OSCAR v3.0

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_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_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_wrap`	wrapper function to run the model in a not-so-flexible standard mode
`fct_process`	equations for the physical processes constituting OSCAR; also contains `OSCAR` and submodels

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`
`E_SO2`	$E_{\mathrm{SO_2}}$	TgS yr^{-1}	`year, reg_land`

In code	In papers	Units	Dims
`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_fmort`	Δf_{mort}	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`f_resp`	$\mathcal{F}_{\text{resp}}$	1	`reg_land, bio_land`	
`D_rh1`	$\Delta\text{rh}_{\text{litt}}$	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`D_fmet`	Δf_{met}	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`D_rh2`	$\Delta\text{rh}_{\text{soil}}$	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_{litt}	PgC Mha^{-1}	`reg_land, bio_land`	**yes**
`D_csoil2`	Δc_{soil}	PgC Mha^{-1}	`reg_land, bio_land`	**yes**
`D_Fveg_bk`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fsoil1_bk`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fsoil2_bk`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fslash`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fhwp`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to, box_hwp`	
`D_NPP_bk`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Efire_bk`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fmort_bk`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	

In code	In papers	Units	Dims	Prog?
`D_RH1_bk`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Fmet_bk`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_RH2_bk`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_Ehwp`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to`	
`D_NBP_bk`	-	PgC yr^{-1}	`reg_land, bio_from, bio_to, box_hwp`	
`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`	$\Delta C_{\mathrm{veg,luc}}$	PgC	`reg_land, bio_from, bio_to`	**yes**
`D_Csoil1_bk`	$\Delta C_{\mathrm{litt,luc}}$	PgC	`reg_land, bio_from, bio_to`	**yes**
`D_Csoil_bk`	$\Delta C_{\mathrm{soil,luc}}$	PgC	`reg_land, bio_from, bio_to`	**yes**
`D_Chwp`	$\Delta C_{\mathrm{hwp,luc}}$	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`	
`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}	-	

In code	In papers	Units	Dims	Prog?
`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`	-	Tg*X* yr^{-1}	`reg_land, bio_land, spc_bb`	
`D_Ebb_ant`	-	Tg*X* yr^{-1}	`reg_land, bio_land, spc_bb`	
`D_Ebb`	ΔE_{bb}	Tg*X* 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}	-	
`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}	-	

In code	In papers	Units	Dims	Prog?
D_f_ageair	-	1	-	
f_hv	$\mathcal{F}_{h\nu}$	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	-	
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	-	

In code	In papers	Units	Dims	Prog?
D_BC	ΔBC	Tg	-	
D_NO3	ΔNO_3	Tg	-	
D_SOA	ΔSOA	Tg	-	
D_Mdust	-	Tg	-	
D_Msalt	-	Tg	-	
RF_SO4	ΔRF^{SO_4}	W m^{-2}	-	
RF_POA	ΔRF^{POA}	W m^{-2}	-	
RF_BC	ΔRF^{BC}	W m^{-2}	-	
RF_NO3	ΔRF^{NO_3}	W m^{-2}	-	
RF_SOA	ΔRF^{SOA}	W m^{-2}	-	
RF_dust	-	W m^{-2}	-	
RF_salt	-	W m^{-2}	-	
D_AERsol	ΔAER_{sol}	Tg	-	
RF_cloud1	-	W m^{-2}	-	
RF_cloud2	-	W m^{-2}	-	
RF_cloud	ΔRF^{cloud}	W m^{-2}	-	
RF_BCsnow	ΔRF^{BCsnow}	W m^{-2}	-	
RF_lcc	ΔRF^{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}	-	

In code	In papers	Units	Dims	Prog?
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

In code	In papers	Units	Dims	Mods
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
k_met	κ_{met}	1	-	-
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
cveg_0	$c_{\text{veg},0}$	PgC Mha^{-1}	reg_land, bio_land	mod_Fland_preind, mod_Efire_preind
mu_0	μ	yr^{-1}	reg_land, bio_land	mod_Fland_preind
rho1_0	ρ_{litt}	yr^{-1}	reg_land, bio_land	mod_Fland_preind
csoil1_0	$c_{\text{litt},0}$	PgC Mha^{-1}	reg_land, bio_land	mod_Fland_preind, mod_Efire_preind
rho2_0	ρ_{soil}	yr^{-1}	reg_land, bio_land	mod_Fland_preind
csoil2_0	$c_{\text{soil},0}$	PgC Mha^{-1}	reg_land, bio_land	mod_Fland_preind, mod_Efire_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	$\tilde{\beta}_{\text{npp}}$	1	reg_land, bio_land	mod_Fland_trans

In code	In papers	Units	Dims	Mods
CO2_cp	CO_{2cp}	ppm	reg_land, bio_land	mod_Fland_trans
g_nppT	$\gamma_{npp,T}$	K^{-1}	reg_land, bio_land	mod_Fland_trans, mod_Fland_fert
g_nppP	$\gamma_{npp,P}$	$[mm\ yr^{-1}]^{-1}$	reg_land, bio_land	mod_Fland_trans, mod_Fland_fert
g_rhoT	$\gamma_{resp,T}$	K^{-1}	reg_land, bio_land	mod_Fland_trans, mod_Fland_resp
g_rhoT1	γ_{resp,T_1}	K^{-1}	reg_land, bio_land	mod_Fland_trans, mod_Fland_resp
g_rhoT2	γ_{resp,T_2}	K^{-2}	reg_land, bio_land	mod_Fland_trans, mod_Fland_resp
g_rhoP	$\gamma_{resp,P}$	$[mm\ yr^{-1}]^{-1}$	reg_land, bio_land	mod_Fland_trans
g_igniC	$\gamma_{igni,C}$	ppm^{-1}	reg_land, bio_land	mod_Efire_trans
g_igniT	$\gamma_{igni,T}$	K^{-1}	reg_land, bio_land	mod_Efire_trans
g_igniP	$\gamma_{igni,P}$	$[mm\ yr^{-1}]^{-1}$	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	-
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	$C_{froz,0}$	PgC	reg_pf	mod_Epf_main
w_clim_pf	$\omega_{T_{pf}}$	1	reg_pf	mod_Epf_main
g_respT_pf	γ_{pf,T_1}	K^{-1}	reg_pf	mod_Epf_main

In code	In papers	Units	Dims	Mods
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
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}	-	-

In code	In papers	Units	Dims	Mods
`CO2_0`	CO_{2_0}	ppm	-	-
`CH4_0`	CH_{4_0}	ppb	-	-
`N2O_0`	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`	$\tau_{\mathrm{h\nu}}^{\mathrm{CH_4}}$	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`
`x_OH_CO`	$\tilde{\chi}_{\mathrm{CO}}^{\mathrm{OH}}$	1	-	`mod_Foh_trans`
`x_OH_VOC`	$\tilde{\chi}_{\mathrm{VOC}}^{\mathrm{OH}}$	1	-	`mod_Foh_trans`
`x2_OH_NOX`	$\chi_{\mathrm{NO_x}}^{\mathrm{OH}}$	[TgN yr^{-1}]$^{-1}$	-	`mod_Foh_trans`
`x2_OH_CO`	$\chi_{\mathrm{CO}}^{\mathrm{OH}}$	[TgC yr^{-1}]$^{-1}$	-	`mod_Foh_trans`
`x2_OH_VOC`	$\chi_{\mathrm{VOC}}^{\mathrm{OH}}$	[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	-	-

In code	In papers	Units	Dims	Mods
`k_svp`	κ_{svp}	1	-	-
`T_svp`	T_{svp}	K	-	-
`O3s_0`	$\mathrm{O_3s_0}$	DU	-	-
`Enat_NOX`	$E_{\mathrm{nat}}^{\mathrm{NO_x}}$	TgN yr^{-1}	-	-
`Enat_CO`	$E_{\mathrm{nat}}^{\mathrm{CO}}$	TgC yr^{-1}	-	-
`Enat_VOC`	$E_{\mathrm{nat}}^{\mathrm{VOC}}$	Tg yr^{-1}	-	-
`kOH_is_Log`	-	`bool`	-	`mod_Foh_fct`
`t_hv_N2O`	$\tau_{\mathrm{h}\nu}^{\mathrm{N_2O}}$	yr	-	`mod_Fhv_tau`
`x_hv_N2O`	$\chi_{\mathrm{N2O}}^{\mathrm{h}\nu}$	1	-	`mod_Fhv_trans`
`x_hv_EESC`	$\chi_{\mathrm{EESC}}^{\mathrm{h}\nu}$	1	-	`mod_Fhv_trans`
`x_hv_age`	$\chi_{\mathrm{age}}^{\mathrm{h}\nu}$	1	-	`mod_Fhv_trans`
`t_OH_Xhalo`	τ_{OH}^{X}	yr	`spc_halo`	-
`t_hv_Xhalo`	$\tau_{\mathrm{h}\nu}^{X}$	yr	`spc_halo`	-
`t_other_Xhalo`	τ_{othr}^{X}	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`
`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`

In code	In papers	Units	Dims	Mods
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	$\mathrm{EESC}_{\mathrm{x}}$	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
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

In code	In papers	Units	Dims	Mods
`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	-	-
`rf_Xhalo`	α_{rf}^{X}	W m^{-2} ppt^{-1}	`spc_halo`	-
`rf_O3t`	$\alpha_{\mathrm{rf}}^{\mathrm{O_3t}}$	W m^{-2} DU^{-1}	-	`mod_O3t_radeff`
`rf_O3s`	$\alpha_{\mathrm{rf}}^{\mathrm{O_3s}}$	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`

In code	In papers	Units	Dims	Mods
`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`	$\mathrm{AER_{sol,0}}$	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	-	-
`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`

In code	In papers	Units	Dims	Mods
`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`