OSCAR v2.2 – Manual

1. License

The OSCAR v2.2 model is distributed under the CeCILL license that is close to and compatible with the GNU GPL license. The full text of the license can be found at http://www.cecill.info/licences/Licence_CeCILL_V2.1-en.html. Note that download or usage of the model implies acceptance of the license terms.

2. General points

OSCAR v2.2 has been developed and tested on Python 2.7.3 under at least two distributions: EPD7 and Anaconda2. The source code is provided firstly for transparency, and only secondly for dissemination. This means that it is provided "as is", and no support of any kind is guaranteed.

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 Some automatic plots can be activated with the `plot` argument, but they may be outdated.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.

The source code and brief manual we provide are for the variant of OSCAR v2.2 called "*lite*", by opposition to the "*attrib*" variant (and probably others in the future). The *lite* variant is the one used in the description paper, and it is the simplest and most straight-forward variant of the model. However, because both variants are developed on the same equations and data, some parts of the code of OSCAR-*lite* are more complicated than they would be otherwise. Specifically, if one digs into the loading file for drivers, one can see the drivers are initially defined following more axes than actually needed. This is solved by executing the formatting file after the loading file. Another example is the simulation options qualified as "useless" hereafter that only affect the *attrib* variant. The *attrib* variant will not be made available.

3. 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:

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	Year of end of simulation.
ind_attrib	(USELESS)
attrib_DRIVERS	(USELESS)
attrib_FEEDBACKS	(USELESS)
attrib_ELUCdelta	(USELESS)
attrib_ELUCampli	(USELESS)
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.
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_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.
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.
mod_SOAradeff	Radiative efficiency of SOA.
mod_DUSTload	(NOT DESCRIBED IN PAPER)
mod_DUSTradeff	(NOT IMPLEMENTED)
mod_SALTload	(NOT DESCRIBED IN PAPER)
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)
mod_SLR	(NOT IMPLEMENTED)

4. 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:

4.1. OSCAR-loadD.py

A. VECTORS

    A.1. Regions

    A.2. Sectors

    A.3. Kinds

    A.4. Biomes

    A.5. Halo

1. GREENHOUSE GASES

    1.1. CDIAC

    1.2. EPA

    1.3. EDGAR

    1.4. EDGAR-FT

    1.5. ACCMIP

    1.6. EDGAR-HYDE

    1.7. Stern1998

    1.8. Davidson2009

    1.9. SRES

    1.10. RCP

    1.A. Past Dataset

    1.B. Final Dataset

    1.11. Peters2011

2. LAND-USE CHANGE

    2.1. LUH1

    2.2. RCP

    2.A. Final Dataset

3. HALOGENATED COMPOUNDS

    3.1. EDGAR

    3.2. EDGAR-FT

    3.3. CMIP5

    3.4. RCP

    3.A. Past Dataset

    3.B. Final Dataset

4. SHORT-LIVED SPECIES

    4.1. EDGAR

    4.2. EDGAR-HTAP

    4.3. ACCMIP

    4.4. SRES

    4.5. RCP

    4.A. Past Dataset

    4.B. Final Dataset

5. RADIATIVE FORCINGS

    5.1. Anthropogenic

    5.2. Natural

B. FINAL DRIVERS

    B.1. Preindustrial

    B.2. Attribution

4.2. `OSCAR-loadP.py`

5. 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:

E_{FF}	EFF	GtC yr^{-1}
E_{CH4}	ECH4	MtC yr^{-1}
E_{N2O}	EN2O	MtN yr^{-1}
$E_{\{HFC\}}$	EHFC	kt yr^{-1}
$E_{\{PFC\}}$	EPFC	kt yr^{-1}
$E_{\{ODS\}}$	EODS	kt yr^{-1}
E_{NOx}	ENOX	MtN yr^{-1}
E_{CO}	ECO	MtC yr^{-1}
E_{VOC}	EVOC	Mt yr^{-1}
E_{SO2}	ESO2	MtS yr^{-1}
E_{NH3}	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}
RF_{con}	RFant	W m^{-2}
RF_{volc}	RFvolc	W m^{-2}
RF_{solar}	RFsolar	W m^{-2}

Variables:

ΔC_{surf}	D_CSURF	GtC
Δdic	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}
Δnpp	D_npp	GtC Mha^{-1} yr^{-1}
Δe_{fire}	D_efire	GtC Mha^{-1} yr^{-1}
Δf_{mort}	D_fmort	GtC Mha^{-1} yr^{-1}
Δrh_{litt}	D_rh1	GtC Mha^{-1} yr^{-1}
Δf_{met}	D_fmet	GtC Mha^{-1} yr^{-1}
Δrh_{soil}	D_rh2	GtC Mha^{-1} yr^{-1}
$\Delta C_{veg,luc}$	CVEG_luc	GtC
$\Delta C_{hwp,luc}^{w=1}$	CHWP1_luc	GtC
$\Delta C_{hwp,luc}^{w=2}$	CHWP2_luc	GtC
$\Delta C_{hwp,luc}^{w=3}$	CHWP3_luc	GtC
$\Delta C_{litt,luc}$	CSOIL1_luc	GtC
$\Delta C_{soil,luc}$	CSOIL2_luc	GtC
ΔA	D_AREA	Mha
$\Delta CO2$	D_CO2	ppm
$\Delta F_{\downarrow ocean}$	OSNK	GtC yr^{-1}
$\Delta F_{\downarrow land}$	LSNK	GtC yr^{-1}
ΔE_{LUC}	ELUC	GtC yr^{-1}
ΔRF^{CO2}	RF_CO2	W m^{-2}
ΔE_{bb}^{CH4}	D_EBB_CH4	MtC yr^{-1}
ΔE_{bb}^{N2O}	D_EBB_N2O	MtN yr^{-1}
ΔE_{bb}^{NOx}	D_EBB_NOX	MtN yr^{-1}
ΔE_{bb}^{CO}	D_EBB_CO	MtC yr^{-1}
ΔE_{bb}^{VOC}	D_EBB_VOC	Mt yr^{-1}
ΔE_{bb}^{SO2}	D_EBB_SO2	MtS yr^{-1}

ΔE_{bb}^{NH3}	D_EBB_NH3	MtN yr^{-1}
ΔE_{bb}^{OC}	D_EBB_OC	MtC yr^{-1}
ΔE_{bb}^{BC}	D_EBB_BC	MtC yr^{-1}
$\Delta CH4_{lag}$	D_CH4_lag	ppb
$\Delta N2O_{lag}$	D_N2O_lag	ppb
$\Delta \{HFC\}_{lag}$	D_HFC_lag	ppt
$\Delta \{PFC\}_{lag}$	D_PFC_lag	ppt
$\Delta \{ODS\}_{lag}$	D_ODS_lag	ppt
$\Delta F_{\downarrow OH}^{CH4}$	D_OHSNK_CH4	MtC yr^{-1}
$\Delta F_{\downarrow hv}^{CH4}$	D_HVSNK_CH4	MtC yr^{-1}
$\Delta F_{\downarrow othr}^{CH4}$	D_XSNK_CH4	MtC yr^{-1}
ΔA_{wet}	D_AWET	Mha
Δe_{wet}	D_ewet	MtC Mha^{-1} yr^{-1}
ΔE_{wet}	D_EWET	MtC yr^{-1}
$\Delta CH4$	D_CH4	ppb
ΔRF^{CH4}	RF_CH4	W m^{-2}
ΔRF^{H2Os}	RF_H2Os	W m^{-2}
$\Delta F_{\downarrow}^{N2O}$	D_HVSNK_N2O	MtN yr^{-1}
$\Delta N2O$	D_N2O	ppb
ΔRF^{N2O}	RF_N2O	W m^{-2}
$\Delta F_{\downarrow OH}^{\{HFC\}}$	D_OHSNK_HFC	kt yr^{-1}
$\Delta F_{\downarrow hv}^{\{HFC\}}$	D_HVSNK_HFC	kt yr^{-1}
$\Delta F_{\downarrow othr}^{\{HFC\}}$	D_XSNK_HFC	kt yr^{-1}
$\Delta F_{\downarrow OH}^{\{PFC\}}$	D_OHSNK_PFC	kt yr^{-1}
$\Delta F_{\downarrow hv}^{\{PFC\}}$	D_HVSNK_PFC	kt yr^{-1}
$\Delta F_{\downarrow othr}^{\{PFC\}}$	D_XSNK_PFC	kt yr^{-1}
$\Delta F_{\downarrow OH}^{\{ODS\}}$	D_OHSNK_ODS	kt yr^{-1}
$\Delta F_{\downarrow hv}^{\{ODS\}}$	D_HVSNK_ODS	kt yr^{-1}
$\Delta F_{\downarrow othr}^{\{ODS\}}$	D_XSNK_ODS	kt yr^{-1}
$\Delta \{HFC\}$	D_HFC	ppt
$\Delta \{PFC\}$	D_PFC	ppt
$\Delta \{ODS\}$	D_ODS	ppt
ΔRF^{halo}	RF_halo	W m^{-2}
$\Delta O3t$	D_O3t	DU
ΔRF^{O3t}	RF_O3t	W m^{-2}
$\Delta EESC$	D_EESC	ppt
$\Delta O3s$	D_O3s	DU
ΔRF^{O3s}	RF_O3s	W m^{-2}
$\Delta SO4$	D_SO4	Tg
ΔPOA	D_POA	Tg
ΔBC	D_BC	Tg
$\Delta NO3$	D_NO3	Tg
ΔSOA	D_SOA	Tg
ΔRF^{SO4}	RF_SO4	W m^{-2}
ΔRF^{POA}	RF_POA	W m^{-2}
ΔRF^{BC}	RF_BC	W m^{-2}
ΔRF^{NO3}	RF_NO3	W m^{-2}
ΔRF^{SOA}	RF_SOA	W m^{-2}
ΔAER_{sol}	D_AERh	Tg
ΔRF^{cloud}	RF_cloud	W m^{-2}
ΔRF^{BCsnow}	RF_bcsnow	W m^{-2}
ΔRF^{LCC}	RF_lcc	W m^{-2}
ΔRF	RF	W m^{-2}
ΔRF_{warm}	RF_warm	W m^{-2}
ΔRF_{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}
ΔOHC	D_OHC	ZJ

Parameters:

ν_{fg}	v_fg	yr^{-1}
A_{ocean}	A_ocean	m^2
π_{circ}	p_circ	-
τ_{circ}	tau_circ	yr
$\mathcal{F}_{\text{pCO2}}$	f_pCO2	ppm
α_{sol}	alpha_sol	µmol m^3 kg^{-1} ppm^{-1}
$\alpha_{\text{atm}}^{\text{CO2}}$	alpha_CO2	GtC ppm^{-1}
π_{mld}	alpha_mld	-
γ_{mld}	gamma_mld	K^{-1}
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	-
β_{npp}	beta_npp	-
$\tilde{\beta}_{\text{npp}}$	beta_npp0	-
CO2_{cp}	CO2_comp	ppm
$\gamma_{\text{npp},T}$	gamma_nppT	K^{-1}
$\gamma_{\text{npp},P}$	gamma_nppP	[mm yr^{-1}]$^{-1}$
$\gamma_{\text{resp},T}$	gamma_rhoT	K^{-1}
γ_{resp,T_1}	gamma_rhoT1	K^{-1}
γ_{resp,T_2}	gamma_rhoT2	K^{-2}
$\gamma_{\text{resp},P}$	gamma_rhoP	[mm yr^{-1}]$^{-1}$
ι	igni_0	yr^{-1}
$\gamma_{\text{igni},C}$	gamma_igniC	ppm^{-1}
$\gamma_{\text{igni},T}$	gamma_igniT	K^{-1}
$\gamma_{\text{igni},P}$	gamma_igniP	[mm yr^{-1}]$^{-1}$
τ_{shift}	tau_shift	yr
π_{agb}	p_AGB	-
π_{hwp}	p_HWP	-
τ_{hwp}	tau_HWP	yr
$\mathcal{F}_{\text{hwp}}$	r_HWP	-
$\alpha_{\text{bb}}^{\text{CH4}}$	alpha_BB_CH4	MtC GtC^{-1}
$\alpha_{\text{bb}}^{\text{N2O}}$	alpha_BB_N2O	MtN GtC^{-1}
$\alpha_{\text{bb}}^{\text{NOx}}$	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}
$\alpha_{\text{bb}}^{\text{SO2}}$	alpha_BB_SO2	MtS GtC^{-1}
$\alpha_{\text{bb}}^{\text{NH3}}$	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
$\alpha_{\text{atm}}^{\text{CH4}}$	alpha_CH4	MtC ppb^{-1}
$\tau_{\text{OH}}^{\text{CH4}}$	tau_CH4_OH	yr
$\tau_{\text{hv}}^{\text{CH4}}$	tau_CH4_hv	yr
$\tau_{\text{soil}}^{\text{CH4}}$	tau_CH4_soil	yr
$\tau_{\text{ocean}}^{\text{CH4}}$	tau_CH4_ocean	yr
$\chi_{\text{CH4}}^{\text{OH}}$	chi_OH_CH4	-

$\chi_{\text{O3s}}^{\text{OH}}$	chi_OH_O3s	-
$\chi_{T_A}^{\text{OH}}$	chi_OH_Tatm	-
$\chi_{Q_A}^{\text{OH}}$	chi_OH_Qatm	-
$\chi_{\text{NOx}}^{\text{OH}}$	chi_OH_NOX	[MtN yr^{-1}]$^{-1}$
$\chi_{\text{CO}}^{\text{OH}}$	chi_OH_CO	[MtC yr^{-1}]$^{-1}$
$\chi_{\text{VOC}}^{\text{OH}}$	chi_OH_VOC	[Mt yr^{-1}]$^{-1}$
$\tilde{\chi}_{\text{NOx}}^{\text{OH}}$	chi_OH_NOX	-
$\tilde{\chi}_{\text{CO}}^{\text{OH}}$	chi_OH_CO	-
$\tilde{\chi}_{\text{VOC}}^{\text{OH}}$	chi_OH_VOC	-
κ_{T_A}	k_Tatm	-
κ_{Q_A}	k_Qatm	-
κ_{svp}	k_svp	-
T_{svp}	T_svp	K
$T_{\text{atm},0}$	Tatm_0	K
$E_{\text{nat}}^{\text{NOx}}$	ENOX_oh	MtN yr^{-1}
$E_{\text{nat}}^{\text{CO}}$	ECO_oh	MtC yr^{-1}
$E_{\text{nat}}^{\text{VOC}}$	EVOC_oh	Mt yr^{-1}
π_{wet}	p_wet	-
$\gamma_{\text{wet},C}$	gamma_wetC	ppm^{-1}
$\gamma_{\text{wet},T}$	gamma_wetT	K^{-1}
$\gamma_{\text{wet},P}$	gamma_wetP	[mm yr^{-1}]$^{-1}$
$\mathcal{F}_{\text{over}}$	f_overlap	W m^{-2}
$\alpha_{\text{atm}}^{\text{N2O}}$	alpha_N2O	MtN ppb^{-1}
$\tau_{\text{hv}}^{\text{N2O}}$	tau_N2O_hv	yr
$\chi_{\text{N2O}}^{\text{hv}}$	chi_hv_N2O	-
$\chi_{\text{EESC}}^{\text{hv}}$	chi_hv_EESC	-
$\chi_{\text{age}}^{\text{hv}}$	chi_hv_age	-
γ_{age}	gamma_age	K^{-1}
$\alpha_{\text{atm}}^{\{\text{HFC}\}}$	alpha_HFC	kt ppt^{-1}
$\alpha_{\text{atm}}^{\{\text{PFC}\}}$	alpha_PFC	kt ppt^{-1}
$\alpha_{\text{atm}}^{\{\text{ODS}\}}$	alpha_ODS	kt ppt^{-1}
$\tau_{\text{OH}}^{\{\text{HFC}\}}$	tau_HFC_OH	yr
$\tau_{\text{hv}}^{\{\text{HFC}\}}$	tau_HFC_hv	yr
$\tau_{\text{othr}}^{\{\text{HFC}\}}$	tau_HFC_othr	yr
$\tau_{\text{OH}}^{\{\text{PFC}\}}$	tau_PFC_OH	yr
$\tau_{\text{hv}}^{\{\text{PFC}\}}$	tau_PFC_hv	yr
$\tau_{\text{othr}}^{\{\text{PFC}\}}$	tau_PFC_othr	yr
$\tau_{\text{OH}}^{\{\text{ODS}\}}$	tau_ODS_OH	yr
$\tau_{\text{hv}}^{\{\text{ODS}\}}$	tau_ODS_hv	yr
$\tau_{\text{othr}}^{\{\text{ODS}\}}$	tau_ODS_othr	yr
$\alpha_{\text{rf}}^{\{\text{HFC}\}}$	radeff_HFC	W m^{-2} ppt^{-1}
$\alpha_{\text{rf}}^{\{\text{PFC}\}}$	radeff_PFC	W m^{-2} ppt^{-1}
$\alpha_{\text{rf}}^{\{\text{ODS}\}}$	radeff_ODS	W m^{-2} ppt^{-1}
$\xi_{\text{CH4}}^{\text{O3t}}$	chi_O3t_CH4	DU
$\xi_{\text{NOx}}^{\text{O3t}}$	chi_O3t_NOX	DU [MtN yr^{-1}]$^{-1}$
$\xi_{\text{CO}}^{\text{O3t}}$	chi_O3t_CO	DU [MtC yr^{-1}]$^{-1}$
$\xi_{\text{VOC}}^{\text{O3t}}$	chi_O3t_VOC	DU [Mt yr^{-1}]$^{-1}$
ω_{NOx}	w_reg_NOX	-
ω_{CO}	w_reg_CO	-
ω_{VOC}	w_reg_VOC	-
π_{reg}	p_reg	-
Γ_{O3t}	Gamma_O3t	DU K^{-1}
$\alpha_{\text{rf}}^{\text{O3t}}$	radeff_O3t	W m^{-2} DU^{-1}
$\pi_{\text{rel}}^{\{\text{ODS}\}}$	f_fracrel	-
$n_{\text{Cl}}^{\{\text{ODS}\}}$	n_Cl	-

$n_{Br}^{\{ODS\}}$	n_Br	-
α_{Cl}^{Br}	alpha_Br	-
ξ_{EESC}^{O3s}	chi_O3s_EESC	DU ppt^{-1}
ξ_{N2O}^{O3s}	chi_O3s_N2O	DU ppb^{-1}
$EESC_{\times}$	EESC_x	ppt
Γ_{O3s}	Gamma_O3s	DU K^{-1}
α_{rf}^{O3s}	radeff_O3s	W m^{-2} DU^{-1}
τ_{SO2}	tau_SO2	yr
τ_{DMS}	tau_DMS	yr
Γ_{SO4}	Gamma_SO4	Tg K^{-1}
ω_{SO2}	w_reg_SO2	-
$\tau_{OM,ff}$	tau_OMff	yr
$\tau_{OM,bb}$	tau_OMbb	yr
Γ_{POA}	Gamma_POA	Tg K^{-1}
ω_{OC}	w_reg_OC	-
α_{OM}^{OC}	alpha_POA	Tg TgC^{-1}
$\tau_{BC,ff}$	tau_BCff	yr
$\tau_{BC,bb}$	tau_BCbb	yr
Γ_{BC}	Gamma_BC	Tg K^{-1}
ω_{BC}	w_reg_BC	-
τ_{NOx}	tau_NOX	yr
τ_{NH3}	tau_NH3	yr
Γ_{NO3}	Gamma_NO3	Tg K^{-1}
τ_{VOC}	tau_VOC	yr
τ_{BVOC}	tau_BVOC	yr
Γ_{SOA}	Gamma_SOA	Tg K^{-1}
α_{rf}^{SO4}	radeff_SO4	W m^{-2} Tg^{-1}
α_{rf}^{POA}	radeff_POA	W m^{-2} Tg^{-1}
α_{rf}^{BC}	radeff_BC	W m^{-2} Tg^{-1}
α_{rf}^{NO3}	radeff_NO3	W m^{-2} Tg^{-1}
α_{rf}^{SOA}	radeff_SOA	W m^{-2} Tg^{-1}
κ_{adj}^{BC}	k_BC_adjust	-
π_{sol}^{SO4}	solub_SO4	-

π_{sol}^{POA}	solub_POA	-
π_{sol}^{BC}	solub_BC	-
π_{sol}^{NO3}	solub_NO3	-
π_{sol}^{SOA}	solub_SOA	-
Φ	Phi_0	W m^{-2}
ω_{BCsnow}	w_reg_BCsnow	-
α_{rf}^{BCsnow}	radeff_BCsnow	W m^{-2} [MtC yr^{-1}]$^{-1}$
π_{trans}	p_trans	-
φ_{rsds}	rsds_alb	W m^{-2}
α_{alb}	alpha_alb	-
κ_{warm}^{BCsnow}	warmeff_BCsnow	-
κ_{warm}^{LCC}	warmeff_LCC	-
κ_{warm}^{volc}	warmeff_volc	-
π_{atm}^{CO2}	p_atm_CO2	-
π_{atm}^{noCO2}	p_atm_noCO2	-
π_{atm}^{O3t}	p_atm_O3t	-
π_{atm}^{strat}	p_atm_strat	-
$\pi_{atm}^{scatter}$	p_atm_scatter	-
π_{atm}^{absorb}	p_atm_absorb	-
π_{atm}^{cloud}	p_atm_cloud	-
π_{atm}^{alb}	p_atm_alb	-
π_{atm}^{solar}	p_atm_solar	-
λ	lambda_0	K [W m^{-2}]$^{-1}$
τ_{T_G}	tau_gst	yr
τ_{T_D}	tau_gst0	yr
θ	theta_0	-
ω_{T_S}	w_reg_sst	-
ω_{T_L}	w_reg_lst	-
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	-
π_{ohc}	p_OHC	-