OSCAR v2.4

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 Some automatic plots can be activated with the plot argument, but they may be outdated.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.
`mod_biomeV3`	Boolean. Forces biome aggregation to be the same as with OSCAR v3. Supersedes `mod_biomeSHR` and `mod_biomeURB` when `True` (default value).
`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.

Option	Description
`scen_ALL`	Scenario for all drivers. Has priority over other `scen_` options.
`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.

Option	Description
`mod_EHWPfct`	Functional form for the oxidation of HWPs.
`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.

Option	Description
`mod_SOAload`	Transient response of SOA burden.
`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.

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
ΔCO_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}
$\Delta \mathrm{CH_4}_{\mathrm{lag}}$	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
$\Delta F_{\downarrow \mathrm{OH}}^{\mathrm{CH_4}}$	D_OHSNK_CH4	MtC yr^{-1}
$\Delta F_{\downarrow \mathrm{h\nu}}^{\mathrm{CH_4}}$	D_HVSNK_CH4	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

In papers	In code	Unit
Δe_{wet}	D_ewet	MtC Mha^{-1} yr^{-1}
ΔE_{wet}	D_EWET	MtC yr^{-1}
ΔCH_4	D_CH4	ppb
$\Delta\text{RF}^{\text{CH}_4}$	RF_CH4	W m^{-2}
$\Delta\text{RF}^{\text{H}_2\text{Os}}$	RF_H2Os	W m^{-2}
$\Delta F_{\downarrow\text{h}\nu}^{\text{N}_2\text{O}}$	D_HVSNK_N2O	MtN yr^{-1}
$\Delta\text{N}_2\text{O}$	D_N2O	ppb
$\Delta\text{RF}^{\text{N}_2\text{O}}$	RF_N2O	W m^{-2}
$\Delta F_{\downarrow\text{OH}}^{\{\text{HFC}\}}$	D_OHSNK_HFC	kt yr^{-1}
$\Delta F_{\downarrow\text{h}\nu}^{\{\text{HFC}\}}$	D_HVSNK_HFC	kt yr^{-1}
$\Delta F_{\downarrow\text{othr}}^{\{\text{HFC}\}}$	D_XSNK_HFC	kt yr^{-1}
$\Delta F_{\downarrow\text{OH}}^{\{\text{PFC}\}}$	D_OHSNK_PFC	kt yr^{-1}
$\Delta F_{\downarrow\text{h}\nu}^{\{\text{PFC}\}}$	D_HVSNK_PFC	kt yr^{-1}
$\Delta F_{\downarrow\text{othr}}^{\{\text{PFC}\}}$	D_XSNK_PFC	kt yr^{-1}
$\Delta F_{\downarrow\text{OH}}^{\{\text{ODS}\}}$	D_OHSNK_ODS	kt yr^{-1}
$\Delta F_{\downarrow\text{h}\nu}^{\{\text{ODS}\}}$	D_HVSNK_ODS	kt yr^{-1}
$\Delta F_{\downarrow\text{othr}}^{\{\text{ODS}\}}$	D_XSNK_ODS	kt yr^{-1}
$\Delta\{\text{HFC}\}$	D_HFC	ppt
$\Delta\{\text{PFC}\}$	D_PFC	ppt
$\Delta\{\text{ODS}\}$	D_ODS	ppt
$\Delta\text{RF}^{\text{halo}}$	RF_halo	W m^{-2}
$\Delta\text{O}_3\text{t}$	D_O3t	DU
$\Delta\text{RF}^{\text{O}_3\text{t}}$	RF_O3t	W m^{-2}

In papers	In code	Unit
$\Delta\mathrm{EESC}$	`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}
$\Delta\mathrm{RF}^{\mathrm{BCsnow}}$	`RF_bcsnow`	W m^{-2}
$\Delta\mathrm{RF}^{\mathrm{LCC}}$	`RF_lcc`	W m^{-2}
$\Delta\mathrm{RF}$	`RF`	W m^{-2}
$\Delta\mathrm{RF_{warm}}$	`RF_warm`	W m^{-2}
$\Delta\mathrm{RF_{atm}}$	`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}

In papers	In code	Unit
ΔP_L	`D_lyp`	mm yr^{-1}

In papers	In code	Unit
$\Delta\mathrm{OHC}$	`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}

In papers	In code	Unit
η	`npp_0`	GtC Mha^{-1} yr^{-1}
μ	`mu_0`	yr^{-1}
ρ_{litt}	`rho1_0`	yr^{-1}
ρ_{soil}	`rho2_0`	yr^{-1}
π_{met}	`p_met`	1
β_{npp}	`beta_npp`	1
$\tilde{\beta}_{\mathrm{npp}}$	`beta_npp0`	1
$\mathrm{CO}_{2\mathrm{cp}}$	`CO2_comp`	ppm
$\gamma_{\mathrm{npp},T}$	`gamma_nppT`	K^{-1}
$\gamma_{\mathrm{npp},P}$	`gamma_nppP`	[mm yr^{-1}]$^{-1}$
$\gamma_{\mathrm{resp},T}$	`gamma_rhoT`	K^{-1}
$\gamma_{\mathrm{resp},T_1}$	`gamma_rhoT1`	K^{-1}
$\gamma_{\mathrm{resp},T_2}$	`gamma_rhoT2`	K^{-2}

In papers	In code	Unit
$\gamma_{\mathrm{resp},P}$	`gamma_rhoP`	[mm yr^{-1}]$^{-1}$
ι	`igni_0`	yr^{-1}
$\gamma_{\mathrm{igni},C}$	`gamma_igniC`	ppm^{-1}
$\gamma_{\mathrm{igni},T}$	`gamma_igniT`	K^{-1}
$\gamma_{\mathrm{igni},P}$	`gamma_igniP`	[mm yr^{-1}]$^{-1}$
$\omega_{T_{\mathrm{pf}}}$	`w_reg_lstPF`	1
γ_{pf,T_1}	`gamma_rhoPF1`	K^{-1}
γ_{pf,T_2}	`gamma_rhoPF2`	K^{-2}
$\omega_{\mathrm{resp,pf}}$	`w_rhoPF`	1
$p_{\mathrm{thaw,min}}$	`pthaw_min`	1
$\kappa_{p_{\mathrm{thaw}}}$	`k_pthaw`	1
$\gamma_{p_{\mathrm{thaw}}}$	`gamma_pthaw`	K^{-1}
$\mathcal{F}_{\nu_{\mathrm{pf}}}$	`f_v_PF`	yr^{-1}
ν_{thaw}	`v_thaw`	yr^{-1}
ν_{froz}	`v_froz`	yr^{-1}
$\pi_{\mathrm{pf},1}$	`p_PF1`	1
$\pi_{\mathrm{pf},2}$	`p_PF2`	1
$\pi_{\mathrm{pf},3}$	`p_PF3`	1
$\tau_{\mathrm{pf},1}$	`tau_PF1`	yr
$\tau_{\mathrm{pf},2}$	`tau_PF2`	yr
$\tau_{\mathrm{pf},3}$	`tau_PF3`	yr
$C_{\mathrm{froz},0}$	`CFROZ_0`	GtC
$\pi_{\mathrm{pf},\mathrm{CH}_4}$	`p_PF_CH4`	1
$\pi_{\mathrm{pf,inst}}$	`p_PF_inst`	1
τ_{shift}	`tau_shift`	yr
π_{agb}	`p_AGB`	1
π_{hwp}	`p_HWP`	1

In papers	In code	Unit
$\pi_{\mathrm{hwp,bb}}^{w=1}$	`p_HWP1_BB`	1
τ_{hwp}	`tau_HWP`	yr
$\mathcal{F}_{\mathrm{hwp}}$	`r_HWP`	1
$\alpha_{\mathrm{bb}}^{\mathrm{CH_4}}$	`alpha_BB_CH4`	MtC GtC^{-1}
$\alpha_{\mathrm{bb}}^{\mathrm{N_2O}}$	`alpha_BB_N2O`	MtN GtC^{-1}
$\alpha_{\mathrm{bb}}^{\mathrm{NO_x}}$	`alpha_BB_NOX`	MtN GtC^{-1}
$\alpha_{\mathrm{bb}}^{\mathrm{CO}}$	`alpha_BB_CO`	MtC GtC^{-1}
$\alpha_{\mathrm{bb}}^{\mathrm{VOC}}$	`alpha_BB_VOC`	Mt GtC^{-1}
$\alpha_{\mathrm{bb}}^{\mathrm{SO_2}}$	`alpha_BB_SO2`	MtS GtC^{-1}
$\alpha_{\mathrm{bb}}^{\mathrm{NH_3}}$	`alpha_BB_NH3`	MtN GtC^{-1}
$\alpha_{\mathrm{bb}}^{\mathrm{OC}}$	`alpha_BB_OC`	MtC GtC^{-1}
$\alpha_{\mathrm{bb}}^{\mathrm{BC}}$	`alpha_BB_BC`	MtC GtC^{-1}
τ_{lag}	`tau_lag`	yr
$\alpha_{\mathrm{atm}}^{\mathrm{CH_4}}$	`alpha_CH4`	MtC ppb^{-1}
$\tau_{\mathrm{OH}}^{\mathrm{CH_4}}$	`tau_CH4_OH`	yr
$\tau_{\mathrm{h\nu}}^{\mathrm{CH_4}}$	`tau_CH4_hv`	yr
$\tau_{\mathrm{soil}}^{\mathrm{CH_4}}$	`tau_CH4_soil`	yr
$\tau_{\mathrm{ocean}}^{\mathrm{CH_4}}$	`tau_CH4_ocean`	yr
$\chi_{\mathrm{O_3s}}^{\mathrm{OH}}$	`chi_OH_O3s`	1
$\chi_{\mathrm{T_A}}^{\mathrm{OH}}$	`chi_OH_Tatm`	1
$\chi_{\mathrm{Q_A}}^{\mathrm{OH}}$	`chi_OH_Qatm`	1
$\chi_{\mathrm{NO_x}}^{\mathrm{OH}}$	`chi_OH_NOX`	[MtN yr^{-1}]$^{-1}$
$\chi_{\mathrm{CO}}^{\mathrm{OH}}$	`chi_OH_CO`	[MtC yr^{-1}]$^{-1}$
$\chi_{\mathrm{VOC}}^{\mathrm{OH}}$	`chi_OH_VOC`	[Mt yr^{-1}]$^{-1}$

In papers	In code	Unit
$\tilde{\chi}^{\mathrm{OH}}_{\mathrm{NO_x}}$	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	MtN yr^{-1}
$E^{\mathrm{CO}}_{\mathrm{nat}}$	ECO_oh	MtC yr^{-1}
$E^{\mathrm{VOC}}_{\mathrm{nat}}$	EVOC_oh	Mt yr^{-1}

π_{wet}	p_wet	1
$\gamma_{\mathrm{wet},C}$	gamma_wetC	ppm^{-1}
$\gamma_{\mathrm{wet},T}$	gamma_wetT	K^{-1}
$\gamma_{\mathrm{wet},P}$	gamma_wetP	$[\mathrm{mm\ yr}^{-1}]^{-1}$

$\mathcal{F}_{\mathrm{over}}$	f_overlap	W m^{-2}

$\alpha^{\mathrm{N_2O}}_{\mathrm{atm}}$	alpha_N2O	MtN ppb^{-1}
$\tau^{\mathrm{N_2O}}_{\mathrm{h\nu}}$	tau_N2O_hv	yr
$\chi^{\mathrm{h\nu}}_{\mathrm{N2O}}$	chi_hv_N2O	1
$\chi^{\mathrm{h\nu}}_{\mathrm{EESC}}$	chi_hv_EESC	1
$\chi^{\mathrm{h\nu}}_{\mathrm{age}}$	chi_hv_age	1
γ_{age}	gamma_age	K^{-1}

$\alpha^{\{\mathrm{HFC}\}}_{\mathrm{atm}}$	alpha_HFC	kt ppt^{-1}
$\alpha^{\{\mathrm{PFC}\}}_{\mathrm{atm}}$	alpha_PFC	kt ppt^{-1}
$\alpha^{\{\mathrm{ODS}\}}_{\mathrm{atm}}$	alpha_ODS	kt ppt^{-1}

In papers	In code	Unit
$\tau_{\mathrm{OH}}^{\{\mathrm{HFC}\}}$	`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}]$^{-1}$
$\chi_{\mathrm{CO}}^{\mathrm{O_3t}}$	`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

In papers	In code	Unit
$n_{\mathrm{Cl}}^{\{\mathrm{ODS}\}}$	`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}
$\tau_{\mathrm{BC,ff}}$	`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}

In papers	In code	Unit
$\alpha_{\mathrm{rf}}^{\mathrm{SO_4}}$	`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
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

In papers	In code	Unit
$\pi_{\mathrm{atm}}^{\mathrm{scatter}}$	`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