in order to interpolate timescales between climates, rather than modelling changes in CO2 over time directly.

outgassing [float, optional] The assumed CO2 outgassing rate in units of Earth outgassing. Default is 1.0.

erosionsupplylimit [float, optional] If set, the maximum CO2 weathering rate per year permitted by erosion, in ubars/year. This is not simply a hard cutoff, but follows Foley 2015 so high weathering below the cutoff is also reduced.

See [1]_ for details on the implementation of supply-limited weathering.

Glaciology

glaciers [dict, optional] A dictionary containing the following arguments: toggle : bool

True/False. Whether or not glaciers should be allowed to grow or shrink in thickness, or be formed from persistent snow on land.

mindepth [float] The minimum snow depth in meters of liquid water equivalent that must persist year-round before the grid cell is considered glaciated. Default is 2 meters.

initialh [float] If >=0, covers the land surface with ice sheets of a height given in meterss. If -1, no initial ice sheets are assumed.

Storm Climatology

stormclim [bool, optional] True/False. Toggles whether or not storm climatology (convective available potential energy, maximum potential intensity, ventilation index, etc) should be computed. If True, output fields related to storm climatology will be added to standard output files. Enabling this mode currently roughly doubles the computational cost of the model. This may improve in future updates. Refer to Paradise, et al 2021 for implementation description.

stormcapture [dict, optional] A dictionary containing arguments controlling when high-cadence output is triggered by storm activity. This dictionary must contain 'toggle', which can be either 1 or 0 (yes or no). It may also contain any namelist parameters accepted by hurricanemod.f90, including the following:

toggle [{0,1}] Whether (1) or not (0) to write high-cadence output when storms occur

NKTRIGGER [{0,1}, optional] (0/1=no/yes). Whether or not to use the Komacek, et al 2020 conditions for hurricane cyclogenesis as the output trigger. Default is no.

VITHRESH [float, optional] (nktrigger) Ventilation index threshold for nktrigger output. Default 0.145

VMXTHRESH [float, optional] (nktrigger) Max potential intensity threshold for nktrigger output.Default 33 m/s

LAVTHRESH [float, optional] (nktrigger) Lower-atmosphere vorticity threshold for nktrigger output. Default 1.2*10^-5 s^-1

VRMTHRESH [float, optional] (unused) Ventilation-reduced maximum intensity threshold. Default 0.577

GPITHRESH [float, optional] (default) Genesis Potential Index threshold. Default 0.37.

MINSURFTEMP [float, optional] (default) Min. surface temperature for storm activity. Default 25C

MAXSURFTEMP [float, optional] (default) Max. surface temperature for storm activity. Default 100C

WINDTHRESH [float, optional] (default) Lower-atmosphere maximum wind threshold for storm activity. Default 33 m/s

SWINDTHRESH [float, optional] (default) Minimum surface windspeed for storm activity. Default 20.5 m/s

SIZETHRESH [float, optional] (default) Minimum number of cells that must trigger to start outputDefault 30

ENDTHRESH [float, optional] (default) Minimum number of cells at which point storm output ends.Default 16

MINSTORMLEN [float, optional] (default) Minimum number of timesteps to write output. Default 256

MAXSTORMLEN [float, optional] (default) Maximum number of timesteps to write output. Default 1024

Note that actual number of writes will be stormlen/interval, as set in highcadence. This interval defaults to 4, so 64 writes minimum, 256 max. For more details on the storm climatology factors considered here, see **[5]_**.

Notes

In some cases, it may be necessary to include physics filters. This typically becomes necessary when sharp features are projected on the model's smallest spectral modes, causing Gibbs "ripples". Earth-like models typically do not require filtering, but tidally-locked models do. Filtering may be beneficial for Earth-like models at very high resolutions as well, or if there is sharp topography.

Three filter functional forms are included in ExoPlaSim: Cesaro, exponential, and Lander-Hoskins. Their functional forms are given below, where n is the wavenumber, and N is the truncation wavenumber (e.g. 21 for T21):

Cesaro: $f(n) = 1 - \frac{n}{N+1}$ **[2]_**

Exponential: $f(n) = \exp\left[-\kappa \left(\frac{n}{N}\right)^\gamma\right]$ **[3]_**

Lander-Hoskins: $f(n) = \exp\left[-\left(\frac{n(n+1)}{n_0(n_0+1)}\right)^2\right]$ [3]_ [4]_

κ is exposed to the user through `filterkappa`, γ is exposed through `filterpower`, and n_0 is exposed through `filterLHN0`.

Physics filters can be applied at two different points; either at the transform from gridpoint to spectral, or the reverse. We find that in most cases, the ideal usage is to use both. Generally, a filter at the gridpoint->spectral transform is good for dealing with oscillations caused by sharp jumps and small features in the gridpoint tendencies. Conversely, a filter at the spectral->gridpoint transform is good for dealing with oscillations that come from small-scale features in the spectral fields causing small-scale features to appear in the gridpoint tendencies [3]_. Since we deal with climate systems where everything is coupled, any oscillations not removed by one filter will be amplified through physical feedbacks if not suppressed by the other filter.

See also:

modify Change model configuration after it has been initialized

References

class exoplasim.**TLmodel**(*resolution='T21'*, *layers=10*, *ncpus=4*, *precision=8*, *debug=False*, *inityear=0*,   *recompile=False*,   *optimization=None*,   *mars=False*, *workdir='most'*, *source=None*, *modelname='MOST_EXP'*)
Bases: *exoplasim.Model*

Create a tidally-locked model.

Identical to exoplasim.Model, except configuration options suitable for tidally-locked models are the default when configure() is called.

configure(*timestep=30.0*, *snapshots=720*, *eccentricity=0.0*, *ozone=False*, *obliquity=0.0*, *physicsfilter='gp|exp|sp'*, ***kwargs*)
Configure the model's namelists and boundary conditions.

The defaults here are appropriate for an Earth model.

Model Operation

noutput [bool, optional] True/False. Whether or not model output should be written. restartfile: Path to a restart file to use for initial conditions. Can be None.

writefrequency [int, optional] How many times per day ExoPlaSim should write output. Ignored by default–default is to write time-averaged output once every 5 days.

timestep [float, optional] Model timestep. Defaults to 45 minutes.

runscript [function , optional] A Python function that accepts a Model object as its first argument. This is the routine that will be run when you issue the Model.run() command. Any keyword arguments passed to run() will be forwarded to the specified function. If not set, the default internal routine will be used.

snapshots [int, optional] How many timesteps should elapse between snapshot outputs. If not set, no snapshots will be written.

highcadence [dict, optional] A dictionary containing the following arguments:

'toggle' [{0,1}] Whether or not high-cadence output should be written (1=yes).

'start' [int] Timestep at which high-cadence output should begin.

> > **'end'** [int] Timestep at which high-cadence output should end.
>
> > **'interval'** [int] How many timesteps should elapse between high-cadence outputs.
>
> **threshold** [float, optional] Energy balance threshold model should run to, if using runtobalance(). Default is <0.05 W/m^2/yr average drift in TOA and surface energy balance over 45-year timescales.
>
> **resources** [list, optional] A list of paths to any additional files that should be available in the run directory.
>
> **otherargs** [dict, optional] Any namelist parameters not included by default in the configuration options. These should be passed as a dictionary, with "PARAMETER@namelist" as the form of the dictionary key, and the parameter value passed as a string. e.g. `otherargs={"N_RUN_MONTHS@plasim_namelist":'4', "NGUI@plasim_namelist:'1'}`

Model Dynamics

> **columnmode** [{None,"-","clear","static","static|clear","clear|static"}, optional] The inclusion of 'static' will disable horizontal advection, forcing ExoPlaSim into a column-only mode of operation. The inclusion of 'clear' will disable the radiative effects of clouds.
>
> **drycore** [bool, optional] True/False. If True, evaporation is turned off, and a dry atmosphere will be used.
>
> **physicsfilter** [str, optional] If not an empty string, specifies the physics filter(s) to be used. Filters can be used during the transform from gridpoint to spectral (`"gp"`), and/or during the transform from spectral to gridpoint (`"sp"`). Filter types are "none", "cesaro", "exp", or "lh" (see the Notes for more details). Combinations of filter types and times should be combined with a `|`, e.g. `physicsfilter="gp|exp|sp"` or `physicsfilter="gp|cesaro"`.
>
> **filterkappa** [float, optional] A constant to be used with the exponential filter. Default is 8.0.
>
> **filterpower** [int, optional] A constant integer to be used with the exponential filter. Default is 8.
>
> **filterLHN0** [float, optional] The constant used in the denominator of the Lander-Hoskins Filter. Default is 15; typically chosen so f(N)=0.1.
>
> **diffusionwaven** [int, optional] The critical wavenumber beyond which hyperdiffusion is applied. Default is 15 for T21.
>
> **qdiffusion** [float, optional] Timescale for humidity hyperdiffusion in days. Default for T21 is 0.1.
>
> **tdiffusion** [float, optional] Timescale for temperature hyperdiffusion in days. Default for T21 is 5.6.
>
> **zdiffusion** [float, optional] Timescale for vorticity hyperdiffusion in days. Default for T21 is 1.1.
>
> **ddiffusion** [float, optional] Timescale for divergence hyperdiffusion in days.. Default for T21 is 0.2.
>
> **diffusionpower** [int, optional] integer exponent used in hyperdiffusion. Default is 2 for T21.

Radiation

flux [float, optional] Incident stellar flux in W/m^2. Default 1367 for Earth.

startemp [float, optional] Effective blackbody temperature for the star. Not used if not set.

starspec [str, optional] Spectral file for the stellar spectrum. Should have two columns and 965 rows, with wavelength in the first column and radiance or intensity in the second. A similarly-named file with the "_hr.dat" suffix must also exist and have 2048 wavelengths.

twobandalbedo [bool, optional] True/False. If True, separate albedos will be calculated for each of the two shortwave bands. If False (default), a single broadband albedo will be computed and used for both.

synchronous [bool, optional] True/False. If True, the Sun is fixed to one longitude in the sky.

substellarlon [float, optional] The longitude of the substellar point, if synchronous==True. Default 180°

pressurebroaden [bool, optional] True/False. If False, pressure-broadening of absorbers no longer depends on surface pressure. Default is True

ozone [bool, optional] True/False. Whether or not forcing from stratospheric ozone should be included.

snowicealbedo [float, optional] A uniform albedo to use for all snow and ice.

soilalbedo [float, optional] A uniform albedo to use for all land.

wetsoil [bool, optional] True/False. If True, land albedo depends on soil moisture (wet=darker).

oceanalbedo [float, optional] A uniform albedo to use for the ocean.

oceanzenith [{"ECHAM-3","ECHAM-6","Lambertian}, optional] The zenith-angle dependence to use for blue-light reflectance from the ocean. Can be `'Lambertian'`/`'uniform'`, `'ECHAM-3'`/`'plasim'`/`'default'`, or `'ECHAM-6'`. The default is `'ECHAM-3'` (synonymous with `'plasim'` and `'default'`), which is the dependence used in the ECHAM-3 model.

Orbital Parameters

year [float, optional] Number of 24-hour days in a sidereal year. Not necessary if eccentricity and obliquity are zero. Defaults if not set to ~365.25 days

rotationperiod [float, optional] Planetary rotation period, in days. Default is 1.0.

eccentricity [float, optional] Orbital eccentricity. If not set, defaults to Earth's (0.016715)

obliquity [float, optional] Axial tilt, in degrees. If not set, defaults to Earth's obliquity (23.441°).

lonvernaleq [float, optional] Longitude of periapse, measured from vernal equinox, in degrees. If not set, defaults to Earth's (102.7°).

fixedorbit [bool, optional] True/False. If True, orbital parameters do not vary over time. If False, variations such as Milankovich cycles will be computed by PlaSim.

Planet Parameters

gravity [float, optional] Surface gravity, in m/s^2. Defaults to 9.80665 m/s^2.

radius [float, optional] Planet radius in Earth radii. Default is 1.0.

orography [float, optional] If set, a scaling factor for topographic relief. If `orography=0.0`, topography will be zeroed-out.

aquaplanet [bool, optional] True/False. If True, the surface will be entirely ocean-covered.

desertplanet [bool, optional] True/False. If True, the surface will be entirely land-covered.

seaice [bool, optional] True/False. If False, disables radiative effects of sea ice (although sea ice itself is still computed).

landmap [str, optional] Path to a `.sra` file containing a land mask for the chosen resolution.

topomap [str, optional] Path to a `.sra` file containing geopotential height map. Must include landmap.

Atmosphere

gascon [float, optional] Effective gas constant. Defaults to 287.0 (Earth), or the gas constant corresponding to the composition specified by partial pressures.

vtype [{0,1,2,3,4,5}, optional] Type of vertical discretization. Can be: 0 Pseudolinear scaling with pressure that maintains resolution near the ground. 1 Linear scaling with pressure. 2 Logarithmic scaling with pressure (resolves high altitudes) 3 Pseudologarithmic scaling with pressure that preserves resolution near the ground. 4 Pseudolinear scaling with pressure, pinned to a specified top pressure. 5 If >10 layers, bottom 10 as if `vtype=4`, and upper layers as if `vtype=2`.

modeltop [float, optional] Pressure of the top layer

tropopause [float, optional] If stratosphere is being included, pressure of the 10th layer (where scheme switches from linear to logarithmic).

stratosphere [bool, optional] True/False. If True, vtype=5 is used, and model is discretized to include a stratosphere.

pressure: float, optional Surface pressure in bars, if not specified through partial pressures.

Gas Partial Pressures

Partial pressures of individual gases can be specified. If pressure and gascon are not explicitly set, these will determine surface pressure, mean molecular weight, and effective gas constant. Note however that Rayleigh scattering assumes an Earth-like composition, and the only absorbers explicitly included in the radiation scheme are CO_2 and H_2O.

pH2 [float, optional] H2 partial pressure in bars.

pHe [float, optional] He partial pressure in bars.

pN2 [float, optional] N2 partial pressure in bars.

pO2 [float, optional] O2 partial pressure in bars.

pH2 [float, optional] H2 partial pressure in bars.

pAr [float, optional] Ar partial pressure in bars.

pNe [float, optional] Ne partial pressure in bars.

pKr [float, optional] Kr partial pressure in bars.

pCO2 [float, optional] CO2 partial pressure in bars. This gets translated into a ppmv concentration, so if you want to specify/vary CO2 but don't need the other gases, specifying pCO2, pressure, and gascon will do the trick. In most use cases, however, just specifying pN2 and pCO2 will give good enough behavior.

pH2O [float, optional] H2O partial pressure in bars. This is only useful in setting the gas constant and surface pressure; it will have no effect on actual moist processes.

Surface Parameters

mldepth [float, optional] Depth of the mixed-layer ocean. Default is 50 meters.

soildepth [float, optional] Scaling factor for the depth of soil layers (default total of 12.4 meters)

cpsoil [float, optional] Heat capacity of the soil, in J/m^3/K. Default is 2.4*10^6.

soilwatercap [float, optional] Water capacity of the soil, in meters. Defaults to 0.5 meters

soilsaturation [float, optional] Initial fractional saturation of the soil. Default is 0.0 (dry).

maxsnow [float, optional] Maximum snow depth (Default is 5 meters; set to -1 to have no limit).

Additional Physics

Carbon-Silicate Weathering

co2weathering [bool, optional] True/False. Toggles whether or not carbon-silicate weathering should be computed. Default is False.

evolveco2 [bool, optional] True/False. If co2weathering==True, toggles whether or not the CO2 partial pressure should be updated every year. Usually the change in pCO2 will be extremely small, so this is not necessary, and weathering experiments try to estimate the average weathering rate for a given climate in order to interpolate timescales between climates, rather than modelling changes in CO2 over time directly.

outgassing [float, optional] The assumed CO2 outgassing rate in units of Earth outgassing. Default is 1.0.

erosionsupplylimit [float, optional] If set, the maximum CO2 weathering rate per year permitted by erosion, in ubars/year. This is not simply a hard cutoff, but follows Foley 2015 so high weathering below the cutoff is also reduced.

See [1]_ for details on the implementation of supply-limited weathering.

Glaciology

glaciers [dict, optional] A dictionary containing the following arguments: toggle : bool

True/False. Whether or not glaciers should be allowed to grow or shrink in thickness, or be formed from persistent snow on land.

mindepth [float] The minimum snow depth in meters of liquid water equivalent that must persist year-round before the grid cell is considered glaciated. Default is 2 meters.

>> **initialh** [float] If >=0, covers the land surface with ice sheets of a height given in meterss. If -1, no initial ice sheets are assumed.

> **Storm Climatology**

>> **stormclim** [bool, optional] True/False. Toggles whether or not storm climatology (convective available potential energy, maximum potential intensity, ventilation index, etc) should be computed. If True, output fields related to storm climatology will be added to standard output files. Enabling this mode currently roughly doubles the computational cost of the model. This may improve in future updates. Refer to Paradise, et al 2021 for implementation description.

>> **stormcapture** [dict, optional] A dictionary containing arguments controlling when high-cadence output is triggered by storm activity. This dictionary must contain 'toggle', which can be either 1 or 0 (yes or no). It may also contain any namelist parameters accepted by hurricanemod.f90, including the following:

>> **toggle** [{0,1}] Whether (1) or not (0) to write high-cadence output when storms occur

>> **NKTRIGGER** [{0,1}, optional] (0/1=no/yes). Whether or not to use the Komacek, et al 2020 conditions for hurricane cyclogenesis as the output trigger. Default is no.

>> **VITHRESH** [float, optional] (nktrigger) Ventilation index threshold for nktrigger output. Default 0.145

>> **VMXTHRESH** [float, optional] (nktrigger) Max potential intensity threshold for nktrigger output.Default 33 m/s

>> **LAVTHRESH** [float, optional] (nktrigger) Lower-atmosphere vorticity threshold for nktrigger output. Default $1.2*10^{-5}$ s^-1

>> **VRMTHRESH** [float, optional] (unused) Ventilation-reduced maximum intensity threshold. Default 0.577

>> **GPITHRESH** [float, optional] (default) Genesis Potential Index threshold. Default 0.37.

>> **MINSURFTEMP** [float, optional] (default) Min. surface temperature for storm activity. Default 25C

>> **MAXSURFTEMP** [float, optional] (default) Max. surface temperature for storm activity. Default 100C

>> **WINDTHRESH** [float, optional] (default) Lower-atmosphere maximum wind threshold for storm activity. Default 33 m/s

>> **SWINDTHRESH** [float, optional] (default) Minimum surface windspeed for storm activity. Default 20.5 m/s

>> **SIZETHRESH** [float, optional] (default) Minimum number of cells that must trigger to start outputDefault 30

>> **ENDTHRESH** [float, optional] (default) Minimum number of cells at which point storm output ends.Default 16

>> **MINSTORMLEN** [float, optional] (default) Minimum number of timesteps to write output. Default 256

>> **MAXSTORMLEN** [float, optional] (default) Maximum number of timesteps to write output. Default 1024

Note that actual number of writes will be stormlen/interval, as set in highcadence. This interval defaults to 4, so 64 writes minimum, 256 max. For more details on the storm climatology factors considered here, see **[5]_**.

Notes

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References

4.1.2 exoplasim

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