OSCAR v3.1

Manual

Basic simulation

Essentially, to make a basic simulation one must:

1. import the `OSCAR` object from `core_fct.fct_process`;
2. define the `Ini` (initial state), `For` (forcing data) and `Par` (parameters) arguments;
3. call `OSCAR` with these arguments (and possibly other optional arguments).

The `run_model` function found in `core_fct.fct_wrap` is a wrapper that does all that and more, using internal data for forcings and parameters. However, this function may not be adequate for advanced usage of OSCAR, in which case it should be used as inspiration for defining one's own run scripts. To further help with this, the `run_scripts` folder contains a few basic examples.

Core structure

Here is a quick overview of the files contained in the `core_fct` folder and their content.

File	Content
`cls_main`	definition of the `Model` and `Process` classes upon which OSCAR v3 is based
`fct_calib`	functions to calibrate some of the model's parameters
`fct_genD`	functions to generate consistent timeseries of drivers
`fct_genMC`	functions to generate the Monte Carlo setup
`fct_loadD`	functions to load the primary drivers
`fct_loadP`	functions to load the primary parameters, some of them being loaded from files and others manually written there
`fct_misc`	a bunch of useful functions, notably including the solving schemes, a generic loading function called `load_data`, and a function to regionally aggregate datasets called `aggreg_region`
`fct_process`	equations for the physical processes constituting OSCAR; also contains `OSCAR` and submodels
`fct_wrap`	wrapper function to run the model in a not-so-flexible standard mode

Dimensions, drivers, variables and parameters

Dimensions

Here is a table summerizing the various dimensions over which OSCAR's input, internal and output data may be defined. Additional dimensions can be added freely to the `Ini`, `For` and/or `Par` arguments, in which case they will be conserved throughout the run, which allows easily parallelizing experiments (e.g. scenarios). This can be heavy on the memory, however.

Dims	Description
`year`	time axis
`config`	Monte Carlo elements
`spc_halo`	species of halogenated compounds
`box_osurf`	pools for the surface ocean carbon cycling
`reg_land`	land carbon-cycle regions
`bio_land`	land carbon-cycle biomes
`bio_from`	origine biomes of the land-use perturbations
`bio_to`	destination biomes of the land-use perturbations
`box_hwp`	pools of harvested wood products
`reg_pf`	regions specific to the permafrost module
`box_thaw`	pools of thawed permafrost
`spc_bb`	species from biomass burning
`reg_slcf`	regions specific to SLCF regional saturation effects
`reg_bcsnow`	regions specific to BC deposition on snow

Drivers

Drivers are the forcing data that need to be prescribed to the model for it to be able to run. They must be prescribed using the `For` argument when calling a `Model` object. The model automatically connects the various processes it is made of, and deduces what input data are required, so that it will display an error message if some drivers are missing in `For`. Assuming `OSCAR` has been imported, a list of the model's drivers can be displayed with `OSCAR.var_in`. More information on the drivers is available in `core_fct.fct_loadD`.

In code	In papers	Units	Dims
`Eff`	E_{FF}	PgC yr^{-1}	`year, reg_land`
`E_CH4`	$E_{\mathrm{CH_4}}$	TgC yr^{-1}	`year, reg_land`
`E_N2O`	$E_{\mathrm{N_2O}}$	TgN yr^{-1}	`year, reg_land`
`E_Xhalo`	E_{X}	Gg yr^{-1}	`year, reg_land, spc_halo`
`E_NOX`	$E_{\mathrm{NO_x}}$	TgN yr^{-1}	`year, reg_land`
`E_CO`	E_{CO}	TgC yr^{-1}	`year, reg_land`
`E_VOC`	E_{VOC}	Tg yr^{-1}	`year, reg_land`

In code	In papers	Units	Dims
`E_SO2`	$E_{\mathrm{SO_2}}$	TgS yr^{-1}	`year, reg_land`
`E_NH3`	$E_{\mathrm{NH_3}}$	TgN yr^{-1}	`year, reg_land`
`E_OC`	E_{OC}	TgC yr^{-1}	`year, reg_land`
`E_BC`	E_{BC}	TgC yr^{-1}	`year, reg_land`
`d_Acover`	δA	Mha yr^{-1}	`year, reg_land, bio_from, bio_to`
`d_Hwood`	δH	PgC yr^{-1}	`year, reg_land, bio_land`
`d_Ashift`	δS	Mha yr^{-1}	`year, reg_land, bio_from, bio_to`
`RF_contr`	$\mathrm{RF}_{\mathrm{con}}$	W m^{-2}	`year`
`RF_volc`	$\mathrm{RF}_{\mathrm{volc}}$	W m^{-2}	`year`
`RF_solar`	$\mathrm{RF}_{\mathrm{solar}}$	W m^{-2}	`year`

Variables

Each of the model's variable is defined through a `Process` object; and a `Model` object is essentially a collection of connected processes. Prognostic variables (i.e. state variables) are those defined through a time-differential equation, while diagnostic variables are defined at any time *t* as a function of prognostic variables and/or other diagnostic variables at that same time *t*. When solving, at every single timestep, the model first solves all prognostic variables, and only then calculates the diagnostic variables. Assuming `OSCAR` has been imported, a list of the model's variables can be displayed with `OSCAR.proc_all`, or somewhat equivalently with `OSCAR.var_mid | OSCAR.var_out`. Prognostic and diagnostic variables can be displayed with `OSCAR.var_prog` and `OSCAR.var_diag`, respectively. More information on each variable/process is available in `core_fct.fct_process`.

In code	In papers	Units	Dims	Prog?
`D_pCO2`	$\mathcal{F}_{\mathrm{pCO_2}}$	ppm	-	
`D_mld`	Δh_{mld}	m	-	
`D_dic`	$\Delta\mathrm{dic}$	µmol kg^{-1}	-	
`D_Fin`	ΔF_{in}	PgC yr^{-1}	`box_osurf`	
`D_Fout`	ΔF_{out}	PgC yr^{-1}	`box_osurf`	
`D_Fcirc`	ΔF_{circ}	PgC yr^{-1}	`box_osurf`	
`D_Focean`	$\Delta F_{\downarrow\mathrm{ocean}}$	PgC yr^{-1}	-	
`D_Cosurf`	ΔC_{surf}	PgC	-	**yes**

In code	In papers	Units	Dims	Prog?
`f_fert`	$\mathcal{F}_{\text{fert}}$	1	`reg_land, bio_land`	
`D_npp`	Δnpp	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`f_igni`	$\mathcal{F}_{\text{igni}}$	1	`reg_land, bio_land`	
`D_efire`	Δe_{fire}	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`D_eharv`	Δe_{harv}	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`D_egraz`	Δe_{graz}	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`D_fmort1`	Δf_{mort1}	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`D_fmort2`	Δf_{mort2}	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`f_resp`	$\mathcal{F}_{\text{resp}}$	1	`reg_land, bio_land`	
`D_rh1`	Δrh_1	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`D_fmet`	Δf_{met}	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`D_rh2`	Δrh_2	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`D_nbp`	-	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`D_cveg`	Δc_{veg}	PgC Mha^{-1}	`reg_land, bio_land`	**yes**
`D_csoil1`	Δc_{soil1}	PgC Mha^{-1}	`reg_land, bio_land`	**yes**
`D_csoil2`	Δc_{soil2}	PgC Mha^{-1}	`reg_land, bio_land`	**yes**
`D_Fveg_bk`	$\delta C_{\text{veg,bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fsoil1_bk`	$\delta C_{\text{soil1,bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	

In code	In papers	Units	Dims	Prog?
`D_Fsoil2_bk`	$\delta C_{\mathrm{soil2,bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fslash`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fslash1`	$\Delta F_{\mathrm{slash1}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fslash2`	$\Delta F_{\mathrm{slash2}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fhwp`	ΔF_{hwp}	PgC yr^{-1}	`reg_land, bio_from, bio_to, box_hwp`	
`D_NPP_bk`	$\Delta \mathrm{NPP}_{\mathrm{bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Efire_bk`	$\Delta E_{\mathrm{fire,bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Eharv_bk`	$\Delta E_{\mathrm{harv,bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Egraz_bk`	$\Delta E_{\mathrm{graz,bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fmort1_bk`	$\Delta F_{\mathrm{mort1,bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fmort2_bk`	$\Delta F_{\mathrm{mort2,bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Rh1_bk`	$\Delta \mathrm{Rh}_{1,\mathrm{bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fmet_bk`	$\Delta F_{\mathrm{met,bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Rh2_bk`	$\Delta \mathrm{Rh}_{2,\mathrm{bk}}$	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Ehwp`	ΔE_{hwp}	PgC yr^{-1}	`reg_land, bio_from, bio_to, box_hwp`	
`D_NBP_bk`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Eluc`	ΔE_{LUC}	PgC yr^{-1}	-	
`D_Fland`	$\Delta F_{\downarrow \mathrm{land}}$	PgC yr^{-1}	-	
`D_Aland`	ΔA	Mha	`reg_land, bio_land`	**yes**
`D_Cveg_bk`	$\Delta C_{\mathrm{veg,bk}}$	PgC	`reg_land, bio_from, bio_to`	**yes**
`D_Csoil1_bk`	$\Delta C_{\mathrm{soil1,bk}}$	PgC	`reg_land, bio_from, bio_to`	**yes**
`D_Csoil2_bk`	$\Delta C_{\mathrm{soil2,bk}}$	PgC	`reg_land, bio_from, bio_to`	**yes**
`D_Chwp`	ΔC_{hwp}	PgC	`reg_land, bio_from, bio_to, box_hwp`	**yes**

`f_resp_pf`	-	1	`reg_pf`	
`D_pthaw_bar`	$\Delta \bar{p}_{\mathrm{thaw}}$	1	`reg_pf`	
`d_pthaw`	$\frac{\mathrm{d}}{\mathrm{d}t} p_{\mathrm{thaw}}$	yr^{-1}	`reg_pf`	

In code	In papers	Units	Dims	Prog?
D_pthaw	Δp_{thaw}	1	reg_pf	yes
D_Fthaw	ΔF_{thaw}	PgC yr^{-1}	reg_pf	
D_Ethaw	-	PgC yr^{-1}	reg_pf, box_thaw	
D_Epf	ΔE_{pf}	PgC yr^{-1}	reg_pf	
D_Epf_CO2	-	PgC yr^{-1}	reg_pf	
D_Epf_CH4	-	TgC yr^{-1}	reg_pf	
D_Cfroz	ΔC_{froz}	PgC	reg_pf	yes
D_Cthaw	ΔC_{thaw}	PgC	reg_pf, box_thaw	yes

D_CO2	$\Delta \mathrm{CO_2}$	ppm	-	yes
AF	-	1	-	
kS	-	yr^{-1}	-	
RF_CO2	$\Delta \mathrm{RF}^{\mathrm{CO_2}}$	W m^{-2}	-	

D_Efire	ΔE_{fire}	PgC yr^{-1}	reg_land, bio_land	
D_Ebb_nat	-	TgX yr^{-1}	reg_land, bio_land, spc_bb	
D_Ebb_ant	-	TgX yr^{-1}	reg_land, bio_land, spc_bb	
D_Ebb	ΔE_{bb}	TgX yr^{-1}	reg_land, bio_land, spc_bb	

D_CH4_lag	$\Delta \mathrm{CH_4}_{\mathrm{lag}}$	ppb	-	yes
D_N2O_lag	$\Delta \mathrm{N_2O}_{\mathrm{lag}}$	ppb	-	yes
D_Xhalo_lag	ΔX_{lag}	ppt	spc_halo	yes

D_Ta	ΔT_A	K	-	
D_f_Qa	$\frac{\Delta Q_A}{Q_{A,0}}$	1	-	
f_kOH	$\mathcal{F}_{\mathrm{OH}}$	1	-	
D_Foh_CH4	-	TgC yr^{-1}	-	
D_Fhv_CH4	-	TgC yr^{-1}	-	
D_Fsoil_CH4	-	TgC yr^{-1}	-	

In code	In papers	Units	Dims	Prog?
D_Focean_CH4	-	TgC yr^{-1}	-	
D_Fsink_CH4	$\Delta F_{\downarrow}^{\mathrm{CH_4}}$	TgC yr^{-1}	-	
D_Foxi_CH4	-	PgC yr^{-1}	-	
D_ewet	Δe_{wet}	TgC Mha^{-1} yr^{-1}	reg_land	
D_Awet	ΔA_{wet}	Mha	reg_land	
D_Ewet	ΔE_{wet}	TgC yr^{-1}	reg_land	
D_CH4	$\Delta \mathrm{CH_4}$	ppb	-	**yes**
tau_CH4	-	yr	-	
RF_CH4	$\Delta \mathrm{RF}^{\mathrm{CH_4}}$	W m^{-2}	-	
RF_H2Os	$\Delta \mathrm{RF}^{\mathrm{H_2Os}}$	W m^{-2}	-	
D_f_ageair	-	1	-	
f_hv	$\mathcal{F}_{\mathrm{h}\nu}$	1	-	
D_Fhv_N2O	-	TgN yr^{-1}	-	
D_Fsink_N2O	$\Delta F_{\downarrow}^{\mathrm{N_2O}}$	TgN yr^{-1}	-	
D_N2O	$\Delta \mathrm{N_2O}$	ppb	-	**yes**
tau_N2O	-	yr	-	
RF_N2O	$\Delta \mathrm{RF}^{\mathrm{N_2O}}$	W m^{-2}	-	
D_Foh_Xhalo	-	Gg yr^{-1}	spc_halo	
D_Fhv_CH4	-	Gg yr^{-1}	spc_halo	
D_Fother_CH4	-	Gg yr^{-1}	spc_halo	
D_Fsink_CH4	$\Delta F_{\downarrow}^{X}$	Gg yr^{-1}	spc_halo	
D_Xhalo	ΔX	ppt	spc_halo	**yes**
RF_Xhalo	$\Delta \mathrm{RF}^{X}$	W m^{-2}	spc_halo	
RF_halo	$\Delta \mathrm{RF}^{\mathrm{halo}}$	W m^{-2}	-	
D_O3t	$\Delta \mathrm{O_3t}$	DU	-	

In code	In papers	Units	Dims	Prog?
`RF_O3t`	$\Delta \mathrm{RF}^{\mathrm{O_3t}}$	W m^{-2}	-	
`D_EESC`	$\Delta \mathrm{EESC}$	ppt	-	
`D_O3s`	$\Delta \mathrm{O_3s}$	DU	-	
`RF_O3s`	$\Delta \mathrm{RF}^{\mathrm{O_3s}}$	W m^{-2}	-	
`D_Edms`	ΔE_{DMS}	TgS yr^{-1}	-	
`D_Ebvoc`	ΔE_{BVOC}	Tg yr^{-1}	-	
`D_Edust`	-	Tg yr^{-1}	-	
`D_Esalt`	-	Tg yr^{-1}	-	
`D_SO4`	$\Delta \mathrm{SO_4}$	Tg	-	
`D_POA`	$\Delta \mathrm{POA}$	Tg	-	
`D_BC`	$\Delta \mathrm{BC}$	Tg	-	
`D_NO3`	$\Delta \mathrm{NO_3}$	Tg	-	
`D_SOA`	$\Delta \mathrm{SOA}$	Tg	-	
`D_Mdust`	-	Tg	-	
`D_Msalt`	-	Tg	-	
`RF_SO4`	$\Delta \mathrm{RF}^{\mathrm{SO_4}}$	W m^{-2}	-	
`RF_POA`	$\Delta \mathrm{RF}^{\mathrm{POA}}$	W m^{-2}	-	
`RF_BC`	$\Delta \mathrm{RF}^{\mathrm{BC}}$	W m^{-2}	-	
`RF_NO3`	$\Delta \mathrm{RF}^{\mathrm{NO_3}}$	W m^{-2}	-	
`RF_SOA`	$\Delta \mathrm{RF}^{\mathrm{SOA}}$	W m^{-2}	-	
`RF_dust`	-	W m^{-2}	-	
`RF_salt`	-	W m^{-2}	-	
`D_AERsol`	$\Delta \mathrm{AER_{sol}}$	Tg	-	
`RF_cloud1`	-	W m^{-2}	-	
`RF_cloud2`	-	W m^{-2}	-	
`RF_cloud`	$\Delta \mathrm{RF}^{\mathrm{cloud}}$	W m^{-2}	-	

In code	In papers	Units	Dims	Prog?
RF_BCsnow	$\Delta\mathrm{RF}^{\mathrm{BCsnow}}$	W m^{-2}	-	
RF_lcc	$\Delta\mathrm{RF}^{\mathrm{LCC}}$	W m^{-2}	-	
RF_nonCO2	-	W m^{-2}	-	
RF_wmghg	-	W m^{-2}	-	
RF_strat	-	W m^{-2}	-	
RF_scatter	-	W m^{-2}	-	
RF_absorb	-	W m^{-2}	-	
RF_AERtot	-	W m^{-2}	-	
RF_slcf	-	W m^{-2}	-	
RF_alb	-	W m^{-2}	-	
RF	$\Delta\mathrm{RF}$	W m^{-2}	-	
RF_warm	$\Delta\mathrm{RF}_{\mathrm{warm}}$	W m^{-2}	-	
RF_atm	$\Delta\mathrm{RF}_{\mathrm{atm}}$	W m^{-2}	-	
D_Tg	ΔT_G	K	-	**yes**
D_Td	ΔT_D	K	-	**yes**
d_Tg	$\frac{\mathrm{d}}{\mathrm{dt}} T_G$	K yr^{-1}	-	
D_Tl	ΔT_L	K	reg_land	
D_To	ΔT_S	K	-	
D_Pg	ΔP_G	mm yr^{-1}	-	**yes**
D_Pl	ΔP_L	mm yr^{-1}	reg_land	
D_OHC	$\Delta\mathrm{OHC}$	ZJ	-	**yes**
D_pH	-	1	-	

Parameters

Parameters are implicitly defined when creating a model's processes. When OSCAR is run, it does not check whether the needed parameters are actually provided in the `Par` argument. Primary parameters can be loaded with the `load_all_param` function defined in `core_fct.fct_loadP`. Many parameters have several possible values, and these different configurations are defined along the various `mod_` dimensions of the dataset containing the primary parameters. Sets of randomly drawn parameters for Monte Carlo runs can be generated using the `generate_config` function defined in `core_fct.fct_genMC`. More information on each parameter is available in `core_fct.fct_loadP`.

In code	In papers	Units	Dims	Mods
`a_dic`	α_{sol}	μmol kg^{-1} [ppm m^{-3}]$^{-1}$	-	-
`mld_0`	$h_{\mathrm{mld},0}$	m	-	`mod_Focean_struct`
`A_ocean`	A_{ocean}	m^2	-	`mod_Focean_struct`
`To_0`	$T_{S,0}$	K	-	`mod_Focean_struct`
`v_fg`	ν_{fg}	yr^{-1}	-	`mod_Focean_struct`
`p_circ`	π_{circ}	1	`box_osurf`	`mod_Focean_struct`
`t_circ`	τ_{circ}	yr	`box_osurf`	`mod_Focean_struct`
`pCO2_is_Pade`	-	`bool`	-	`mod_Focean_chem`
`p_mld`	π_{mld}	1	-	`mod_Focean_trans`
`g_mld`	γ_{mld}	K^{-1}	-	`mod_Focean_trans`
`fert_is_Log`	-	`bool`	-	`mod_Fland_fert`
`t_shift`	τ_{shift}	yr	-	-
`npp_0`	η	PgC Mha^{-1} yr^{-1}	`reg_land`, `bio_land`	`mod_Fland_preind`
`igni_0`	ι	yr^{-1}	`reg_land`, `bio_land`	`mod_Efire_preind`
`harv_0`	ϵ_{harv}	yr^{-1}	`reg_land`, `bio_land`	`mod_Eharv_preind`
`graz_0`	ϵ_{graz}	yr^{-1}	`reg_land`, `bio_land`	`mod_Egraz_preind`
`mu1_0`	μ_1	yr^{-1}	`reg_land`, `bio_land`	`mod_Fland_preind`
`mu2_0`	μ_2	yr^{-1}	`reg_land`, `bio_land`	`mod_Fland_preind`
`muM_0`	μ_{met}	yr^{-1}	`reg_land`, `bio_land`	`mod_Fland_preind`

In code	In papers	Units	Dims	Mods
rho1_0	ρ_1	yr^{-1}	reg_land, bio_land	mod_Fland_preind
rho2_0	ρ_2	yr^{-1}	reg_land, bio_land	mod_Fland_preind
p_agb	π_{agb}	1	reg_land, bio_land	mod_Eluc_agb
b_npp	β_{npp}	1	reg_land, bio_land	mod_Fland_trans
b2_npp	$\tilde{\beta}_{\mathrm{npp}}$	1	reg_land, bio_land	mod_Fland_trans
CO2_cp	$\mathrm{CO}_{2\mathrm{cp}}$	ppm	reg_land, bio_land	mod_Fland_trans
g_nppT	$\gamma_{\mathrm{npp},T}$	K^{-1}	reg_land, bio_land	mod_Fland_trans, mod_Fland_fert
g_nppP	$\gamma_{\mathrm{npp},P}$	$[mm\ yr^{-1}]^{-1}$	reg_land, bio_land	mod_Fland_trans, mod_Fland_fert
g_rhoT	$\gamma_{\mathrm{resp},T}$	K^{-1}	reg_land, bio_land	mod_Fland_trans, mod_Fland_resp
g_rhoT1	$\gamma_{\mathrm{resp},T_1}$	K^{-1}	reg_land, bio_land	mod_Fland_trans, mod_Fland_resp
g_rhoT2	$\gamma_{\mathrm{resp},T_2}$	K^{-2}	reg_land, bio_land	mod_Fland_trans, mod_Fland_resp
g_rhoP	$\gamma_{\mathrm{resp},P}$	$[mm\ yr^{-1}]^{-1}$	reg_land, bio_land	mod_Fland_trans
g_igniC	$\gamma_{\mathrm{igni},C}$	ppm^{-1}	reg_land, bio_land	mod_Efire_trans
g_igniT	$\gamma_{\mathrm{igni},T}$	K^{-1}	reg_land, bio_land	mod_Efire_trans
g_igniP	$\gamma_{\mathrm{igni},P}$	$[mm\ yr^{-1}]^{-1}$	reg_land, bio_land	mod_Efire_trans
t_hwp	τ_{hwp}	yr	box_hwp	mod_Ehwp_tau
w_t_hwp	-	1	-	mod_Ehwp_speed
p_hwp_bb	-	1	box_hwp	-

In code	In papers	Units	Dims	Mods
p_hwp	π_{hwp}	1	reg_land, bio_land, box_hwp	mod_Ehwp_bb
a_bb	α_{bb}	Tg*X* PgC^{-1}	reg_land, bio_land, spc_bb	-
Cfroz_0	$C_{\mathrm{froz},0}$	PgC	reg_pf	mod_Epf_main
w_clim_pf	$\omega_{T_{\mathrm{pf}}}$	1	reg_pf	mod_Epf_main
g_respT_pf	γ_{pf,T_1}	K^{-1}	reg_pf	mod_Epf_main
g_respT2_pf	γ_{pf,T_2}	K^{-2}	reg_pf	mod_Epf_main
k_resp_pf	$\kappa_{\mathrm{resp,pf}}$	1	reg_pf	mod_Epf_main
pthaw_min	$p_{\mathrm{thaw,min}}$	1	reg_pf	mod_Epf_main
g_pthaw	$\gamma_{p_{\mathrm{thaw}}}$	K^{-1}	reg_pf	mod_Epf_main
k_pthaw	$\kappa_{p_{\mathrm{thaw}}}$	1	reg_pf	mod_Epf_main
v_thaw	ν_{thaw}	yr^{-1}	reg_pf	mod_Epf_main
v_froz	ν_{froz}	yr^{-1}	reg_pf	mod_Epf_main
p_pf_thaw	π_{thaw}	1	reg_pf, box_thaw	mod_Epf_main
t_pf_thaw	τ_{thaw}	yr	reg_pf, box_thaw	mod_Epf_main
p_pf_inst	-	1	-	-
p_pf_CH4	-	1	-	mod_Epf_CH4
ewet_0	$e_{\mathrm{wet},0}$	TgC yr^{-1}	reg_land	mod_Ewet_preind
Awet_0	$A_{\mathrm{wet},0}$	Mha	reg_land	mod_Ewet_preind
p_wet	π_{wet}	1	reg_land, bio_land	mod_Ewet_preind
g_wetC	$\gamma_{\mathrm{wet},C}$	ppm^{-1}	reg_land	mod_Awet_trans
g_wetT	$\gamma_{\mathrm{wet},T}$	K^{-1}	reg_land	mod_Awet_trans
g_wetP	$\gamma_{\mathrm{wet},P}$	[mm yr^{-1}]$^{-1}$	reg_land	mod_Awet_trans

In code	In papers	Units	Dims	Mods
a_CO2	$\alpha_{\mathrm{atm}}^{\mathrm{CO_2}}$	PgC ppm^{-1}	-	-
a_CH4	$\alpha_{\mathrm{atm}}^{\mathrm{CH_4}}$	TgC ppb^{-1}	-	-
a_N2O	$\alpha_{\mathrm{atm}}^{\mathrm{N_2O}}$	TgC ppb^{-1}	-	-
a_Xhalo	$\alpha_{\mathrm{atm}}^{X}$	Gg ppt^{-1}	spc_halo	-
a_SO4	-	Tg TgS^{-1}	-	-
a_POM	$\alpha_{\mathrm{OM}}^{\mathrm{OC}}$	Tg TgC^{-1}	-	mod_POA_conv
a_NO3	-	Tg TgN^{-1}	-	-
CO2_0	$\mathrm{CO_2}_0$	ppm	-	-
CH4_0	$\mathrm{CH_4}_0$	ppb	-	-
N2O_0	$\mathrm{N_2O}_0$	ppb	-	-
Xhalo_0	X_0	ppt	spc_halo	-
p_CH4geo	-	1	-	-
g_ageair	γ_{age}	K^{-1}	-	mod_Fhv_ageair
w_t_OH	-	1	-	-
w_t_hv	-	1	-	-
t_OH_CH4	$\tau_{\mathrm{OH}}^{\mathrm{CH_4}}$	yr	-	mod_Foh_tau
t_hv_CH4	$\tau_{h\nu}^{\mathrm{CH_4}}$	yr	-	-
t_soil_CH4	$\tau_{\mathrm{soil}}^{\mathrm{CH_4}}$	yr	-	-
t_ocean_CH4	$\tau_{\mathrm{ocean}}^{\mathrm{CH_4}}$	yr	-	-
x_OH_Ta	$\chi_{\mathrm{T_A}}^{\mathrm{OH}}$	1	-	mod_Foh_trans
x_OH_Qa	$\chi_{\mathrm{Q_A}}^{\mathrm{OH}}$	1	-	mod_Foh_trans
x_OH_O3s	$\chi_{\mathrm{O_3s}}^{\mathrm{OH}}$	1	-	mod_Foh_trans
x_OH_CH4	$\chi_{\mathrm{CH4}}^{\mathrm{OH}}$	1	-	mod_Foh_trans
x_OH_NOX	$\tilde{\chi}_{\mathrm{NO_x}}^{\mathrm{OH}}$	1	-	mod_Foh_trans

In code	In papers	Units	Dims	Mods
x_OH_CO	$\tilde{\chi}^{\mathrm{OH}}_{\mathrm{CO}}$	1	-	mod_Foh_trans
x_OH_VOC	$\tilde{\chi}^{\mathrm{OH}}_{\mathrm{VOC}}$	1	-	mod_Foh_trans
x2_OH_NOX	$\chi^{\mathrm{OH}}_{\mathrm{NO_x}}$	$[\mathrm{TgN\ yr^{-1}}]^{-1}$	-	mod_Foh_trans
x2_OH_CO	$\chi^{\mathrm{OH}}_{\mathrm{CO}}$	$[\mathrm{TgC\ yr^{-1}}]^{-1}$	-	mod_Foh_trans
x2_OH_VOC	$\chi^{\mathrm{OH}}_{\mathrm{VOC}}$	$[\mathrm{Tg\ yr^{-1}}]^{-1}$	-	mod_Foh_trans
w_clim_Ta	$\kappa_{\mathrm{T_A}}$	1	-	-
k_Qa	$\kappa_{\mathrm{Q_A}}$	1	-	-
Ta_0	$T_{A,0}$	K	-	-
k_svp	κ_{svp}	1	-	-
T_svp	T_{svp}	K	-	-
O3s_0	$\mathrm{O_3s_0}$	DU	-	-
Enat_NOX	$E^{\mathrm{NO_x}}_{\mathrm{nat}}$	$\mathrm{TgN\ yr^{-1}}$	-	-
Enat_CO	$E^{\mathrm{CO}}_{\mathrm{nat}}$	$\mathrm{TgC\ yr^{-1}}$	-	-
Enat_VOC	$E^{\mathrm{VOC}}_{\mathrm{nat}}$	$\mathrm{Tg\ yr^{-1}}$	-	-
kOH_is_Log	-	bool	-	mod_Foh_fct
t_hv_N2O	$\tau^{\mathrm{N_2O}}_{\mathrm{h\nu}}$	yr	-	mod_Fhv_tau
x_hv_N2O	$\chi^{\mathrm{h\nu}}_{\mathrm{N2O}}$	1	-	mod_Fhv_trans
x_hv_EESC	$\chi^{\mathrm{h\nu}}_{\mathrm{EESC}}$	1	-	mod_Fhv_trans
x_hv_age	$\chi^{\mathrm{h\nu}}_{\mathrm{age}}$	1	-	mod_Fhv_trans
t_OH_Xhalo	τ^{X}_{OH}	yr	spc_halo	-
t_hv_Xhalo	$\tau^{X}_{\mathrm{h\nu}}$	yr	spc_halo	-
t_other_Xhalo	τ^{X}_{othr}	yr	spc_halo	-
p_reg_slcf	π_{reg}	1	reg_land, reg_slcf	-
w_reg_NOX	$\omega_{\mathrm{NO_x}}$	1	reg_slcf	mod_O3t_regsat

In code	In papers	Units	Dims	Mods
`w_reg_CO`	ω_{CO}	1	`reg_slcf`	`mod_O3t_regsat`
`w_reg_VOC`	ω_{VOC}	1	`reg_slcf`	`mod_O3t_regsat`
`x_O3t_CH4`	$\chi_{\mathrm{CH_4}}^{\mathrm{O_3t}}$	DU	-	`mod_O3t_emis`
`x_O3t_NOX`	$\chi_{\mathrm{NO_x}}^{\mathrm{O_3t}}$	DU [TgN yr^{-1}]$^{-1}$	-	`mod_O3t_emis`
`x_O3t_CO`	$\chi_{\mathrm{CO}}^{\mathrm{O_3t}}$	DU [TgC yr^{-1}]$^{-1}$	-	`mod_O3t_emis`
`x_O3t_VOC`	$\chi_{\mathrm{VOC}}^{\mathrm{O_3t}}$	DU [Tg yr^{-1}]$^{-1}$	-	`mod_O3t_emis`
`G_O3t`	$\Gamma_{\mathrm{O_3t}}$	DU K^{-1}	-	`mod_O3t_clim`
`t_lag`	τ_{lag}	yr	-	-
`p_fracrel`	π_{rel}^{X}	1	`spc_halo`	`mod_O3s_fracrel`
`k_Br_Cl`	$\alpha_{\mathrm{Cl}}^{\mathrm{Br}}$	1	-	-
`n_Cl`	n_{Cl}^{X}	1	`spc_halo`	-
`n_Br`	n_{Br}^{X}	1	`spc_halo`	-
`EESC_x`	$\mathrm{EESC_x}$	ppt	-	-
`k_EESC_N2O`	$\frac{\chi_{\mathrm{N2O}}^{\mathrm{O_3s}}}{\chi_{\mathrm{EESC}}^{\mathrm{O_3s}}}$	ppt ppb^{-1}	-	`mod_O3s_nitrous`, `mod_O3s_fracrel`
`x_O3s_EESC`	$\chi_{\mathrm{EESC}}^{\mathrm{O_3s}}$	DU ppt^{-1}	-	`mod_O3s_trans`
`G_O3s`	$\Gamma_{\mathrm{O_3s}}$	DU K^{-1}	-	`mod_O3s_trans`
`w_reg_SO2`	$\omega_{\mathrm{SO_2}}$	1	`reg_slcf`	`mod_SO4_regsat`
`w_reg_OC`	ω_{OC}	1	`reg_slcf`	`mod_POA_regsat`
`w_reg_BC`	ω_{BC}	1	`reg_slcf`	`mod_BC_regsat`
`t_SO2`	$\tau_{\mathrm{SO_2}}$	yr	-	`mod_SO4_load`
`t_DMS`	τ_{DMS}	yr	-	`mod_SO4_load`
`G_SO4`	$\Gamma_{\mathrm{SO_4}}$	Tg K^{-1}	-	`mod_SO4_load`
`t_OMff`	$\tau_{\mathrm{OM,ff}}$	yr	-	`mod_POA_load`
`t_OMbb`	$\tau_{\mathrm{OM,bb}}$	yr	-	`mod_POA_load`

In code	In papers	Units	Dims	Mods
`G_POA`	Γ_{POA}	Tg K^{-1}	-	`mod_POA_load`
`t_BCff`	$\tau_{\mathrm{BC,ff}}$	yr	-	`mod_BC_load`
`t_BCbb`	$\tau_{\mathrm{BC,bb}}$	yr	-	`mod_BC_load`
`G_BC`	Γ_{BC}	Tg K^{-1}	-	`mod_BC_load`
`t_NOX`	$\tau_{\mathrm{NO_x}}$	yr	-	`mod_NO3_load`
`t_NH3`	$\tau_{\mathrm{NH_3}}$	yr	-	`mod_NO3_load`
`G_NO3`	$\Gamma_{\mathrm{NO_3}}$	Tg K^{-1}	-	`mod_NO3_load`
`t_VOC`	τ_{VOC}	yr	-	`mod_SOA_load`
`t_BVOC`	τ_{BVOC}	yr	-	`mod_SOA_load`
`G_SOA`	Γ_{SOA}	Tg K^{-1}	-	`mod_SOA_load`
`t_dust`	-	yr	-	`mod_Mdust_load`
`G_dust`	-	Tg K^{-1}	-	`mod_Mdust_load`
`t_salt`	-	yr	-	`mod_Msalt_load`
`G_salt`	-	Tg K^{-1}	-	`mod_Msalt_load`
`p_sol_SO4`	$\pi_{\mathrm{sol}}^{\mathrm{SO_4}}$	1	-	`mod_RFcloud_solub`
`p_sol_POA`	$\pi_{\mathrm{sol}}^{\mathrm{POA}}$	1	-	`mod_RFcloud_solub`
`p_sol_BC`	$\pi_{\mathrm{sol}}^{\mathrm{BC}}$	1	-	`mod_RFcloud_solub`
`p_sol_NO3`	$\pi_{\mathrm{sol}}^{\mathrm{NO_3}}$	1	-	`mod_RFcloud_solub`
`p_sol_SOA`	$\pi_{\mathrm{sol}}^{\mathrm{SOA}}$	1	-	`mod_RFcloud_solub`
`p_sol_dust`	-	1	-	`mod_RFcloud_solub`
`p_sol_salt`	-	1	-	`mod_RFcloud_solub`
`rf_CO2`	$\alpha_{\mathrm{rf}}^{\mathrm{CO_2}}$	W m^{-2}	-	-
`rf_CH4`	$\alpha_{\mathrm{rf}}^{\mathrm{CH_4}}$	W m^{-2} ppb$^{-0.5}$	-	-
`rf_N2O`	$\alpha_{\mathrm{rf}}^{\mathrm{N_2O}}$	W m^{-2} ppb$^{-0.5}$	-	-
`k_rf_H2Os`	$\frac{\alpha_{\mathrm{rf}}^{\mathrm{H_2Os}}}{\alpha_{\mathrm{rf}}^{\mathrm{CH_4}}}$	1	-	-

In code	In papers	Units	Dims	Mods
rf_Xhalo	α_{rf}^{X}	W m^{-2} ppt^{-1}	spc_halo	-
rf_O3t	$\alpha_{\mathrm{rf}}^{\mathrm{O_3 t}}$	W m^{-2} DU^{-1}	-	mod_O3t_radeff
rf_O3s	$\alpha_{\mathrm{rf}}^{\mathrm{O_3 s}}$	W m^{-2} DU^{-1}	-	mod_O3s_radeff
rf_SO4	$\alpha_{\mathrm{rf}}^{\mathrm{SO_4}}$	W m^{-2} Tg^{-1}	-	mod_SO4_radeff
rf_POA	$\alpha_{\mathrm{rf}}^{\mathrm{POA}}$	W m^{-2} Tg^{-1}	-	mod_POA_radeff
rf_BC	$\alpha_{\mathrm{rf}}^{\mathrm{BC}}$	W m^{-2} Tg^{-1}	-	mod_BC_radeff
rf_NO3	$\alpha_{\mathrm{rf}}^{\mathrm{NO_3}}$	W m^{-2} Tg^{-1}	-	mod_NO3_radeff
rf_SOA	$\alpha_{\mathrm{rf}}^{\mathrm{SOA}}$	W m^{-2} Tg^{-1}	-	mod_SOA_radeff
rf_dust	-	W m^{-2} Tg^{-1}	-	-
rf_salt	-	W m^{-2} Tg^{-1}	-	-
k_adj_BC	$\kappa_{\mathrm{adj}}^{\mathrm{BC}}$	1	-	mod_BC_adjust
Phi_0	Φ	W m^{-2}	-	mod_RFcloud_erf, mod_RFcloud_solub
AERsol_0	$\mathrm{AER}_{\mathrm{sol,0}}$	Tg	-	mod_RFcloud_solub, mod_RFcloud_erf, mod_RFcloud_preind
p_reg_bcsnow	π_{reg}	1	reg_land, reg_bcsnow	-
w_reg_bcsnow	ω_{BCsnow}	1	reg_bcsnow	mod_RFbcsnow_reg
rf_bcsnow	$\alpha_{\mathrm{rf}}^{\mathrm{BCsnow}}$	W m^{-2} [TgC yr^{-1}]$^{-1}$	-	mod_RFbcsnow_rf
p_trans	π_{trans}	1	-	-
alpha_alb	α_{alb}	1	reg_land, bio_land	mod_RFlcc_alb, mod_RFlcc_flux, mod_RFlcc_cover
F_rsds	ϕ_{rsds}	W m^{-2}	reg_land	mod_RFlcc_flux
w_warm_volc	$\kappa_{\mathrm{warm}}^{\mathrm{volc}}$	1	-	-

In code	In papers	Units	Dims	Mods
w_warm_bcsnow	$\kappa_{\mathrm{warm}}^{\mathrm{BCsnow}}$	1	-	mod_RFbcsnow_warmeff
w_warm_lcc	$\kappa_{\mathrm{warm}}^{\mathrm{LCC}}$	1	-	mod_RFlcc_warmeff
p_atm_CO2	$\pi_{\mathrm{atm}}^{\mathrm{CO_2}}$	1	-	mod_Pg_radfact
p_atm_nonCO2	$\pi_{\mathrm{atm}}^{\mathrm{noCO_2}}$	1	-	mod_Pg_radfact
p_atm_O3t	$\pi_{\mathrm{atm}}^{\mathrm{O_3t}}$	1	-	mod_Pg_radfact
p_atm_strat	$\pi_{\mathrm{atm}}^{\mathrm{strat}}$	1	-	mod_Pg_radfact
p_atm_scatter	$\pi_{\mathrm{atm}}^{\mathrm{scatter}}$	1	-	mod_Pg_radfact
p_atm_absorb	$\pi_{\mathrm{atm}}^{\mathrm{absorb}}$	1	-	mod_Pg_radfact
p_atm_cloud	$\pi_{\mathrm{atm}}^{\mathrm{cloud}}$	1	-	mod_Pg_radfact
p_atm_alb	$\pi_{\mathrm{atm}}^{\mathrm{alb}}$	1	-	mod_Pg_radfact
p_atm_solar	$\pi_{\mathrm{atm}}^{\mathrm{solar}}$	1	-	mod_Pg_radfact
lambda_0	λ	K [W m^{-2}]$^{-1}$	-	mod_Tg_resp
Th_g	$\frac{\tau_{T_G}}{\lambda}$	yr W m^{-2} K^{-1}	-	mod_Tg_resp
Th_d	$\frac{\tau_{T_D}}{\lambda}$	yr W m^{-2} K^{-1}	-	mod_Tg_resp
th_0	$\frac{\theta}{\lambda}$	W m^{-2} K^{-1}	-	mod_Tg_resp
w_clim_Tl	ω_{T_L}	1	reg_land	mod_Tl_pattern, mod_Tg_resp
w_clim_To	ω_{T_S}	1	-	mod_Tl_pattern, mod_Tg_resp
a_prec	α_{P_G}	mm yr^{-1} K^{-1}	-	mod_Pg_resp
b_prec	β_{P_G}	mm yr^{-1} [W m^{-2}]$^{-1}$	-	mod_Pg_resp
w_clim_Pl	ω_{P_L}	1	reg_land	mod_Pl_pattern, mod_Pg_resp
p_ohc	π_{ohc}	1	-	-
pH_is_Log	-	bool	-	mod_pH_fct