OSCAR

Manual

Basic simulation

Essentially, to make a basic simulation one must:

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

The `run_scripts` folder contains a few extra 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 being loaded from files and others manually written therein
`fct_process_alt`	functions to replace some processes with alternative formulations
`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`
`mod_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`
`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`	F_{pCO_2}	ppm	-	
`D_mld`	Δh_{mld}	m	-	
`D_dic`	Δdic	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`	$\Delta F_{\downarrow ocean}$	PgC yr^{-1}	-	
`D_Cosurf`	ΔC_{surf}	PgC	-	yes
`f_fert`	F_{fert}	1	`reg_land, bio_land`	
`D_npp`	Δnpp	PgC Mha^{-1} yr^{-1}	`reg_land, bio_land`	
`f_igni`	F_{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`	F_{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`	

In code	In papers	Units	Dims	Prog?
`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`	$\Delta c_{\mathrm{soil1}}$	PgC Mha^{-1}	`reg_land, bio_land`	yes
`D_csoil2`	$\Delta c_{\mathrm{soil2}}$	PgC Mha^{-1}	`reg_land, bio_land`	yes
`D_Fveg_bk`	$\delta C_{\mathrm{veg,bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Fsoil1_bk`	$\delta C_{\mathrm{soil1,bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Fsoil2_bk`	$\delta C_{\mathrm{soil2,bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Fslash1`	$\Delta F_{\mathrm{slash1}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Fslash2`	$\Delta F_{\mathrm{slash2}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Fhwp`	ΔF_{hwp}	PgC yr^{-1}	`reg_land, bio_land, box_hwp` †	
`D_NPP_bk`	$\Delta \mathrm{NPP}_{\mathrm{bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Efire_bk`	$\Delta E_{\mathrm{fire,bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Eharv_bk`	$\Delta E_{\mathrm{harv,bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Egraz_bk`	$\Delta E_{\mathrm{graz,bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Fmort1_bk`	$\Delta F_{\mathrm{mort1,bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Fmort2_bk`	$\Delta F_{\mathrm{mort2,bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Rh1_bk`	$\Delta \mathrm{Rh}_{1,\mathrm{bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Fmet_bk`	$\Delta F_{\mathrm{met,bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Rh2_bk`	$\Delta \mathrm{Rh}_{2,\mathrm{bk}}$	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Ehwp`	ΔE_{hwp}	PgC yr^{-1}	`reg_land, bio_land, box_hwp` †	
`D_NBP_bk`	-	PgC yr^{-1}	`reg_land, bio_land` †	
`D_Eluc`	ΔE_{LUC}	PgC yr^{-1}	-	
`D_Fland`	$\Delta F_{\downarrow \mathrm{land}}$	PgC yr^{-1}	-	
`D_Flasc`	ΔF_{LASC}	PgC yr^{-1}	-	
`D_Aland`	ΔA	Mha	`reg_land, bio_land`	yes

In code	In papers	Units	Dims	Prog?
D_Cveg_bk	$\Delta C_{\mathrm{veg,bk}}$	PgC	reg_land, bio_land †	yes
D_Csoil1_bk	$\Delta C_{\mathrm{soil1,bk}}$	PgC	reg_land, bio_land †	yes
D_Csoil2_bk	$\Delta C_{\mathrm{soil2,bk}}$	PgC	reg_land, bio_land †	yes
D_Chwp	ΔC_{hwp}	PgC	reg_land, bio_land, 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
d_CO2	$\frac{\mathrm{d}}{\mathrm{d}t} \mathrm{CO}_2$	ppm yr^{-1}	-	
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	

In code	In papers	Units	Dims	Prog?
`D_Ebb`	ΔE_{bb}	TgX yr^{-1}	`reg_land, bio_land, spc_bb`	
`D_CH4_lag`	$\Delta \mathrm{CH4}_{\mathrm{lag}}$	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`	$\mathrm{F_{OH}}$	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}	-	
`D_f_ageair`	-	1	-	
`f_hv`	$\mathrm{F}_{\mathrm{h}\nu}$	1	-	
`D_Fhv_N2O`	-	TgN yr^{-1}	-	

In code	In papers	Units	Dims	Prog?
`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	-	
`D_BC`	$\Delta \mathrm{BC}$	Tg	-	
`D_NO3`	$\Delta \mathrm{NO_3}$	Tg	-	

In code	In papers	Units	Dims	Prog?
`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}	-	
`RF_alb`	-	W m^{-2}	-	
`RF`	ΔRF	W m^{-2}	-	

In code	In papers	Units	Dims	Prog?
`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`	$\frac{\mathrm{d}}{\mathrm{d}t} T_G$	K yr^{-1}	-	
`CFF`	-	W m^{-2} K^{-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_OHC`	$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{OHC}$	ZJ yr^{-1}	-	
`D_pH`	-	1	-	

† default; can be altered through the `fct_process_alt` functions.

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_stru`

In code	In papers	Units	Dims	Mods
`A_ocean`	A_ocean	m^2	-	`mod_Focean_stru`
`To_0`	$T_{S,0}$	K	-	`mod_Focean_stru`
`v_fg`	ν_fg	yr^{-1}	-	`mod_Focean_stru`
`p_circ`	π_circ	1	`box_osurf`	`mod_Focean_stru`
`t_circ`	τ_circ	yr	`box_osurf`	`mod_Focean_stru`
`pCO2_is_Pade`	-	`bool`	-	`mod_Focean_chem`
`p_mld`	π_mld	1	-	`mod_Focean_trar`
`g_mld`	γ_mld	K^{-1}	-	`mod_Focean_trar`
`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_preir`
`igni_0`	ι	yr^{-1}	`reg_land`, `bio_land`	`mod_Efire_preir`
`harv_0`	ϵ_harv	yr^{-1}	`reg_land`, `bio_land`	`mod_Eharv_preir`
`graz_0`	ϵ_graz	yr^{-1}	`reg_land`, `bio_land`	`mod_Egraz_preir`
`mu1_0`	μ_1	yr^{-1}	`reg_land`, `bio_land`	`mod_Fland_preir`
`mu2_0`	μ_2	yr^{-1}	`reg_land`, `bio_land`	`mod_Fland_preir`
`muM_0`	μ_met	yr^{-1}	`reg_land`, `bio_land`	`mod_Fland_preir`
`rho1_0`	ρ_1	yr^{-1}	`reg_land`, `bio_land`	`mod_Fland_preir`
`rho2_0`	ρ_2	yr^{-1}	`reg_land`, `bio_land`	`mod_Fland_preir`

In code	In papers	Units	Dims	Mods
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	$\widetilde{\beta}_{\text{npp}}$	1	reg_land, bio_land	mod_Fland_trans
CO2_cp	$\text{CO}_{2\,\text{cp}}$	ppm	reg_land, bio_land	mod_Fland_trans
g_nppT	$\gamma_{\text{npp},T}$	K^{-1}	reg_land, bio_land	mod_Fland_trans mod_Fland_fert
g_nppP	$\gamma_{\text{npp},P}$	$[\text{mm yr}^{-1}]^{-1}$	reg_land, bio_land	mod_Fland_trans mod_Fland_fert
g_rhoT	$\gamma_{\text{resp},T}$	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	$\gamma_{\text{resp},P}$	$[\text{mm yr}^{-1}]^{-1}$	reg_land, bio_land	mod_Fland_trans
g_igniC	$\gamma_{\text{igni},C}$	ppm^{-1}	reg_land, bio_land	mod_Efire_trans
g_igniT	$\gamma_{\text{igni},T}$	K^{-1}	reg_land, bio_land	mod_Efire_trans
g_igniP	$\gamma_{\text{igni},P}$	$[\text{mm yr}^{-1}]^{-1}$	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}	TgX 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	v_{thaw}	yr^{-1}	reg_pf	mod_Epf_main
v_froz	v_{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_preinc
Awet_0	$A_{\mathrm{wet},0}$	Mha	reg_land	mod_Ewet_preinc
p_wet	π_{wet}	1	reg_land, bio_land	mod_Ewet_preinc
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

In code	In papers	Units	Dims	Mods
`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}	-	-
`CO2_0`	$\mathrm{CO2}_0$	ppm	-	-
`CH4_0`	$\mathrm{CH4}_0$	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`	$\tau_{\mathrm{h}\nu}^{\mathrm{CH_4}}$	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`

In code	In papers	Units	Dims	Mods
`x_OH_NOX`	$\tilde{\chi}^{\mathrm{OH}}_{\mathrm{NO_x}}$	1	-	`mod_Foh_trans`
`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`	$\mathrm{O_3 s_0}$	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`	-

In code	In papers	Units	Dims	Mods
`w_reg_NOX`	ω_{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`	$\chi^{O_3t}_{CH_4}$	DU	-	`mod_O3t_emis`
`x_O3t_NOX`	$\chi^{O_3t}_{NO_x}$	DU [TgN $yr^{-1}]^{-1}$	-	`mod_O3t_emis`
`x_O3t_CO`	$\chi^{O_3t}_{CO}$	DU [TgC $yr^{-1}]^{-1}$	-	`mod_O3t_emis`
`x_O3t_VOC`	$\chi^{O_3t}_{VOC}$	DU [Tg $yr^{-1}]^{-1}$	-	`mod_O3t_emis`
`G_O3t`	Γ_{O_3t}	DU K^{-1}	-	`mod_O3t_clim`
`t_lag`	τ_{lag}	yr	-	-
`p_fracrel`	π^X_{rel}	1	`spc_halo`	`mod_O3s_fracrel`
`k_Br_Cl`	α^{Br}_{Cl}	1	-	-
`n_Cl`	n^X_{Cl}	1	`spc_halo`	-
`n_Br`	n^X_{Br}	1	`spc_halo`	-
`EESC_x`	$EESC_\times$	ppt	-	-
`k_EESC_N2O`	$\frac{\chi^{O_3s}_{N2O}}{\chi^{O_3s}_{EESC}}$	ppt ppb^{-1}	-	`mod_O3s_nitrous` `mod_O3s_fracrel`
`x_O3s_EESC`	$\chi^{O_3s}_{EESC}$	DU ppt^{-1}	-	`mod_O3s_trans`
`G_O3s`	Γ_{O_3s}	DU K^{-1}	-	`mod_O3s_trans`
`w_reg_SO2`	ω_{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`	τ_{SO_2}	yr	-	`mod_SO4_load`
`t_DMS`	τ_{DMS}	yr	-	`mod_SO4_load`
`G_SO4`	Γ_{SO_4}	Tg K^{-1}	-	`mod_SO4_load`
`t_OMff`	$\tau_{OM,ff}$	yr	-	`mod_POA_load`

In code	In papers	Units	Dims	Mods
`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`
`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_sol`
`p_sol_POA`	$\pi_{\mathrm{sol}}^{\mathrm{POA}}$	1	-	`mod_RFcloud_sol`
`p_sol_BC`	$\pi_{\mathrm{sol}}^{\mathrm{BC}}$	1	-	`mod_RFcloud_sol`
`p_sol_NO3`	$\pi_{\mathrm{sol}}^{\mathrm{NO_3}}$	1	-	`mod_RFcloud_sol`
`p_sol_SOA`	$\pi_{\mathrm{sol}}^{\mathrm{SOA}}$	1	-	`mod_RFcloud_sol`
`p_sol_dust`	-	1	-	`mod_RFcloud_sol`
`p_sol_salt`	-	1	-	`mod_RFcloud_sol`
`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$^{-0.5}$	-	-

In code	In papers	Units	Dims	Mods
`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`
`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_sol`
`AERsol_0`	$\mathrm{AER}_{\mathrm{sol,0}}$	Tg	-	`mod_RFcloud_sol` `mod_RFcloud_erf_` `mod_RFcloud_pre`
`p_reg_bcsnow`	π_{reg}	1	`reg_land`, `reg_bcsnow`	-
`w_reg_bcsnow`	ω_{BCsnow}	1	`reg_bcsnow`	`mod_RFbcsnow_re`
`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`

In code	In papers	Units	Dims	Mods
`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_wa`
`w_warm_lcc`	$\kappa_{\mathrm{warm}}^{\mathrm{LCC}}$	1	-	`mod_RFlcc_warme`
`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`
`e_ohu`	-	1	-	-
`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`

In code	In papers	Units	Dims	Mods
`p_ohc`	π_{ohc}	1	-	-
`pH_is_Log`	-	`bool`	-	`mod_pH_fct`