OSCAR *v2.3*

Manual

Basic simulation

To make a basic simulation, one needs to execute the main file `OSCAR.py` after what the `OSCAR_lite` function will be available. Execution of the function without any argument will launch a simulation with the options specified in `OSCAR.py`. One can manually change the drivers of OSCAR by specifying their values as arguments of the main function. More generally, a look at the function definition in `OSCAR-fct.py` is strongly advised, as one can see the various optional arguments (and their default value), such as the choice of output variables or the possibility to use OSCAR in a concentration-driven fashion. Some automatic plots can be activated with the plot argument, but they may be outdated. A code example to use OSCAR in a probabilistic setup is provided in the `test_overall.py` file.

Simulation options

Any simulation with OSCAR should start with executing the main file `OSCAR.py` in which all the options for the simulation are set. The provided file is set to the "default" parameterization of the model -- i.e. a sort of "average" parameterization that simulates a reasonable climate change over the historical period. Even in a probabilistic setup the `OSCAR.py` should be executed once, so as to load everything. Only after should the probabilistic loading/simulating occur (as in `test_overall.py`). The following table describes the various options available:

Option	Description
`p`	Number of time-steps within one year of simulation.
`fC`	(NOT IMPLEMENTED)
`fT`	Turn on or off the climate feedbacks.
`dty`	Precision of numerical computation.
`PI_1750`	Boolean. If `False`, the years 1700 to 1750 are simulated. This has very little effect on the numerical outputs and it can be used to test the stability of the model.
`ind_final`	End year of simulation.
`ind_attrib`	(USELESS)
`attrib_DRIVERS`	(USELESS)
`attrib_FEEDBACKS`	(USELESS)
`attrib_ELUCdelta`	(USELESS)
`attrib_ELUCampli`	(USELESS)

Option	Description
`mod_regionI`	Regional aggregation. New regions can be defined manually as aggregates of GTAP7 regions, but it requires coding and extension of the `#DATA.Regions_GTAP.csv` file.
`mod_regionJ`	(USELESS)
`mod_sector`	(USELESS)
`mod_kindFF`	(USELESS)
`mod_kindLUC`	(USELESS)
`mod_kindGHG`	(USELESS)
`mod_kindCHI`	(USELESS)
`mod_kingAER`	(USELESS)
`mod_kindRF`	(USELESS)
`mod_kindGE`	(USELESS)
`mod_biomeSHR`	How the “shrubland” biome is accounted for.
`mod_biomeURB`	How the “urban” biome is accounted for.
`data_EFF`	Dataset for fossil-fuel emissions.
`data_LULCC`	Dataset of land-use and land-cover change drivers.
`data_ECH4`	Dataset for methane emissions.
`data_EN2O`	Dataset for nitrous oxide emissions.
`data_Ehalo`	Dataset for halogenated compounds emissions.
`data_ENOX`	Dataset for nitrogen oxides emissions.
`data_ECO`	Dataset for carbon monoxide emissions.
`data_EVOC`	Dataset for volatile organic compounds emissions
`data_ESO2`	Dataset for sulfur dioxide emissions.
`data_ENH3`	Dataset for ammonia emissions.
`data_EOC`	Dataset for organic carbon emissions.
`data_EBC`	Dataset for black carbon emissions.
`data_RFant`	Dataset for other anthropogenic RF.
`data_RFnat`	Dataset for natural RF.
`mod_DATAscen`	How the transition between historical emissions and scenarios is handled.
`scen_ALL`	Scenario for all drivers. Has priority over other `scen_` options.

Option	Description
scen_EFF	Scenario for fossil-fuel emissions.
scen_LULCC	Scenario of land-use and land-cover change drivers.
scen_ECH4	Scenario for methane emissions.
scen_EN2O	Scenario for nitrous oxide emissions.
scen_Ehalo	Scenario for halogenated compounds emissions.
scen_ENOX	Scenario for nitrogen oxides emissions.
scen_ECO	Scenario for carbon monoxide emissions.
scen_EVOC	Scenario for volatile organic compounds emissions
scen_ESO2	Scenario for sulfur dioxide emissions.
scen_ENH3	Scenario for ammonia emissions.
scen_EOC	Scenario for organic carbon emissions.
scen_EBC	Scenario for black carbon emissions.
scen_RFant	Scenario for other anthropogenic RF.
scen_RFnat	Scenario for natural RF.
mod_OSNKstruct	Structure and impulse response function of the ocean C-cycle model.
mod_OSNKchem	Function emulating the carbonate chemistry.
mod_OSNKtrans	Transient response of the MLD.
mod_LSNKnpp	Functional form of fertilization effect.
mod_LSNKrho	Functional form of heterotrophic respiration rate.
mod_LSNKpreind	Preindustrial land carbon stocks and fluxes.
mod_LSNKtrans	Transient response of NPP and HR.
mod_LSNKcover	Preindustrial natural land-cover.
mod_EFIREpreind	Preindustrial wildfire fluxes.
mod_EFIREtrans	Transient response of wildfires.
mod_EPFmain	Permafrost carbon model.
mod_EPFmethane	Fraction of permafrost carbon emitted as methane.
mod_ELUCagb	Above-ground biomass fractions.
mod_EHWPbb	Biomass burning of non-commercial harvested wood products.
mod_EHWPtau	Time constants for the oxidation of HWPs.
mod_EHWPfct	Functional form for the oxidation of HWPs.

Option	Description
mod_OHSNKtau	Lifetime of methane with respect to the OH sink.
mod_OHSNKfct	Functional form of the OH sink's response to ozone precursors.
mod_OHSNKtrans	Transient response of the OH sink.
mod_EWETpreind	Preindustrial wetlands emissions.
mod_AWETtrans	Transient response of wetlands area extent.
mod_HVSNKtau	Lifetime of nitrous oxide with respect to the stratospheric sink.
mod_HVSNKtrans	Transient response of the stratospheric sink.
mod_HVSNKcirc	Transient response of the stratospheric age-of-air.
mod_O3Tregsat	Regionalization of the tropospheric O3 chemistry.
mod_O3Temis	Transient response of tropospheric O3 to precursors and methane.
mod_O3Tclim	Transient response of tropospheric O3 to climate.
mod_O3Tradeff	Radiative efficiency of tropospheric O3.
mod_O3Sfracrel	Fractional release factors for EESC.
mod_O3Strans	Transient response of stratospheric O3 to EESC and climate.
mod_O3Snitrous	Transient response of stratospheric O3 to N2O.
mod_O3Sradeff	Radiative efficiency of stratospheric O3.
mod_SO4regsat	Regionalization of SO4 burden.
mod_SO4load	Transient response of SO4 burden.
mod_SO4radeff	Radiative efficiency of SO4.
mod_POAconv	Conversion factor for OC/OM.
mod_POAregsat	Regionalization of POA burden.
mod_POAload	Transient response of POA burden.
mod_POAradeff	Radiative efficiency of POA.
mod_BCregsat	Regionalization of BC burden.
mod_BCload	Transient response of BC burden.
mod_BCradeff	Radiative efficiency of BC.
mod_BCadjust	Semi-direct effect of BC.
mod_NO3load	Transient response of NO3 burden.
mod_NO3radeff	Radiative efficiency of NO3.
mod_SOAload	Transient response of SOA burden.

Option	Description
`mod_SOAradeff`	Radiative efficiency of SOA.
`mod_DUSTload`	(NOT DESCRIBED IN PAPER) Transient response of mineral dust burden.
`mod_DUSTradeff`	(NOT IMPLEMENTED)
`mod_SALTload`	(NOT DESCRIBED IN PAPER) Transient response of sea salt burden.
`mod_SALTradeff`	(NOT IMPLEMENTED)
`mod_CLOUDsolub`	Solubility fractions for the indirect effect.
`mod_CLOUDerf`	Present-day RF used as reference for the indirect effect.
`mod_CLOUDpreind`	Adjustment of preindustrial burden of hydrophilic aerosols.
`mod_ALBBCreg`	Regionalization of BC deposition on snow.
`mod_ALBBCrf`	Radiative efficiency with respect to emissions of BC deposition on snow.
`mod_ALBBCwarm`	Warming efficacy of BC deposition on snow.
`mod_ALBLCalb`	Albedo climatology for LCC albedo effect.
`mod_ALBLCcover`	Land-cover climatology for LCC albedo effect.
`mod_ALBLCwarm`	Warming efficacy of LCC albedo effect.
`mod_TEMPresp`	Global surface temperature response.
`mod_TEMPpattern`	Experiment for pattern scaling of temperature.
`mod_PRECresp`	Global precipitations response.
`mod_PRECradfact`	Atmospheric fractions of RF for global precipitations.
`mod_PRECpattern`	Experiment for pattern scaling of precipitations.
`mod_ACIDsurf`	(NOT DESCRIBED IN PAPER) Functional form for surface ocean acidification.
`mod_SLR`	(NOT IMPLEMENTED)

Load order

After reading the chosen simulation options, the main file execute four other files: `OSCAR-loadD.py` used to load the drivers, `OSCAR-loadP.py` used to load the parameters, `OSCAR-format.py` used to format the drivers, and `OSCAR-fct.py` used to load the model's main function. When using the model in a probabilistic setup, the two load files can be used separately, albeit with two important limitations: `OSCAR-loadD.py` must be followed by `OSCAR-format.py`, and the two options `data_LULCC` and `mod_LSNKcover` affect both the drivers and the parameters of the model. In a probabilistic setup, it is recommended to reload `OSCAR-fct.py` each time, or to be careful with the drivers of `OSCAR_lite` since it already has default arguments from the initial loading. The two following sections give details of the structure of the two load files.

`OSCAR-loadD.py`

`OSCAR-loadP.py`

Drivers, variables and parameters names and units

Here we provide the correspondence between the notations used in the description paper and the names used in the model's code, as well as the (implicit) units used in the model. In some cases there is no direct correspondence, because of the way the model is actually coded. Names should remain self-explanatory. Colored variables are new, and their notation may change.

Drivers

In papers	In code	Unit
E_{FF}	EFF	GtC yr^{-1}
$E_{\mathrm{CH_4}}$	ECH4	MtC yr^{-1}
$E_{\mathrm{N_2O}}$	EN2O	MtN yr^{-1}
$E_{\{\mathrm{HFC}\}}$	EHFC	kt yr^{-1}
$E_{\{\mathrm{PFC}\}}$	EPFC	kt yr^{-1}
$E_{\{\mathrm{ODS}\}}$	EODS	kt yr^{-1}

In papers	In code	Unit
$E_{\mathrm{NO_x}}$	`ENOX`	MtN yr^{-1}
E_{CO}	`ECO`	MtC yr^{-1}
E_{VOC}	`EVOC`	Mt yr^{-1}
$E_{\mathrm{SO_2}}$	`ESO2`	MtS yr^{-1}
$E_{\mathrm{NH_3}}$	`ENH3`	MtN yr^{-1}
E_{OC}	`EOC`	MtC yr^{-1}
E_{BC}	`EBC`	MtC yr^{-1}
δA	`LUC`	Mha yr^{-1}
δH	`HARV`	GtC yr^{-1}
δS	`SHIFT`	Mha yr^{-1}
$\mathrm{RF}_{\mathrm{con}}$	`RFant`	W m^{-2}
$\mathrm{RF}_{\mathrm{volc}}$	`RFvolc`	W m^{-2}
$\mathrm{RF}_{\mathrm{solar}}$	`RFsolar`	W m^{-2}

Variables

In papers	In code	Unit
ΔC_{surf}	`D_CSURF`	GtC
$\Delta \mathrm{dic}$	`D_dic`	µmol kg^{-1}
Δh_{mld}	`D_mld`	m
ΔF_{in}	`D_FIN`	GtC yr^{-1}
ΔF_{out}	`D_FOUT`	GtC yr^{-1}
ΔF_{circ}	`D_FCIRC`	GtC yr^{-1}
Δc_{veg}	`D_cveg`	GtC Mha^{-1}
Δc_{litt}	`D_csoil1`	GtC Mha^{-1}
Δc_{soil}	`D_csoil2`	GtC Mha^{-1}
$\Delta \mathrm{npp}$	`D_npp`	GtC Mha^{-1} yr^{-1}

In papers	In code	Unit
Δe_{fire}	`D_efire`	GtC Mha^{-1} yr^{-1}
Δf_{mort}	`D_fmort`	GtC Mha^{-1} yr^{-1}
$\Delta \text{rh}_{\text{litt}}$	`D_rh1`	GtC Mha^{-1} yr^{-1}
Δf_{met}	`D_fmet`	GtC Mha^{-1} yr^{-1}
$\Delta \text{rh}_{\text{soil}}$	`D_rh2`	GtC Mha^{-1} yr^{-1}
Δp_{thaw}	`pthaw`	1
$\Delta \bar{p}_{\text{thaw}}$	`pthaw_bar`	1
$\Delta C_{\text{thaw},1}$	`CTHAW1`	GtC
$\Delta C_{\text{thaw},2}$	`CTHAW2`	GtC
$\Delta C_{\text{thaw},3}$	`CTHAW3`	GtC
ΔC_{froz}	`D_CFROZ`	GtC
ΔF_{thaw}	`FTHAW`	GtC yr^{-1}
$\Delta E_{\text{thaw},1}$	`ETHAW1`	GtC yr^{-1}
$\Delta E_{\text{thaw},2}$	`ETHAW2`	GtC yr^{-1}
$\Delta E_{\text{thaw},3}$	`ETHAW3`	GtC yr^{-1}
$\Delta E_{\text{pf}}^{\text{CO}_2}$	`EPF_CO2`	GtC yr^{-1}
$\Delta E_{\text{pf}}^{\text{CH}_4}$	`EPF_CH4`	MtC yr^{-1}
ΔE_{pf}	`EPF`	GtC yr^{-1}
$\Delta C_{\text{veg,luc}}$	`CVEG_luc`	GtC
$\Delta C_{\text{hwp,luc}}^{w=1}$	`CHWP1_luc`	GtC
$\Delta C_{\text{hwp,luc}}^{w=2}$	`CHWP2_luc`	GtC
$\Delta C_{\text{hwp,luc}}^{w=3}$	`CHWP3_luc`	GtC
$\Delta C_{\text{litt,luc}}$	`CSOIL1_luc`	GtC
$\Delta C_{\text{soil,luc}}$	`CSOIL2_luc`	GtC
ΔA	`D_AREA`	Mha

In papers	In code	Unit
$\Delta\mathrm{CO}_2$	D_CO2	ppm
$\Delta F_{\downarrow\mathrm{ocean}}$	OSNK	GtC yr^{-1}
$\Delta F_{\downarrow\mathrm{land}}$	LSNK	GtC yr^{-1}
ΔE_{LUC}	ELUC	GtC yr^{-1}
$\Delta\mathrm{RF}^{\mathrm{CO_2}}$	RF_CO2	W m^{-2}
$\Delta E_{\mathrm{bb}}^{\mathrm{CH_4}}$	D_EBB_CH4	MtC yr^{-1}
$\Delta E_{\mathrm{bb}}^{\mathrm{N_2O}}$	D_EBB_N2O	MtN yr^{-1}
$\Delta E_{\mathrm{bb}}^{\mathrm{NO_x}}$	D_EBB_NOX	MtN yr^{-1}
$\Delta E_{\mathrm{bb}}^{\mathrm{CO}}$	D_EBB_CO	MtC yr^{-1}
$\Delta E_{\mathrm{bb}}^{\mathrm{VOC}}$	D_EBB_VOC	Mt yr^{-1}
$\Delta E_{\mathrm{bb}}^{\mathrm{SO_2}}$	D_EBB_SO2	MtS yr^{-1}
$\Delta E_{\mathrm{bb}}^{\mathrm{NH_3}}$	D_EBB_NH3	MtN yr^{-1}
$\Delta E_{\mathrm{bb}}^{\mathrm{OC}}$	D_EBB_OC	MtC yr^{-1}
$\Delta E_{\mathrm{bb}}^{\mathrm{BC}}$	D_EBB_BC	MtC yr^{-1}
$\Delta\mathrm{CH_4}_{\mathrm{bb,lag}}$	D_CH4bb_lag	ppb
$\Delta\mathrm{CH_4}_{\mathrm{ff,lag}}$	D_CH4ff_lag	ppb
$\Delta\mathrm{CH_4}_{\mathrm{lag}}$	D_CH4_lag	ppb
$\Delta\mathrm{N_2O}_{\mathrm{lag}}$	D_N2O_lag	ppb
$\Delta\{\mathrm{HFC}\}_{\mathrm{lag}}$	D_HFC_lag	ppt
$\Delta\{\mathrm{PFC}\}_{\mathrm{lag}}$	D_PFC_lag	ppt
$\Delta\{\mathrm{ODS}\}_{\mathrm{lag}}$	D_ODS_lag	ppt
$\Delta F_{\downarrow\mathrm{OH}}^{\mathrm{CH_4,bb}}$	D_OHSNK_CH4bb	MtC yr^{-1}
$\Delta F_{\downarrow\mathrm{OH}}^{\mathrm{CH_4,ff}}$	D_OHSNK_CH4ff	MtC yr^{-1}
$\Delta F_{\downarrow\mathrm{OH}}^{\mathrm{CH_4}}$	D_OHSNK_CH4	MtC yr^{-1}

In papers	In code	Unit
$\Delta F_{\downarrow h\nu}^{\mathrm{CH_4,bb}}$	D_HVSNK_CH4bb	MtC yr^{-1}
$\Delta F_{\downarrow h\nu}^{\mathrm{CH_4,ff}}$	D_HVSNK_CH4ff	MtC yr^{-1}
$\Delta F_{\downarrow h\nu}^{\mathrm{CH_4}}$	D_HVSNK_CH4	MtC yr^{-1}
$\Delta F_{\downarrow \mathrm{othr}}^{\mathrm{CH_4,bb}}$	D_XSNK_CH4bb	MtC yr^{-1}
$\Delta F_{\downarrow \mathrm{othr}}^{\mathrm{CH_4,ff}}$	D_XSNK_CH4ff	MtC yr^{-1}
$\Delta F_{\downarrow \mathrm{othr}}^{\mathrm{CH_4}}$	D_XSNK_CH4	MtC yr^{-1}
$\Delta F_{\mathrm{oxi,CH_4}}$	D_FOXI_CH4	GtC yr^{-1}
ΔA_{wet}	D_AWET	Mha
Δe_{wet}	D_ewet	MtC Mha^{-1} yr^{-1}
ΔE_{wet}	D_EWET	MtC yr^{-1}
$\Delta \mathrm{CH_4}_{\mathrm{bb}}$	D_CH4bb	ppb
$\Delta \mathrm{CH_4}_{\mathrm{ff}}$	D_CH4ff	ppb
$\Delta \mathrm{CH_4}$	D_CH4	ppb
$\Delta \mathrm{RF}^{\mathrm{CH_4}}$	RF_CH4	W m^{-2}
$\Delta \mathrm{RF}^{\mathrm{H_2Os}}$	RF_H2Os	W m^{-2}
$\Delta F_{\downarrow h\nu}^{\mathrm{N_2O}}$	D_HVSNK_N2O	MtN yr^{-1}
$\Delta \mathrm{N_2O}$	D_N2O	ppb
$\Delta \mathrm{RF}^{\mathrm{N_2O}}$	RF_N2O	W m^{-2}
$\Delta F_{\downarrow \mathrm{OH}}^{\{\mathrm{HFC}\}}$	D_OHSNK_HFC	kt yr^{-1}
$\Delta F_{\downarrow h\nu}^{\{\mathrm{HFC}\}}$	D_HVSNK_HFC	kt yr^{-1}
$\Delta F_{\downarrow \mathrm{othr}}^{\{\mathrm{HFC}\}}$	D_XSNK_HFC	kt yr^{-1}
$\Delta F_{\downarrow \mathrm{OH}}^{\{\mathrm{PFC}\}}$	D_OHSNK_PFC	kt yr^{-1}
$\Delta F_{\downarrow h\nu}^{\{\mathrm{PFC}\}}$	D_HVSNK_PFC	kt yr^{-1}

In papers	In code	Unit
$\Delta F_{\downarrow \mathrm{othr}}^{\{\mathrm{PFC}\}}$	D_XSNK_PFC	kt yr^{-1}
$\Delta F_{\downarrow \mathrm{OH}}^{\{\mathrm{ODS}\}}$	D_OHSNK_ODS	kt yr^{-1}
$\Delta F_{\downarrow \mathrm{h}\nu}^{\{\mathrm{ODS}\}}$	D_HVSNK_ODS	kt yr^{-1}
$\Delta F_{\downarrow \mathrm{othr}}^{\{\mathrm{ODS}\}}$	D_XSNK_ODS	kt yr^{-1}
$\Delta\{\mathrm{HFC}\}$	D_HFC	ppt
$\Delta\{\mathrm{PFC}\}$	D_PFC	ppt
$\Delta\{\mathrm{ODS}\}$	D_ODS	ppt
$\Delta\mathrm{RF}^{\mathrm{halo}}$	RF_halo	W m^{-2}
$\Delta\mathrm{O_3t}$	D_O3t	DU
$\Delta\mathrm{RF}^{\mathrm{O_3t}}$	RF_O3t	W m^{-2}
$\Delta\mathrm{EESC}$	D_EESC	ppt
$\Delta\mathrm{O_3s}$	D_O3s	DU
$\Delta\mathrm{RF}^{\mathrm{O_3s}}$	RF_O3s	W m^{-2}
$\Delta\mathrm{SO_4}$	D_SO4	Tg
$\Delta\mathrm{POA}$	D_POA	Tg
$\Delta\mathrm{BC}$	D_BC	Tg
$\Delta\mathrm{NO_3}$	D_NO3	Tg
$\Delta\mathrm{SOA}$	D_SOA	Tg
$\Delta\mathrm{RF}^{\mathrm{SO_4}}$	RF_SO4	W m^{-2}
$\Delta\mathrm{RF}^{\mathrm{POA}}$	RF_POA	W m^{-2}
$\Delta\mathrm{RF}^{\mathrm{BC}}$	RF_BC	W m^{-2}
$\Delta\mathrm{RF}^{\mathrm{NO_3}}$	RF_NO3	W m^{-2}
$\Delta\mathrm{RF}^{\mathrm{SOA}}$	RF_SOA	W m^{-2}
$\Delta\mathrm{AER_{sol}}$	D_AERh	Tg
$\Delta\mathrm{RF}^{\mathrm{cloud}}$	RF_cloud	W m^{-2}

In papers	In code	Unit
$\Delta\mathrm{RF}^{\mathrm{BCsnow}}$	`RF_bcsnow`	W m^{-2}
$\Delta\mathrm{RF}^{\mathrm{LCC}}$	`RF_lcc`	W m^{-2}
$\Delta\mathrm{RF}$	`RF`	W m^{-2}
$\Delta\mathrm{RF}_{\mathrm{warm}}$	`RF_warm`	W m^{-2}
$\Delta\mathrm{RF}_{\mathrm{atm}}$	`RF_atm`	W m^{-2}
ΔT_G	`D_gst`	K
ΔT_D	`D_gst0`	K
ΔT_S	`D_sst`	K
ΔT_L	`D_lst`	K
ΔP_G	`D_gyp`	mm yr^{-1}
ΔP_L	`D_lyp`	mm yr^{-1}
$\Delta\mathrm{OHC}$	`D_OHC`	ZJ

Parameters

In papers	In code	Unit
ν_{fg}	`v_fg`	yr^{-1}
A_{ocean}	`A_ocean`	m^2
π_{circ}	`p_circ`	1
τ_{circ}	`tau_circ`	yr
$\mathcal{F}_{\mathrm{pCO_2}}$	`f_pCO2`	ppm
α_{sol}	`alpha_sol`	µmol kg^{-1} [ppm m^{-3}]$^{-1}$
$\alpha_{\mathrm{atm}}^{\mathrm{CO_2}}$	`alpha_CO2`	GtC ppm^{-1}
π_{mld}	`alpha_mld`	1
γ_{mld}	`gamma_mld`	K^{-1}
η	`npp_0`	GtC Mha^{-1} yr^{-1}
μ	`mu_0`	yr^{-1}

In papers	In code	Unit
$\rho_{\rm litt}$	`rho1_0`	yr^{-1}
$\rho_{\rm soil}$	`rho2_0`	yr^{-1}
$\pi_{\rm met}$	`p_met`	1
$\beta_{\rm npp}$	`beta_npp`	1
$\tilde{\beta}_{\rm npp}$	`beta_npp0`	1
$\mathrm{CO}_{2\mathrm{cp}}$	`CO2_comp`	ppm
$\gamma_{{\rm npp},T}$	`gamma_nppT`	K^{-1}
$\gamma_{{\rm npp},P}$	`gamma_nppP`	[mm yr^{-1}]$^{-1}$
$\gamma_{{\rm resp},T}$	`gamma_rhoT`	K^{-1}
$\gamma_{{\rm resp},T_1}$	`gamma_rhoT1`	K^{-1}
$\gamma_{{\rm resp},T_2}$	`gamma_rhoT2`	K^{-2}
$\gamma_{{\rm resp},P}$	`gamma_rhoP`	[mm yr^{-1}]$^{-1}$
ι	`igni_0`	yr^{-1}
$\gamma_{{\rm igni},C}$	`gamma_igniC`	ppm^{-1}
$\gamma_{{\rm igni},T}$	`gamma_igniT`	K^{-1}
$\gamma_{{\rm igni},P}$	`gamma_igniP`	[mm yr^{-1}]$^{-1}$
$\omega_{T_{\rm pf}}$	`w_reg_lstPF`	1
$\gamma_{{\rm pf},T_1}$	`gamma_rhoPF1`	K^{-1}
$\gamma_{{\rm pf},T_2}$	`gamma_rhoPF2`	K^{-2}
$\omega_{\rm resp,pf}$	`w_rhoPF`	1
$p_{\rm thaw,min}$	`pthaw_min`	1
$\kappa_{p_{\rm thaw}}$	`k_pthaw`	1
$\gamma_{p_{\rm thaw}}$	`gamma_pthaw`	K^{-1}
$\mathcal{F}_{\nu_{\rm pf}}$	`f_v_PF`	yr^{-1}
$\nu_{\rm thaw}$	`v_thaw`	yr^{-1}
$\nu_{\rm froz}$	`v_froz`	yr^{-1}

In papers	In code	Unit
$\pi_{\text{pf},1}$	p_PF1	1
$\pi_{\text{pf},2}$	p_PF2	1
$\pi_{\text{pf},3}$	p_PF3	1
$\tau_{\text{pf},1}$	tau_PF1	yr
$\tau_{\text{pf},2}$	tau_PF2	yr
$\tau_{\text{pf},3}$	tau_PF3	yr
$C_{\text{froz},0}$	CFROZ_0	GtC
$\pi_{\text{pf},\text{CH}_4}$	p_PF_CH4	1
$\pi_{\text{pf},\text{inst}}$	p_PF_inst	1
τ_{shift}	tau_shift	yr
π_{agb}	p_AGB	1
π_{hwp}	p_HWP	1
τ_{hwp}	tau_HWP	yr
$\mathcal{F}_{\text{hwp}}$	r_HWP	1
$\alpha_{\text{bb}}^{\text{CH}_4}$	alpha_BB_CH4	MtC GtC^{-1}
$\alpha_{\text{bb}}^{\text{N}_2\text{O}}$	alpha_BB_N2O	MtN GtC^{-1}
$\alpha_{\text{bb}}^{\text{NO}_\text{x}}$	alpha_BB_NOX	MtN GtC^{-1}
$\alpha_{\text{bb}}^{\text{CO}}$	alpha_BB_CO	MtC GtC^{-1}
$\alpha_{\text{bb}}^{\text{VOC}}$	alpha_BB_VOC	Mt GtC^{-1}
$\alpha_{\text{bb}}^{\text{SO}_2}$	alpha_BB_SO2	MtS GtC^{-1}
$\alpha_{\text{bb}}^{\text{NH}_3}$	alpha_BB_NH3	MtN GtC^{-1}
$\alpha_{\text{bb}}^{\text{OC}}$	alpha_BB_OC	MtC GtC^{-1}
$\alpha_{\text{bb}}^{\text{BC}}$	alpha_BB_BC	MtC GtC^{-1}
τ_{lag}	tau_lag	yr
$\alpha_{\text{atm}}^{\text{CH}_4}$	alpha_CH4	MtC ppb^{-1}
$\tau_{\text{OH}}^{\text{CH}_4}$	tau_CH4_OH	yr

In papers	In code	Unit
$\tau^{\mathrm{CH_4}}_{\mathrm{h\nu}}$	`tau_CH4_hv`	yr
$\tau^{\mathrm{CH_4}}_{\mathrm{soil}}$	`tau_CH4_soil`	yr
$\tau^{\mathrm{CH_4}}_{\mathrm{ocean}}$	`tau_CH4_ocean`	yr
$\chi^{\mathrm{OH}}_{\mathrm{O_3s}}$	`chi_OH_O3s`	1
$\chi^{\mathrm{OH}}_{\mathrm{T_A}}$	`chi_OH_Tatm`	1
$\chi^{\mathrm{OH}}_{\mathrm{Q_A}}$	`chi_OH_Qatm`	1
$\chi^{\mathrm{OH}}_{\mathrm{NO_x}}$	`chi_OH_NOX`	$[\mathrm{MtN\ yr^{-1}}]^{-1}$
$\chi^{\mathrm{OH}}_{\mathrm{CO}}$	`chi_OH_CO`	$[\mathrm{MtC\ yr^{-1}}]^{-1}$
$\chi^{\mathrm{OH}}_{\mathrm{VOC}}$	`chi_OH_VOC`	$[\mathrm{Mt\ yr^{-1}}]^{-1}$
$\tilde{\chi}^{\mathrm{OH}}_{\mathrm{NO_x}}$	`chi_OH_NOX`	1
$\tilde{\chi}^{\mathrm{OH}}_{\mathrm{CO}}$	`chi_OH_CO`	1
$\tilde{\chi}^{\mathrm{OH}}_{\mathrm{VOC}}$	`chi_OH_VOC`	1
$\kappa_{\mathrm{T_A}}$	`k_Tatm`	1
$\kappa_{\mathrm{Q_A}}$	`k_Qatm`	1
κ_{svp}	`k_svp`	1
T_{svp}	`T_svp`	K
$T_{\mathrm{atm,0}}$	`Tatm_0`	K
$E^{\mathrm{NO_x}}_{\mathrm{nat}}$	`ENOC_oh`	$\mathrm{MtN\ yr^{-1}}$
$E^{\mathrm{CO}}_{\mathrm{nat}}$	`ECO_oh`	$\mathrm{MtC\ yr^{-1}}$
$E^{\mathrm{VOC}}_{\mathrm{nat}}$	`EVOC_oh`	$\mathrm{Mt\ yr^{-1}}$
π_{wet}	`p_wet`	1
$\gamma_{\mathrm{wet},C}$	`gamma_wetC`	$\mathrm{ppm^{-1}}$
$\gamma_{\mathrm{wet},T}$	`gamma_wetT`	$\mathrm{K^{-1}}$
$\gamma_{\mathrm{wet},P}$	`gamma_wetP`	$[\mathrm{mm\ yr^{-1}}]^{-1}$
$\mathcal{F}_{\mathrm{over}}$	`f_overlap`	$\mathrm{W\ m^{-2}}$

In papers	In code	Unit
$\alpha_{\mathrm{atm}}^{\mathrm{N_2O}}$	alpha_N2O	MtN ppb^{-1}
$\tau_{\mathrm{h\nu}}^{\mathrm{N_2O}}$	tau_N2O_hv	yr
$\chi_{\mathrm{N2O}}^{\mathrm{h\nu}}$	chi_hv_N2O	1
$\chi_{\mathrm{EESC}}^{\mathrm{h\nu}}$	chi_hv_EESC	1
$\chi_{\mathrm{age}}^{\mathrm{h\nu}}$	chi_hv_age	1
γ_{age}	gamma_age	K^{-1}
$\alpha_{\mathrm{atm}}^{\{\mathrm{HFC}\}}$	alpha_HFC	kt ppt^{-1}
$\alpha_{\mathrm{atm}}^{\{\mathrm{PFC}\}}$	alpha_PFC	kt ppt^{-1}
$\alpha_{\mathrm{atm}}^{\{\mathrm{ODS}\}}$	alpha_ODS	kt ppt^{-1}
$\tau_{\mathrm{OH}}^{\{\mathrm{HFC}\}}$	tau_HFC_OH	yr
$\tau_{\mathrm{h\nu}}^{\{\mathrm{HFC}\}}$	tau_HFC_hv	yr
$\tau_{\mathrm{othr}}^{\{\mathrm{HFC}\}}$	tau_HFC_othr	yr
$\tau_{\mathrm{OH}}^{\{\mathrm{PFC}\}}$	tau_PFC_OH	yr
$\tau_{\mathrm{h\nu}}^{\{\mathrm{PFC}\}}$	tau_PFC_hv	yr
$\tau_{\mathrm{othr}}^{\{\mathrm{PFC}\}}$	tau_PFC_othr	yr
$\tau_{\mathrm{OH}}^{\{\mathrm{ODS}\}}$	tau_ODS_OH	yr
$\tau_{\mathrm{h\nu}}^{\{\mathrm{ODS}\}}$	tau_ODS_hv	yr
$\tau_{\mathrm{othr}}^{\{\mathrm{ODS}\}}$	tau_ODS_othr	yr
$\alpha_{\mathrm{rf}}^{\{\mathrm{HFC}\}}$	radeff_HFC	W m^{-2} ppt^{-1}
$\alpha_{\mathrm{rf}}^{\{\mathrm{PFC}\}}$	radeff_PFC	W m^{-2} ppt^{-1}
$\alpha_{\mathrm{rf}}^{\{\mathrm{ODS}\}}$	radeff_ODS	W m^{-2} ppt^{-1}
$\chi_{\mathrm{CH_4}}^{\mathrm{O_3t}}$	chi_O3t_CH4	DU
$\chi_{\mathrm{NO_x}}^{\mathrm{O_3t}}$	chi_O3t_NOX	DU [MtN yr^{-1}]$^{-1}$

In papers	In code	Unit
$\chi_{\mathrm{CO}}^{\mathrm{O_3t}}$	`chi_O3t_CO`	DU [MtC yr^{-1}]$^{-1}$
$\chi_{\mathrm{VOC}}^{\mathrm{O_3t}}$	`chi_O3t_VOC`	DU [Mt yr^{-1}]$^{-1}$
$\omega_{\mathrm{NO_x}}$	`w_reg_NOX`	1
ω_{CO}	`w_reg_CO`	1
ω_{VOC}	`w_reg_VOC`	1
π_{reg}	`p_reg`	1
$\Gamma_{\mathrm{O_3t}}$	`Gamma_O3t`	DU K^{-1}
$\alpha_{\mathrm{rf}}^{\mathrm{O_3t}}$	`radeff_O3t`	W m^{-2} DU^{-1}
$\pi_{\mathrm{rel}}^{\{\mathrm{ODS}\}}$	`f_fracrel`	1
$n_{\mathrm{Cl}}^{\{\mathrm{ODS}\}}$	`n_Cl`	1
$n_{\mathrm{Br}}^{\{\mathrm{ODS}\}}$	`n_Br`	1
$\alpha_{\mathrm{Cl}}^{\mathrm{Br}}$	`alpha_Br`	1
$\chi_{\mathrm{EESC}}^{\mathrm{O_3s}}$	`chi_O3s_EESC`	DU ppt^{-1}
$\chi_{\mathrm{N_2O}}^{\mathrm{O_3s}}$	`chi_O3s_N2O`	DU ppb^{-1}
$\mathrm{EESC}_{\times}$	`EESC_x`	ppt
$\Gamma_{\mathrm{O_3s}}$	`Gamma_O3s`	DU K^{-1}
$\alpha_{\mathrm{rf}}^{\mathrm{O_3s}}$	`radeff_O3s`	W m^{-2} DU^{-1}
$\tau_{\mathrm{SO_2}}$	`tau_SO2`	yr
τ_{DMS}	`tau_DMS`	yr
$\Gamma_{\mathrm{SO_4}}$	`Gamma_SO4`	Tg K^{-1}
$\omega_{\mathrm{SO_2}}$	`w_reg_SO2`	1
$\tau_{\mathrm{OM,ff}}$	`tau_OMff`	yr
$\tau_{\mathrm{OM,bb}}$	`tau_OMbb`	yr
Γ_{POA}	`Gamma_POA`	Tg K^{-1}
ω_{OC}	`w_reg_OC`	1
$\alpha_{\mathrm{OM}}^{\mathrm{OC}}$	`alpha_POA`	Tg TgC^{-1}

In papers	In code	Unit
$\tau_{\mathrm{BC,ff}}$	`tau_BCff`	yr
$\tau_{\mathrm{BC,bb}}$	`tau_BCbb`	yr
Γ_{BC}	`Gamma_BC`	Tg K^{-1}
ω_{BC}	`w_reg_BC`	1
$\tau_{\mathrm{NO_x}}$	`tau_NOX`	yr
$\tau_{\mathrm{NH_3}}$	`tau_NH3`	yr
$\Gamma_{\mathrm{NO_3}}$	`Gamma_NO3`	Tg K^{-1}
τ_{VOC}	`tau_VOC`	yr
τ_{BVOC}	`tau_BVOC`	yr
Γ_{SOA}	`Gamma_SOA`	Tg K^{-1}
$\alpha_{\mathrm{rf}}^{\mathrm{SO_4}}$	`radeff_SO4`	W m^{-2} Tg^{-1}
$\alpha_{\mathrm{rf}}^{\mathrm{POA}}$	`radeff_POA`	W m^{-2} Tg^{-1}
$\alpha_{\mathrm{rf}}^{\mathrm{BC}}$	`radeff_BC`	W m^{-2} Tg^{-1}
$\alpha_{\mathrm{rf}}^{\mathrm{NO_3}}$	`radeff_NO3`	W m^{-2} Tg^{-1}
$\alpha_{\mathrm{rf}}^{\mathrm{SOA}}$	`radeff_SOA`	W m^{-2} Tg^{-1}
$\kappa_{\mathrm{adj}}^{\mathrm{BC}}$	`k_BC_adjust`	1
$\pi_{\mathrm{sol}}^{\mathrm{SO_4}}$	`solub_SO4`	1
$\pi_{\mathrm{sol}}^{\mathrm{POA}}$	`solub_POA`	1
$\pi_{\mathrm{sol}}^{\mathrm{BC}}$	`solub_BC`	1
$\pi_{\mathrm{sol}}^{\mathrm{NO_3}}$	`solub_NO3`	1
$\pi_{\mathrm{sol}}^{\mathrm{SOA}}$	`solub_SOA`	1
Φ	`Phi_0`	W m^{-2}
ω_{BCsnow}	`w_reg_BCsnow`	1
$\alpha_{\mathrm{rf}}^{\mathrm{BCsnow}}$	`radeff_BCsnow`	W m^{-2} [MtC yr^{-1}]$^{-1}$
π_{trans}	`p_trans`	1

In papers	In code	Unit
ϕ_{rsds}	`rsds_alb`	W m^{-2}
α_{alb}	`alpha_alb`	1
$\kappa_{\mathrm{warm}}^{\mathrm{BCsnow}}$	`warmeff_BCsnow`	1
$\kappa_{\mathrm{warm}}^{\mathrm{LCC}}$	`warmeff_LCC`	1
$\kappa_{\mathrm{warm}}^{\mathrm{volc}}$	`warmeff_volc`	1
$\pi_{\mathrm{atm}}^{\mathrm{CO_2}}$	`p_atm_CO2`	1
$\pi_{\mathrm{atm}}^{\mathrm{noCO_2}}$	`p_atm_noCO2`	1
$\pi_{\mathrm{atm}}^{\mathrm{O_3t}}$	`p_atm_O3t`	1
$\pi_{\mathrm{atm}}^{\mathrm{strat}}$	`p_atm_strat`	1
$\pi_{\mathrm{atm}}^{\mathrm{scatter}}$	`p_atm_scatter`	1
$\pi_{\mathrm{atm}}^{\mathrm{absorb}}$	`p_atm_absorb`	1
$\pi_{\mathrm{atm}}^{\mathrm{cloud}}$	`p_atm_cloud`	1
$\pi_{\mathrm{atm}}^{\mathrm{alb}}$	`p_atm_alb`	1
$\pi_{\mathrm{atm}}^{\mathrm{solar}}$	`p_atm_solar`	1
λ	`lambda_0`	K [W m^{-2}]$^{-1}$
τ_{T_G}	`tau_gst`	yr
τ_{T_D}	`tau_gst0`	yr
θ	`theta_0`	1
ω_{T_S}	`w_reg_sst`	1
ω_{T_L}	`w_reg_lst`	1
α_{P_G}	`alpha_gyp`	mm yr^{-1} K^{-1}
β_{P_G}	`beta_gyp`	mm yr^{-1} [W m^{-2}]$^{-1}$
ω_{P_L}	`w_reg_lyp`	1
π_{ohc}	`p_OHC`	1