

# OSCAR v3.0.1

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## 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
<code>cls_main</code>	definition of the <code>Model</code> and <code>Process</code> classes upon which OSCAR v3 is based
<code>fct_misc</code>	a bunch of useful functions, notably including the solving schemes, a generic loading function called <code>load_data</code> , and a function to regionally aggregate datasets called <code>aggreg_region</code>
<code>fct_genD</code>	functions to generate consistent timeseries of drivers
<code>fct_genMC</code>	functions to generate the Monte Carlo setup
<code>fct_loadD</code>	functions to load the primary drivers
<code>fct_loadP</code>	functions to load the primary parameters, some of them being loaded from files and others manually written there
<code>fct_wrap</code>	wrapper function to run the model in a not-so-flexible standard mode
<code>fct_process</code>	equations for the physical processes constituting OSCAR; also contains <code>OSCAR</code> 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
<code>year</code>	time axis
<code>config</code>	Monte Carlo elements
<code>spc_halo</code>	species of halogenated compounds
<code>box_osurf</code>	pools for the surface ocean carbon cycling
<code>reg_land</code>	land carbon-cycle regions
<code>bio_land</code>	land carbon-cycle biomes
<code>bio_from</code>	origine biomes of the land-use perturbations
<code>bio_to</code>	destination biomes of the land-use perturbations
<code>box_hwp</code>	pools of harvested wood products
<code>reg_pf</code>	regions specific to the permafrost module
<code>box_thaw</code>	pools of thawed permafrost
<code>spc_bb</code>	species from biomass burning
<code>reg_slcf</code>	regions specific to SLCF regional saturation effects
<code>reg_bcsnow</code>	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
<code>E<sub>ff</sub></code>	$E_{FF}$	PgC yr <sup>-1</sup>	<code>year</code> , <code>reg_land</code>
<code>E<sub>CH4</sub></code>	$E_{CH_4}$	TgC yr <sup>-1</sup>	<code>year</code> , <code>reg_land</code>
<code>E<sub>N2O</sub></code>	$E_{N_2O}$	TgN yr <sup>-1</sup>	<code>year</code> , <code>reg_land</code>
<code>E<sub>Xhalo</sub></code>	$E_X$	Gg yr <sup>-1</sup>	<code>year</code> , <code>reg_land</code> , <code>spc_halo</code>
<code>E<sub>NOX</sub></code>	$E_{NO_x}$	TgN yr <sup>-1</sup>	<code>year</code> , <code>reg_land</code>
<code>E<sub>CO</sub></code>	$E_{CO}$	TgC yr <sup>-1</sup>	<code>year</code> , <code>reg_land</code>
<code>E<sub>VOC</sub></code>	$E_{VOC}$	Tg yr <sup>-1</sup>	<code>year</code> , <code>reg_land</code>
<code>E<sub>SO2</sub></code>	$E_{SO_2}$	TgS yr <sup>-1</sup>	<code>year</code> , <code>reg_land</code>

In code	In papers	Units	Dims
$E_{\text{NH}_3}$	$E_{\text{NH}_3}$	TgN yr <sup>-1</sup>	year, reg_land
$E_{\text{OC}}$	$E_{\text{OC}}$	TgC yr <sup>-1</sup>	year, reg_land
$E_{\text{BC}}$	$E_{\text{BC}}$	TgC yr <sup>-1</sup>	year, reg_land
$d_{\text{Acover}}$	$\delta A$	Mha yr <sup>-1</sup>	year, reg_land, bio_from, bio_to
$d_{\text{Hwood}}$	$\delta H$	PgC yr <sup>-1</sup>	year, reg_land, bio_land
$d_{\text{Ashift}}$	$\delta S$	Mha yr <sup>-1</sup>	year, reg_land, bio_from, bio_to
$\text{RF}_{\text{contr}}$	$\text{RF}_{\text{con}}$	W m <sup>-2</sup>	year
$\text{RF}_{\text{volc}}$	$\text{RF}_{\text{volc}}$	W m <sup>-2</sup>	year
$\text{RF}_{\text{solar}}$	$\text{RF}_{\text{solar}}$	W m <sup>-2</sup>	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?
$D_{\text{pCO}_2}$	$\mathcal{F}_{\text{pCO}_2}$	ppm	-	
$D_{\text{mld}}$	$\Delta h_{\text{mld}}$	m	-	
$D_{\text{dic}}$	$\Delta \text{dic}$	μmol kg <sup>-1</sup>	-	
$D_{\text{Fin}}$	$\Delta F_{\text{in}}$	PgC yr <sup>-1</sup>	box_osurf	
$D_{\text{Fout}}$	$\Delta F_{\text{out}}$	PgC yr <sup>-1</sup>	box_osurf	
$D_{\text{Fcirc}}$	$\Delta F_{\text{circ}}$	PgC yr <sup>-1</sup>	box_osurf	
$D_{\text{Focean}}$	$\Delta F_{\downarrow \text{ocean}}$	PgC yr <sup>-1</sup>	-	
$D_{\text{Cosurf}}$	$\Delta C_{\text{surf}}$	PgC	-	yes

In code	In papers	Units	Dims	Prog?
f_fert	$\mathcal{F}_{\text{fert}}$	1	reg_land, bio_land	
D_npp	$\Delta npp$	PgC Mha <sup>-1</sup> yr <sup>-1</sup>	reg_land, bio_land	
f_igni	$\mathcal{F}_{\text{igni}}$	1	reg_land, bio_land	
D_efire	$\Delta e_{\text{fire}}$	PgC Mha <sup>-1</sup> yr <sup>-1</sup>	reg_land, bio_land	
D_fmort	$\Delta f_{\text{mort}}$	PgC Mha <sup>-1</sup> yr <sup>-1</sup>	reg_land, bio_land	
f_resp	$\mathcal{F}_{\text{resp}}$	1	reg_land, bio_land	
D_rh1	$\Delta rh_{\text{litt}}$	PgC Mha <sup>-1</sup> yr <sup>-1</sup>	reg_land, bio_land	
D_fmet	$\Delta f_{\text{met}}$	PgC Mha <sup>-1</sup> yr <sup>-1</sup>	reg_land, bio_land	
D_rh2	$\Delta rh_{\text{soil}}$	PgC Mha <sup>-1</sup> yr <sup>-1</sup>	reg_land, bio_land	
D_nbp	-	PgC Mha <sup>-1</sup> yr <sup>-1</sup>	reg_land, bio_land	
D_cveg	$\Delta c_{\text{veg}}$	PgC Mha <sup>-1</sup>	reg_land, bio_land	yes
D_csoil1	$\Delta c_{\text{litt}}$	PgC Mha <sup>-1</sup>	reg_land, bio_land	yes
D_csoil2	$\Delta c_{\text{soil}}$	PgC Mha <sup>-1</sup>	reg_land, bio_land	yes
D_Fveg_bk	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to	
D_Fsoil1_bk	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to	
D_Fsoil2_bk	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to	
D_Fslash	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to	
D_Fhwp	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to, box_hwp	
D_NPP_bk	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to	
D_Efire_bk	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to	
D_Fmort_bk	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to	

In code	In papers	Units	Dims	Prog?
D_RH1_bk	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to	
D_Fmet_bk	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to	
D_RH2_bk	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to	
D_Ehwp	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to	
D_NBP_bk	-	PgC yr <sup>-1</sup>	reg_land, bio_from, bio_to, box_hwp	
D_Eluc	$\Delta E_{\text{LUC}}$	PgC yr <sup>-1</sup>	-	
D_Fland	$\Delta F_{\downarrow \text{land}}$	PgC yr <sup>-1</sup>	-	
D_Aland	$\Delta A$	Mha	reg_land, bio_land	yes
D_Cveg_bk	$\Delta C_{\text{veg,luc}}$	PgC	reg_land, bio_from, bio_to	yes
D_Csoil1_bk	$\Delta C_{\text{litt,luc}}$	PgC	reg_land, bio_from, bio_to	yes
D_Csoil_bk	$\Delta C_{\text{soil,luc}}$	PgC	reg_land, bio_from, bio_to	yes
D_Chwp	$\Delta C_{\text{hwp,luc}}$	PgC	reg_land, bio_from, bio_to, box_hwp	yes
f_resp_pf	-	1	reg_pf	
D_pthaw_bar	$\Delta \bar{p}_{\text{thaw}}$	1	reg_pf	
d_pthaw	$\frac{d}{dt} p_{\text{thaw}}$	yr <sup>-1</sup>	reg_pf	
D_pthaw	$\Delta p_{\text{thaw}}$	1	reg_pf	yes
D_Fthaw	$\Delta F_{\text{thaw}}$	PgC yr <sup>-1</sup>	reg_pf	
D_Ethaw	-	PgC yr <sup>-1</sup>	reg_pf, box_thaw	
D_Epf	$\Delta E_{\text{pf}}$	PgC yr <sup>-1</sup>	reg_pf	
D_Epf_CO2	-	PgC yr <sup>-1</sup>	reg_pf	
D_Epf_CH4	-	TgC yr <sup>-1</sup>	reg_pf	
D_Cfroz	$\Delta C_{\text{froz}}$	PgC	reg_pf	yes
D_Cthaw	$\Delta C_{\text{thaw}}$	PgC	reg_pf, box_thaw	yes
D_CO2	$\Delta \text{CO}_2$	ppm	-	yes
AF	-	1	-	
kS	-	yr <sup>-1</sup>	-	

In code	In papers	Units	Dims	Prog?
RF_CO2	$\Delta RF^{CO_2}$	W m <sup>-2</sup>	-	
D_Efire	$\Delta E_{\text{fire}}$	PgC yr <sup>-1</sup>	reg_land, bio_land	
D_Ebb_nat	-	TgX yr <sup>-1</sup>	reg_land, bio_land, spc_bb	
D_Ebb_ant	-	TgX yr <sup>-1</sup>	reg_land, bio_land, spc_bb	
D_Ebb	$\Delta E_{\text{bb}}$	TgX yr <sup>-1</sup>	reg_land, bio_land, spc_bb	
D_CH4_lag	$\Delta CH_4_{\text{lag}}$	ppb	-	yes
D_N2O_lag	$\Delta N_2O_{\text{lag}}$	ppb	-	yes
D_Xhalo_lag	$\Delta X_{\text{lag}}$	ppt	spc_halo	yes
D_Ta	$\Delta T_A$	K	-	
D_f_Qa	$\frac{\Delta Q_A}{Q_{A,0}}$	1	-	
f_kOH	$\mathcal{F}_{\text{OH}}$	1	-	
D_Foh_CH4	-	TgC yr <sup>-1</sup>	-	
D_Fhv_CH4	-	TgC yr <sup>-1</sup>	-	
D_Fsoil_CH4	-	TgC yr <sup>-1</sup>	-	
D_Focean_CH4	-	TgC yr <sup>-1</sup>	-	
D_Fsink_CH4	$\Delta F_{\downarrow}^{CH_4}$	TgC yr <sup>-1</sup>	-	
D_Foxi_CH4	-	PgC yr <sup>-1</sup>	-	
D_ewet	$\Delta e_{\text{wet}}$	TgC Mha <sup>-1</sup> yr <sup>-1</sup>	reg_land	
D_Awet	$\Delta A_{\text{wet}}$	Mha	reg_land	
D_Ewet	$\Delta E_{\text{wet}}$	TgC yr <sup>-1</sup>	reg_land	
D_CH4	$\Delta CH_4$	ppb	-	yes
tau_CH4	-	yr	-	
RF_CH4	$\Delta RF^{CH_4}$	W m <sup>-2</sup>	-	
RF_H2Os	$\Delta RF^{H_2Os}$	W m <sup>-2</sup>	-	

In code	In papers	Units	Dims	Prog?
D_f_ageair	-	1	-	
f_hv	$\mathcal{F}_{hv}$	1	-	
D_Fhv_N2O	-	TgN yr <sup>-1</sup>	-	
D_Fsink_N2O	$\Delta F_{\downarrow}^{N_2O}$	TgN yr <sup>-1</sup>	-	
D_N2O	$\Delta N_2O$	ppb	-	yes
tau_N2O	-	yr	-	
RF_N2O	$\Delta RF^{N_2O}$	W m <sup>-2</sup>	-	
D_Foh_Xhalo	-	Gg yr <sup>-1</sup>	spc_halo	
D_Fhv_CH4	-	Gg yr <sup>-1</sup>	spc_halo	
D_Fother_CH4	-	Gg yr <sup>-1</sup>	spc_halo	
D_Fsink_CH4	$\Delta F_{\downarrow}^X$	Gg yr <sup>-1</sup>	spc_halo	
D_Xhalo	$\Delta X$	ppt	spc_halo	yes
RF_Xhalo	$\Delta RF^X$	W m <sup>-2</sup>	spc_halo	
RF_halo	$\Delta RF^{halo}$	W m <sup>-2</sup>	-	
D_O3t	$\Delta O_{3t}$	DU	-	
RF_O3t	$\Delta RF^{O_{3t}}$	W m <sup>-2</sup>	-	
D_EESC	$\Delta EESC$	ppt	-	
D_O3s	$\Delta O_{3s}$	DU	-	
RF_O3s	$\Delta RF^{O_{3s}}$	W m <sup>-2</sup>	-	
D_Edms	$\Delta E_{DMS}$	TgS yr <sup>-1</sup>	-	
D_Ebvoc	$\Delta E_{BVOC}$	Tg yr <sup>-1</sup>	-	
D_Edust	-	Tg yr <sup>-1</sup>	-	
D_Esalt	-	Tg yr <sup>-1</sup>	-	
D_SO4	$\Delta SO_4$	Tg	-	
D_POA	$\Delta POA$	Tg	-	

In code	In papers	Units	Dims	Prog?
D_BC	$\Delta BC$	Tg	-	
D_NO3	$\Delta NO_3$	Tg	-	
D_SOA	$\Delta SOA$	Tg	-	
D_Mdust	-	Tg	-	
D_Msalt	-	Tg	-	
RF_SO4	$\Delta RF^{SO_4}$	W m <sup>-2</sup>	-	
RF_POA	$\Delta RF^{POA}$	W m <sup>-2</sup>	-	
RF_BC	$\Delta RF^{BC}$	W m <sup>-2</sup>	-	
RF_NO3	$\Delta RF^{NO_3}$	W m <sup>-2</sup>	-	
RF_SOA	$\Delta RF^{SOA}$	W m <sup>-2</sup>	-	
RF_dust	-	W m <sup>-2</sup>	-	
RF_salt	-	W m <sup>-2</sup>	-	
D_AERsol	$\Delta AER_{sol}$	Tg	-	
RF_cloud1	-	W m <sup>-2</sup>	-	
RF_cloud2	-	W m <sup>-2</sup>	-	
RF_cloud	$\Delta RF^{cloud}$	W m <sup>-2</sup>	-	
RF_BCsnow	$\Delta RF^{BCsnow}$	W m <sup>-2</sup>	-	
RF_lcc	$\Delta RF^{LCC}$	W m <sup>-2</sup>	-	
RF_nonCO2	-	W m <sup>-2</sup>	-	
RF_wmghg	-	W m <sup>-2</sup>	-	
RF_strat	-	W m <sup>-2</sup>	-	
RF_scatter	-	W m <sup>-2</sup>	-	
RF_absorb	-	W m <sup>-2</sup>	-	
RF_AERtot	-	W m <sup>-2</sup>	-	
RF_slcf	-	W m <sup>-2</sup>	-	



In code	In papers	Units	Dims	Prog?
RF_alb	-	$\text{W m}^{-2}$	-	
RF	$\Delta \text{RF}$	$\text{W m}^{-2}$	-	
RF_warm	$\Delta \text{RF}_{\text{warm}}$	$\text{W m}^{-2}$	-	
RF_atm	$\Delta \text{RF}_{\text{atm}}$	$\text{W m}^{-2}$	-	
D_Tg	$\Delta T_G$	K	-	yes
D_Td	$\Delta T_D$	K	-	yes
d_Tg	$\frac{d}{dt} T_G$	$\text{K yr}^{-1}$	-	
D_Tl	$\Delta T_L$	K	reg_land	
D_To	$\Delta T_S$	K	-	
D_Pg	$\Delta P_G$	$\text{mm yr}^{-1}$	-	yes
D_Pl	$\Delta P_L$	$\text{mm yr}^{-1}$	reg_land	
D_OHC	$\Delta \text{OHC}$	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	$\alpha_{\text{sol}}$	$\mu\text{mol kg}^{-1} [\text{ppm m}^{-3}]^{-1}$	-	-
mld_0	$h_{\text{mld},0}$	m	-	mod_Focean_struct
A_ocean	$A_{\text{ocean}}$	$\text{m}^2$	-	mod_Focean_struct
To_0	$T_{S,0}$	K	-	mod_Focean_struct
v_fg	$\nu_{\text{fg}}$	$\text{yr}^{-1}$	-	mod_Focean_struct

In code	In papers	Units	Dims	Mods
p_circ	$\pi_{\text{circ}}$	1	box_osurf	mod_Focean_struct
t_circ	$\tau_{\text{circ}}$	yr	box_osurf	mod_Focean_struct
pCO2_is_Pade	-	bool	-	mod_Focean_chem
p_mld	$\pi_{\text{mld}}$	1	-	mod_Focean_trans
g_mld	$\gamma_{\text{mld}}$	K <sup>-1</sup>	-	mod_Focean_trans
fert_is_Log	-	bool	-	mod_Fland_fert
k_met	$\kappa_{\text{met}}$	1	-	-
t_shift	$\tau_{\text{shift}}$	yr	-	-
npp_0	$\eta$	PgC Mha <sup>-1</sup> yr <sup>-1</sup>	reg_land, bio_land	mod_Fland_preind
igni_0	$\ell$	yr <sup>-1</sup>	reg_land, bio_land	mod_Efire_preind
cveg_0	$C_{\text{veg},0}$	PgC Mha <sup>-1</sup>	reg_land, bio_land	mod_Fland_preind, mod_Efire_preind
mu_0	$\mu$	yr <sup>-1</sup>	reg_land, bio_land	mod_Fland_preind
rho1_0	$\rho_{\text{litt}}$	yr <sup>-1</sup>	reg_land, bio_land	mod_Fland_preind
csoil1_0	$C_{\text{litt},0}$	PgC Mha <sup>-1</sup>	reg_land, bio_land	mod_Fland_preind, mod_Efire_preind
rho2_0	$\rho_{\text{soil}}$	yr <sup>-1</sup>	reg_land, bio_land	mod_Fland_preind
csoil2_0	$C_{\text{soil},0}$	PgC Mha <sup>-1</sup>	reg_land, bio_land	mod_Fland_preind, mod_Efire_preind
p_agb	$\pi_{\text{agb}}$	1	reg_land, bio_land	mod_Eluc_agb
b_npp	$\beta_{\text{npp}}$	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
C02_cp	CO <sub>2cp</sub>	ppm	reg_land, bio_land	mod_Fland_trans
g_nppT	$\gamma_{npp,T}$	K <sup>-1</sup>	reg_land, bio_land	mod_Fland_trans, mod_Fland_fert
g_nppP	$\gamma_{npp,P}$	[mm yr <sup>-1</sup> ] <sup>-1</sup>	reg_land, bio_land	mod_Fland_trans, mod_Fland_fert
g_rhoT	$\gamma_{resp,T}$	K <sup>-1</sup>	reg_land, bio_land	mod_Fland_trans, mod_Fland_resp
g_rhoT1	$\gamma_{resp,T_1}$	K <sup>-1</sup>	reg_land, bio_land	mod_Fland_trans, mod_Fland_resp
g_rhoT2	$\gamma_{resp,T_2}$	K <sup>-2</sup>	reg_land, bio_land	mod_Fland_trans, mod_Fland_resp
g_rhoP	$\gamma_{resp,P}$	[mm yr <sup>-1</sup> ] <sup>-1</sup>	reg_land, bio_land	mod_Fland_trans
g_igniC	$\gamma_{igni,C}$	ppm <sup>-1</sup>	reg_land, bio_land	mod_Efire_trans
g_igniT	$\gamma_{igni,T}$	K <sup>-1</sup>	reg_land, bio_land	mod_Efire_trans
g_igniP	$\gamma_{igni,P}$	[mm yr <sup>-1</sup> ] <sup>-1</sup>	reg_land, bio_land	mod_Efire_trans
t_hwp	$\tau_{hwp}$	yr	box_hwp	mod_Ehwp_tau
w_t_hwp	-	1	-	mod_Ehwp_speed
p_hwp_bb	-	1	box_hwp	-
p_hwp	$\pi_{hwp}$	1	reg_land, bio_land, box_hwp	mod_Ehwp_bb
a_bb	$\alpha_{bb}$	TgX PgC <sup>-1</sup>	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	$\gamma_{pf,T_1}$	K <sup>-1</sup>	reg_pf	mod_Epf_main

In code	In papers	Units	Dims	Mods
g_respT2_pf	$\gamma_{pf,T_2}$	K <sup>-2</sup>	reg_pf	mod_Epf_main
k_resp_pf	$\kappa_{resp,pf}$	1	reg_pf	mod_Epf_main
p_thaw_min	$p_{thaw,min}$	1	reg_pf	mod_Epf_main
g_pthaw	$\gamma_{pthaw}$	K <sup>-1</sup>	reg_pf	mod_Epf_main
k_pthaw	$\kappa_{pthaw}$	1	reg_pf	mod_Epf_main
v_thaw	$\nu_{thaw}$	yr <sup>-1</sup>	reg_pf	mod_Epf_main
v_froz	$\nu_{froz}$	yr <sup>-1</sup>	reg_pf	mod_Epf_main
p_pf_thaw	$\pi_{thaw}$	1	reg_pf, box_thaw	mod_Epf_main
t_pf_thaw	$\tau_{thaw}$	yr	reg_pf, box_thaw	mod_Epf_main
p_pf_inst	-	1	-	-
p_pf_CH4	-	1	-	mod_Epf_CH4
ewet_0	$e_{wet,0}$	TgC yr <sup>-1</sup>	reg_land	mod_Ewet_preind
Awet_0	$A_{wet,0}$	Mha	reg_land	mod_Ewet_preind
p_wet	$\pi_{wet}$	1	reg_land, bio_land	mod_Ewet_preind
g_wetC	$\gamma_{wet,C}$	ppm <sup>-1</sup>	reg_land	mod_Awet_trans
g_wetT	$\gamma_{wet,T}$	K <sup>-1</sup>	reg_land	mod_Awet_trans
g_wetP	$\gamma_{wet,P}$	[mm yr <sup>-1</sup> ] <sup>-1</sup>	reg_land	mod_Awet_trans
a_CO2	$\alpha_{atm}^{CO_2}$	PgC ppm <sup>-1</sup>	-	-
a_CH4	$\alpha_{atm}^{CH_4}$	TgC ppb <sup>-1</sup>	-	-
a_N2O	$\alpha_{atm}^{N_2O}$	TgC ppb <sup>-1</sup>	-	-
a_Xhalo	$\alpha_{atm}^X$	Gg ppt <sup>-1</sup>	spc_halo	-
a_S04	-	Tg TgS <sup>-1</sup>	-	-
a_POM	$\alpha_{OM}^{OC}$	Tg TgC <sup>-1</sup>	-	mod_POA_conv
a_N03	-	Tg TgN <sup>-1</sup>	-	-

In code	In papers	Units	Dims	Mods
C02_0	CO <sub>20</sub>	ppm	-	-
CH4_0	CH <sub>40</sub>	ppb	-	-
N2O_0	N <sub>2</sub> O <sub>0</sub>	ppb	-	-
Xhalo_0	X <sub>0</sub>	ppt	spc_halo	-
p_CH4geo	-	1	-	-
g_ageair	$\gamma_{age}$	K <sup>-1</sup>	-	mod_Fhv_ageair
w_t_OH	-	1	-	-
w_t_hv	-	1	-	-
t_OH_CH4	$\tau_{OH}^{CH_4}$	yr	-	mod_Foh_tau
t_hv_CH4	$\tau_{hv}^{CH_4}$	yr	-	-
t_soil_CH4	$\tau_{soil}^{CH_4}$	yr	-	-
t_ocean_CH4	$\tau_{ocean}^{CH_4}$	yr	-	-
x_OH-Ta	$\chi_{TA}^{OH}$	1	-	mod_Foh_trans
x_OH-Qa	$\chi_{QA}^{OH}$	1	-	mod_Foh_trans
x_OH_O3s	$\chi_{O_3s}^{OH}$	1	-	mod_Foh_trans
x_OH_CH4	$\chi_{CH_4}^{OH}$	1	-	mod_Foh_trans
x_OH_NOX	$\tilde{\chi}_{NO_x}^{OH}$	1	-	mod_Foh_trans
x_OH_CO	$\tilde{\chi}_{CO}^{OH}$	1	-	mod_Foh_trans
x_OH_VOC	$\tilde{\chi}_{VOC}^{OH}$	1	-	mod_Foh_trans
x2_OH_NOX	$\chi_{NO_x}^{OH}$	[TgN yr <sup>-1</sup> ] <sup>-1</sup>	-	mod_Foh_trans
x2_OH_CO	$\chi_{CO}^{OH}$	[TgC yr <sup>-1</sup> ] <sup>-1</sup>	-	mod_Foh_trans
x2_OH_VOC	$\chi_{VOC}^{OH}$	[Tg yr <sup>-1</sup> ] <sup>-1</sup>	-	mod_Foh_trans
w_clim-Ta	$\kappa_{TA}$	1	-	-
k_Qa	$\kappa_{QA}$	1	-	-
Ta_0	T <sub>A,0</sub>	K	-	-

In code	In papers	Units	Dims	Mods
k_svp	$\kappa_{\text{svp}}$	1	-	-
T_svp	$T_{\text{svp}}$	K	-	-
O3s_0	$O_3s_0$	DU	-	-
Enat_NOX	$E_{\text{nat}}^{\text{NO}_x}$	TgN yr <sup>-1</sup>	-	-
Enat_CO	$E_{\text{nat}}^{\text{CO}}$	TgC yr <sup>-1</sup>	-	-
Enat_VOC	$E_{\text{nat}}^{\text{VOC}}$	Tg yr <sup>-1</sup>	-	-
kOH_is_Log	-	bool	-	mod_Foh_fct
t_hv_N2O	$\tau_{\text{h}\nu}^{\text{N}_2\text{O}}$	yr	-	mod_Fhv_tau
x_hv_N2O	$\chi_{\text{N}_2\text{O}}^{\text{h}\nu}$	1	-	mod_Fhv_trans
x_hv_EESC	$\chi_{\text{EESC}}^{\text{h}\nu}$	1	-	mod_Fhv_trans
x_hv_age	$\chi_{\text{age}}^{\text{h}\nu}$	1	-	mod_Fhv_trans
t_OH_Xhalo	$\tau_{\text{OH}}^X$	yr	spc_halo	-
t_hv_Xhalo	$\tau_{\text{h}\nu}^X$	yr	spc_halo	-
t_other_Xhalo	$\tau_{\text{othr}}^X$	yr	spc_halo	-
p_reg_slcf	$\pi_{\text{reg}}$	1	reg_land, reg_slcf	-
w_reg_NOX	$\omega_{\text{NO}_x}$	1	reg_slcf	mod_03t_regsat
w_reg_CO	$\omega_{\text{CO}}$	1	reg_slcf	mod_03t_regsat
w_reg_VOC	$\omega_{\text{VOC}}$	1	reg_slcf	mod_03t_regsat
x_03t_CH4	$\chi_{\text{CH}_4}^{\text{O}_3\text{t}}$	DU	-	mod_03t_emis
x_03t_NOX	$\chi_{\text{NO}_x}^{\text{O}_3\text{t}}$	DU [TgN yr <sup>-1</sup> ] <sup>-1</sup>	-	mod_03t_emis
x_03t_CO	$\chi_{\text{CO}}^{\text{O}_3\text{t}}$	DU [TgC yr <sup>-1</sup> ] <sup>-1</sup>	-	mod_03t_emis
x_03t_VOC	$\chi_{\text{VOC}}^{\text{O}_3\text{t}}$	DU [Tg yr <sup>-1</sup> ] <sup>-1</sup>	-	mod_03t_emis
G_03t	$\Gamma_{\text{O}_3\text{t}}$	DU K <sup>-1</sup>	-	mod_03t_clim

In code	In papers	Units	Dims	Mods
t_lag	$\tau_{\text{lag}}$	yr	-	-
p_fracrel	$\pi_{\text{rel}}^X$	1	spc_halo	mod_03s_fracrel
k_Br_Cl	$\alpha_{\text{Cl}}^{\text{Br}}$	1	-	-
n_Cl	$n_{\text{Cl}}^X$	1	spc_halo	-
n_Br	$n_{\text{Br}}^X$	1	spc_halo	-
EESC_x	$\text{EESC}_x$	ppt	-	-
k_EESC_N2O	$\frac{\chi_{\text{N2O}}^{\text{O3s}}}{\chi_{\text{EESC}}^{\text{O3s}}}$	ppt ppb <sup>-1</sup>	-	mod_03s_nitrous, mod_03s_fracrel
x_O3s_EESC	$\chi_{\text{EESC}}^{\text{O3s}}$	DU ppt <sup>-1</sup>	-	mod_03s_trans
G_O3s	$\Gamma_{\text{O3s}}$	DU K <sup>-1</sup>	-	mod_03s_trans
w_reg_SO2	$\omega_{\text{SO2}}$	1	reg_slcf	mod_S04_regsat
w_reg_OC	$\omega_{\text{OC}}$	1	reg_slcf	mod_POA_regsat
w_reg_BC	$\omega_{\text{BC}}$	1	reg_slcf	mod_BC_regsat
t_SO2	$\tau_{\text{SO2}}$	yr	-	mod_S04_load
t_DMS	$\tau_{\text{DMS}}$	yr	-	mod_S04_load
G_S04	$\Gamma_{\text{SO4}}$	Tg K <sup>-1</sup>	-	mod_S04_load
t_OMff	$\tau_{\text{OM,ff}}$	yr	-	mod_POA_load
t_OMbb	$\tau_{\text{OM,bb}}$	yr	-	mod_POA_load
G_POA	$\Gamma_{\text{POA}}$	Tg K <sup>-1</sup>	-	mod_POA_load
t_BCff	$\tau_{\text{BC,ff}}$	yr	-	mod_BC_load
t_BCbb	$\tau_{\text{BC,bb}}$	yr	-	mod_BC_load
G_BC	$\Gamma_{\text{BC}}$	Tg K <sup>-1</sup>	-	mod_BC_load
t_NOX	$\tau_{\text{NO}_x}$	yr	-	mod_N03_load
t_NH3	$\tau_{\text{NH}_3}$	yr	-	mod_N03_load
G_N03	$\Gamma_{\text{NO}_3}$	Tg K <sup>-1</sup>	-	mod_N03_load
t_VOC	$\tau_{\text{VOC}}$	yr	-	mod_S0A_load

In code	In papers	Units	Dims	Mods
t_BVOC	$\tau_{\text{BVOC}}$	yr	-	mod_SOA_load
G_SOA	$\Gamma_{\text{SOA}}$	Tg K <sup>-1</sup>	-	mod_SOA_load
t_dust	-	yr	-	mod_Mdust_load
G_dust	-	Tg K <sup>-1</sup>	-	mod_Mdust_load
t_salt	-	yr	-	mod_Msalt_load
G_salt	-	Tg K <sup>-1</sup>	-	mod_Msalt_load
p_sol_S04	$\pi_{\text{sol}}^{\text{SO}_4}$	1	-	mod_RFcloud_solub
p_sol_POA	$\pi_{\text{sol}}^{\text{POA}}$	1	-	mod_RFcloud_solub
p_sol_BC	$\pi_{\text{sol}}^{\text{BC}}$	1	-	mod_RFcloud_solub
p_sol_N03	$\pi_{\text{sol}}^{\text{NO}_3}$	1	-	mod_RFcloud_solub
p_sol_S0A	$\pi_{\text{sol}}^{\text{SOA}}$	1	-	mod_RFcloud_solub
p_sol_dust	-	1	-	mod_RFcloud_solub
p_sol_salt	-	1	-	mod_RFcloud_solub
r_f_CO2	$\alpha_{\text{rf}}^{\text{CO}_2}$	W m <sup>-2</sup>	-	-
r_f_CH4	$\alpha_{\text{rf}}^{\text{CH}_4}$	W m <sup>-2</sup> ppb <sup>-0.5</sup>	-	-
r_f_N2O	$\alpha_{\text{rf}}^{\text{N}_2\text{O}}$	W m <sup>-2</sup> ppb <sup>-0.5</sup>	-	-
k_rf_H2Os	$\frac{\alpha_{\text{rf}}^{\text{H}_2\text{Os}}}{\alpha_{\text{rf}}^{\text{CH}_4}}$	1	-	-
r_f_Xhalo	$\alpha_{\text{rf}}^X$	W m <sup>-2</sup> ppt <sup>-1</sup>	spc_halo	-
r_f_O3t	$\alpha_{\text{rf}}^{\text{O}_3\text{t}}$	W m <sup>-2</sup> DU <sup>-1</sup>	-	mod_O3t_radeff
r_f_O3s	$\alpha_{\text{rf}}^{\text{O}_3\text{s}}$	W m <sup>-2</sup> DU <sup>-1</sup>	-	mod_O3s_radeff
r_f_S04	$\alpha_{\text{rf}}^{\text{SO}_4}$	W m <sup>-2</sup> Tg <sup>-1</sup>	-	mod_S04_radeff
r_f_POA	$\alpha_{\text{rf}}^{\text{POA}}$	W m <sup>-2</sup> Tg <sup>-1</sup>	-	mod_POA_radeff
r_f_BC	$\alpha_{\text{rf}}^{\text{BC}}$	W m <sup>-2</sup> Tg <sup>-1</sup>	-	mod_BC_radeff



In code	In papers	Units	Dims	Mods
rf_N03	$\alpha_{\text{rf}}^{\text{NO}_3}$	$\text{W m}^{-2} \text{ Tg}^{-1}$	-	mod_N03_radeff
rf_SOA	$\alpha_{\text{rf}}^{\text{SOA}}$	$\text{W m}^{-2} \text{ Tg}^{-1}$	-	mod_SOA_radeff
rf_dust	-	$\text{W m}^{-2} \text{ Tg}^{-1}$	-	-
rf_salt	-	$\text{W m}^{-2} \text{ Tg}^{-1}$	-	-
k_adj_BC	$\kappa_{\text{adj}}^{\text{BC}}$	1	-	mod_BC_adjust
Phi_0	$\Phi$	$\text{W m}^{-2}$	-	mod_RFcloud_erf, mod_RFcloud_solub
AERsol_0	$\text{AER}_{\text{sol},0}$	Tg	-	mod_RFcloud_solub, mod_RFcloud_erf, mod_RFcloud_preind
p_reg_bcsnow	$\pi_{\text{reg}}$	1	reg_land, reg_bcsnow	-
w_reg_bcsnow	$\omega_{\text{BCsnow}}$	1	reg_bcsnow	mod_RFbcsnow_reg
rf_bcsnow	$\alpha_{\text{rf}}^{\text{BCsnow}}$	$\text{W m}^{-2} [\text{TgC yr}^{-1}]^{-1}$	-	mod_RFbcsnow_rf
p_trans	$\pi_{\text{trans}}$	1	-	-
alpha_alb	$\alpha_{\text{alb}}$	1	reg_land, bio_land	mod_RFlcc_alb, mod_RFlcc_flux, mod_RFlcc_cover
F_rsds	$\phi_{\text{rsds}}$	$\text{W m}^{-2}$	reg_land	mod_RFlcc_flux
w_warm_volc	$\kappa_{\text{warm}}^{\text{volc}}$	1	-	-
w_warm_bcsnow	$\kappa_{\text{warm}}^{\text{BCsnow}}$	1	-	mod_RFbcsnow_warmeff
w_warm_lcc	$\kappa_{\text{warm}}^{\text{LCC}}$	1	-	mod_RFlcc_warmeff
p_atm_CO2	$\pi_{\text{atm}}^{\text{CO}_2}$	1	-	mod_Pg_radfact
p_atm_nonCO2	$\pi_{\text{atm}}^{\text{noCO}_2}$	1	-	mod_Pg_radfact
p_atm_O3t	$\pi_{\text{atm}}^{\text{O}_3\text{t}}$	1	-	mod_Pg_radfact
p_atm_strat	$\pi_{\text{atm}}^{\text{strat}}$	1	-	mod_Pg_radfact

In code	In papers	Units	Dims	Mods
p_atm_scatter	$\pi_{\text{atm}}^{\text{scatter}}$	1	-	mod_Pg_radfact
p_atm_absorb	$\pi_{\text{atm}}^{\text{absorb}}$	1	-	mod_Pg_radfact
p_atm_cloud	$\pi_{\text{atm}}^{\text{cloud}}$	1	-	mod_Pg_radfact
p_atm_alb	$\pi_{\text{atm}}^{\text{alb}}$	1	-	mod_Pg_radfact
p_atm_solar	$\pi_{\text{atm}}^{\text{solar}}$	1	-	mod_Pg_radfact
lambda_0	$\lambda$	K [W m <sup>-2</sup> ] <sup>-1</sup>	-	mod_Tg_resp
Th_g	$\frac{\tau_{T_G}}{\lambda}$	yr W m <sup>-2</sup> K <sup>-1</sup>	-	mod_Tg_resp
Th_d	$\frac{\tau_{T_D}}{\lambda}$	yr W m <sup>-2</sup> K <sup>-1</sup>	-	mod_Tg_resp
th_0	$\frac{\theta}{\lambda}$	W m <sup>-2</sup> K <sup>-1</sup>	-	mod_Tg_resp
w_clim_Tl	$\omega_{T_L}$	1	reg_land	mod_Tl_pattern, mod_Tg_resp
w_clim_To	$\omega_{T_S}$	1	-	mod_Tl_pattern, mod_Tg_resp
a_prec	$\alpha_{P_G}$	mm yr <sup>-1</sup> K <sup>-1</sup>	-	mod_Pg_resp
b_prec	$\beta_{P_G}$	mm yr <sup>-1</sup> [W m <sup>-2</sup> ] <sup>-1</sup>	-	mod_Pg_resp
w_clim_Pl	$\omega_{P_L}$	1	reg_land	mod_Pl_pattern, mod_Pg_resp
p_ohc	$\pi_{\text{ohc}}$	1	-	-
pH_is_Log	-	bool	-	mod_pH_fct