2-1_compute_delta_T_sensitivity

February 14, 2020

1 Plot temperature response over time

This notebook does the same as 2_compute_delta_T.ipynb except that it varies the ECS parameter and outputs a table of changes in temperature with respect to some reference year (defined below).

[22]:
```
from ar6_ch6_rcmipfigs.constants import BASE_DIR
from ar6_ch6_rcmipfigs.constants import OUTPUT_DATA_DIR, INPUT_DATA_DIR,␣
↪RESULTS_DIR

PATH_DATASET = OUTPUT_DATA_DIR + '/forcing_data_rcmip_models.nc'
PATH_DT_OUTPUT = RESULTS_DIR + '/tables/table_sens_dT_cs.csv'
```

Output table found in:

[23]:
```
print(PATH_DT_OUTPUT)
```

```
/home/sarambl/PHD/IPCC/public/AR6_CH6_RCMIPFIGS/ar6_ch6_rcmipfigs/results/tables
/table_sens_dT_cs.csv
```

1.0.1 General about computing ΔT:

We compute the change in GSAT temperature (ΔT) from the effective radiative forcing (ERF) estimated from the RCMIP models (Nicholls et al 2020), by integrating with the impulse response function (IRF(t-t')) (Geoffroy at al 2013). See Nicholls et al (2020) for description of the RCMIP models and output.

For any forcing agent x, with estimated ERF_x, the change in temperature ΔT is calculated as:

$$\Delta T_x(t) = \int_0^t ERF_x(t')IRF(t-t')dt'$$

The Impulse response function (IRF): In these calculations we use the impulse response function (Geoffroy et al 2013):

$$\text{IRF}(t) = 0.885 \cdot \left(\frac{0.587}{4.1} \cdot exp\left(\frac{-t}{4.1}\right) + \frac{0.413}{249} \cdot exp\left(\frac{-t}{249}\right)\right)$$

$$\text{IRF}(t) = \frac{1}{\lambda} \sum_{i=1}^{2} \frac{a_i}{\tau_i} \cdot exp\left(\frac{-t}{\tau_i}\right)$$

with $\frac{1}{\lambda} = 0.885$ (K/Wm^{-2}), $a_1 = 0.587$, $\tau_1 = 4.1$(yr), $a_2 = 0.413$ and $\tau_2 = 249$(yr) (note that $i = 1$ is the fast response and $i = 2$ is the slow response and that $a_1 + a_2 = 1$)

1.1 Input data:

See README.md

2 Code + figures

[24]:
```
from ar6_ch6_rcmipfigs.constants import BASE_DIR
from ar6_ch6_rcmipfigs.constants import OUTPUT_DATA_DIR, INPUT_DATA_DIR,␣
↪RESULTS_DIR

PATH_DATASET = OUTPUT_DATA_DIR + '/forcing_data_rcmip_models.nc'
PATH_DT_OUTPUT = RESULTS_DIR + '/tables/table_sens_dT_cs.csv'
```

Output table found in:

[25]:
```
print(PATH_DT_OUTPUT)
```

```
/home/sarambl/PHD/IPCC/public/AR6_CH6_RCMIPFIGS/ar6_ch6_rcmipfigs/results/tables
/table_sens_dT_cs.csv
```

2.1 Imports:

[26]:
```
import xarray as xr
from IPython.display import clear_output
import numpy as np
import os
import re
from pathlib import Path
import pandas as pd
import tqdm
from scmdata import df_append, ScmDataFrame
import matplotlib.pyplot as plt

%load_ext autoreload
```

```
%autoreload 2
```

```
The autoreload extension is already loaded. To reload it, use:
  %reload_ext autoreload
```

[27]:
```
climatemodel = 'climatemodel'
scenario = 'scenario'
variable = 'variable'
time = 'time'
```

2.2 Set values:

ECS parameters:

[28]:
```
ECS2ecsf = {'ECS = 2K':0.526, 'ECS = 3.4K':0.884, 'ECS = 5K': 1.136 }
```

Year to integrate from and to:

[29]:
```
first_y ='1850'
last_y = '2100'
```

Set reference year for temperature change:

[30]:
```
ref_year = '2021'
```

Years to output change in

[31]:
```
years= ['2040', '2100']
```

2.3 IRF:

[32]:
```
def IRF(t, l=0.885, alpha1=0.587 / 4.1, alpha2=0.413 / 249, tau1=4.1, tau2=249):
    """
    Returns the IRF function for:
    :param t: Time in years
    :param l: climate sensitivity factor
    :param alpha1:
    :param alpha2:
    :param tau1:
    :param tau2:
    :return:
    IRF
    """
    return l * (alpha1 * np.exp(-t / tau1) + alpha2 * np.exp(-t / tau2))
```

2.4 ERF:

Read ERF from file

2.4.1 Define variables to look at:

[33]:
```
# variables to plot:
variables_erf_comp = [
    'Effective Radiative Forcing|Anthropogenic|CH4',
    'Effective Radiative Forcing|Anthropogenic|Aerosols',
    'Effective Radiative Forcing|Anthropogenic|Tropospheric Ozone',
    'Effective Radiative Forcing|Anthropogenic|F-Gases|HFC',
    'Effective Radiative Forcing|Anthropogenic|Other|BC on Snow']
# total ERFs for anthropogenic and total:
variables_erf_tot = ['Effective Radiative Forcing|Anthropogenic',
                     'Effective Radiative Forcing']
# Scenarios to plot:
scenarios_fl = ['ssp119', 'ssp126', 'ssp245', 'ssp370',␣
 ↪'ssp370-lowNTCF-aerchemmip',  # 'ssp370-lowNTCF', Due to mistake here
                'ssp585', 'historical']
```

2.4.2 Open dataset:

[34]:
```
ds = xr.open_dataset(PATH_DATASET)
```

2.5 Integrate:

The code below integrates the read in ERFs with the pre defined impulse response function (IRF).

$$\Delta T(t) = \int_0^t ERF(t')IRF(t-t')dt'$$

[35]:
```
name_deltaT = 'Delta T'


def new_varname(var, nname):
    """
    var:str
        Old variable of format varname|bla|bla
    nname:str
        name for the resulting variable, based on var
    Returns
```

```
    -------
    new variable name with nname|bla|bla
    """
    return nname + '|' + '|'.join(var.split('|')[1:])


def integrate_(i, var, nvar, ds, ds_DT, csfac=0.885):
    """

    Parameters
    ----------
    i:int
        the index for the integral
    var:str
        the name of the EFR variables to integrate
    nvar:str
        the name of output integrated value

    ds:xr.Dataset
        the ds with the intput data
    ds_DT: xr.Dataset
        the ouptut ds with the integrated results
    csfac: climate sensitivity factor (for IRF)
    Returns
    -------
    None

    """
    # lets create a ds that goes from 0 to i inclusive
    ds_short = ds[{'time': slice(0, i + 1)}].copy()
    # lets get the current year
    current_year = ds_short['time'][{'time': i}].dt.year
    # lets get a list of years
    years = ds_short['time'].dt.year
    # lets get the year delta until current year(i)
    ds_short['end_year_delta'] = current_year - years

    # lets get the irf values from 0 until i
    ds_short['irf'] = IRF(
        ds_short['end_year_delta'] * ds_short['delta_t'], l=csfac
    )

    # lets do the famous integral
    ds_short['to_integrate'] = \
        ds_short[var] * \
        ds_short['irf'] * \
        ds_short['delta_t']
```

```
    # lets sum all the values up until i and set
    # this value at ds_DT
    # If whole array is null, set value to nan
    if np.all(ds_short['to_integrate'].isnull()):  # or last_null:
        _val = np.nan
    else:
        #

        _ds_int = ds_short['to_integrate'].sum(['time'])
        # mask where last value is null (in order to not get intgral
        _ds_m1 = ds_short['to_integrate'].isel(time=-1)
        # where no forcing data)
        _val = _ds_int.where(_ds_m1.notnull())
    # set value in dataframe:
    ds_DT[nvar][{'time': i}] = _val


def integrate_to_dT(ds, from_t, to_t, variables, csfac=0.885):
    """
    Integrate forcing to temperature change.

    :param ds: dataset containing the focings
    :param from_t: start time
    :param to_t: end time
    :param variables: variables to integrate
    :param csfac: climate sensitivity factor
    :return:
    """
    # slice dataset
    ds_sl = ds.sel(time=slice(from_t, to_t))
    len_time = len(ds_sl['time'])
    # lets create a result DS
    ds_DT = ds_sl.copy()

    # lets define the vars of the ds
    vars = variables  # variables_erf_comp+ variables_erf_tot #['EFR']
    for var in variables:
        namevar = new_varname(var, name_deltaT)
        # set all values to zero for results dataarray:
        ds_DT[namevar] = ds_DT[var] * 0
        # Units Kelvin:
        ds_DT[namevar].attrs['unit'] = 'K'
        if 'unit' in ds_DT[namevar].coords:
            ds_DT[namevar].coords['unit'] = 'K'

    for i in range(len_time):
```

```
        # da = ds[var]
        if (i % 20) == 0:
            print('%s of %s done' % (i, len_time))
        for var in variables:
            namevar = new_varname(var, name_deltaT)  # 'Delta T|' + '|'.
↪join(var.split('|')[1:])

            # print(var)
            integrate_(i, var, namevar, ds_sl, ds_DT, csfac=csfac)
    clear_output()

    fname = 'DT_%s-%s.nc' % (from_t, to_t)
    # save dataset.
    ds_DT.to_netcdf(fname)
    return ds_DT
```

2.6 Compute ΔT with 3 different climate sensitivities

[36]:
```
dic_ds = {}
for key  in ECS2ecsf:
    dic_ds[key] = integrate_to_dT(ds, first_y,␣
↪last_y,(variables_erf_comp+variables_erf_tot), csfac=ECS2ecsf[key])
```

2.7 Table

2.7.1 Setup table:

[37]:
```
iterables = [list(ECS2ecsf.keys()), years]

def setup_table(scenario_n=''):
    _i = pd.MultiIndex.from_product(iterables, names=['', ''])
    table = pd.DataFrame(columns=[var.split('|')[-1] for var in␣
↪variables_erf_comp], index = _i).transpose()
    table.index.name=scenario_n
    return table
```

[51]:
```
# Dicitonary of tables with different ESC:
scntab_dic = {}
for scn in scenarios_fl:
    # Loop over scenrarios
    tab = setup_table(scenario_n=scn) # make table
    for var in variables_erf_comp:
        # Loop over variables
        tabvar = var.split('|')[-1]
```

```
        dtvar = new_varname(var, name_deltaT)
        for key in ECS2ecsf:
            # Loop over ESC parameters
            for year in years:
                _tab_da = dic_ds[key][dtvar].sel(scenario=scn,␣
↪time=slice(year,year))-  dic_ds[key][dtvar].sel(scenario=scn,␣
↪time=slice(ref_year,ref_year)).squeeze()
                tab.loc[tabvar,key][year]=_tab_da.squeeze().
↪mean('climatemodel').values
    scntab_dic[scn]=tab.copy()
```

```
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
```

[52]:

```
from IPython.display import display

for key in scntab_dic:
    display(scntab_dic[key])
```

```
                                  ECS = 2K                          \
                                      2040                    2100
ssp119
CH4                    -0.02659828770048701     -0.1296912754447551
Aerosols                0.15646387941855683      0.2249195956185493
Tropospheric Ozone     -0.04992508208229368    -0.10048092297791049
HFC                    0.003468253587250494  -0.002976168491636381 7
BC on Snow            -0.011329101981495735    -0.01697901215240332

                                ECS = 3.4K                          \
                                      2040                  2100
ssp119
```

```
CH4                  -0.04470130480462069    -0.2179602423824401
Aerosols              0.26295450457415265     0.37800175385322743
Tropospheric Ozone   -0.08390451057176351    -0.16886907968150738
HFC                   0.005828775990740371  -0.005001773662750117
BC on Snow           -0.019039783558255186   -0.02853506985308847

                                ECS = 5K
                                    2040                    2100
ssp119
CH4                  -0.05744421069915064    -0.2800937051430452
Aerosols               0.3379143859685943      0.4857579099290342
Tropospheric Ozone   -0.10782299096099926    -0.2170082290929777
HFC                  0.0074903727663812964  -0.006427618643534087
BC on Snow           -0.024467414165359597   -0.03666950153066572


                                ECS = 2K                        \
                                    2040                    2100
ssp126
CH4                  -0.017367724889572122   -0.1231558283831311
Aerosols              0.12215597107108145     0.22774103852286798
Tropospheric Ozone  -0.033763352537327304  -0.09404727045262026
HFC                   0.011032221399586888  -0.00132423401564886
BC on Snow           -0.009436533713336538  -0.01532641975381759

                               ECS = 3.4K                       \
                                    2040                    2100
ssp126
CH4                  -0.02918834373076379    -0.20697671538153598
Aerosols              0.2052963468190799      0.3827434943996489
Tropospheric Ozone    -0.0567429727053181    -0.15805662942987894
HFC                  0.018540843568887466  -0.002225518763942189
BC on Snow            -0.0158591174954173   -0.025757709244058458

                                ECS = 5K
                                    2040                     2100
ssp126
CH4                  -0.03750900280333449     -0.2659791274586253
Aerosols              0.2638197398037043       0.4918513683687795
Tropospheric Ozone   -0.07291857125932286    -0.20311349664292128
HFC                   0.023826242414316925  -0.0028599426649754825
BC on Snow           -0.020380042392300957   -0.03310040463942353 5


                                ECS = 2K                        \
                                    2040                    2100
ssp245
CH4                   0.028937393882524302  -0.004182704112309194
Aerosols              0.03637900641138267     0.1367591718072312
```

```
Tropospheric Ozone  0.0009328311281484147  -0.039034660403500676
HFC                  0.018234694544699594   0.038451376778719744
BC on Snow          -0.003402782920874044  -0.012488796472324282

                                ECS = 3.4K                          \
                                      2040                    2100
ssp245
CH4                   0.04863242622082048  -0.007029487519546129
Aerosols              0.06113886248604996    0.22983860813230494
Tropospheric Ozone  0.0015677237971163881   -0.06560197679979962
HFC                   0.030645380185388666   0.06462170546081415
BC on Snow          -0.005718745441164742  -0.020988775820408107

                                ECS = 5K
                                      2040                    2100
ssp245
CH4                   0.06249596853716284  -0.009033368577154454
Aerosols              0.07856758799112298     0.2953582113555412
Tropospheric Ozone   0.002014631485887075   -0.08430299281060225
HFC                   0.039381393541404436   0.08304327760575213
BC on Snow          -0.007348976042039757  -0.026972001506768793

                                ECS = 2K                            \
                                      2040                    2100
ssp370
CH4                   0.05457162376258964    0.21565799113002856
Aerosols            -0.011068885443324872  -0.007421477076560101
Tropospheric Ozone    0.024602751780866523   0.06349719049159727
HFC                   0.01704878795819055    0.06493327819133399
BC on Snow          0.0036842324966297967   0.006754058664053657

                                ECS = 3.4K                          \
                                      2040                    2100
ssp370
CH4                     0.0917135273880785    0.36243662387632175
Aerosols            -0.018602461467488916  -0.012472596455663742
Tropospheric Ozone    0.041347590445410684      0.106713909495384
HFC                   0.028652335655970435    0.10912741049646246
BC on Snow            0.006191751952510926    0.01135092748863771

                                ECS = 5K
                                    2040                      2100
ssp370
CH4                   0.11785810759372976   0.46575566145192465
Aerosols            -0.02390542559623008  -0.01602813300184842
Tropospheric Ozone    0.05313446011989424   0.13713461672709976
HFC                   0.03682019604658643   0.14023612932577073
```

```
BC on Snow          0.007956821513633937  0.014586712247842122


                                        ECS = 2K                          \
                                            2040                    2100
ssp370-lowNTCF-aerchemmip
CH4                            0.05457162366753363      0.21565799026157
Aerosols                       0.06273291382163072   0.14244876622095556
Tropospheric Ozone          -0.0032062710739075963  0.012046389288997983
HFC                            0.01704878793732071    0.0649332767375719
BC on Snow                  -0.0037433274391409396  -0.00704176174526431

                                      ECS = 3.4K                          \
                                            2040                    2100
ssp370-lowNTCF-aerchemmip
CH4                            0.09171352722832657     0.3624366224167831
Aerosols                       0.10542945973064936    0.23940058809757553
Tropospheric Ozone          -0.005388485987327574    0.02024526260736541
HFC                              0.0286523356208964    0.10912740805325775
BC on Snow                  -0.006291067407225456  -0.011834443693562069

                                       ECS = 5K
                                            2040                    2100
ssp370-lowNTCF-aerchemmip
CH4                            0.11785810738843767     0.4657556595763185
Aerosols                       0.13548401159956747    0.30764600461407887
Tropospheric Ozone          -0.006924570228058991   0.026016536563311144
HFC                            0.03682019600151392    0.14023612618608688
BC on Snow                  -0.008084448613810082  -0.015208063389011895


                                    ECS = 2K                              \
                                        2040                        2100
ssp585
CH4                        0.044123353916243016     0.11489216246985463
Aerosols                   0.047101148762349374      0.0979238452792276
Tropospheric Ozone          0.01531662537912159    0.011390724974023542
HFC                        0.02710784418483706     0.14984300008060603
BC on Snow              -0.0018159626749880552  -0.0035326595202287737

                                    ECS = 3.4K                            \
                                        2040                        2100
ssp585
CH4                        0.07415407768433238    0.19308872932196103
Aerosols                   0.07915858461200927    0.16457163351109735
Tropospheric Ozone         0.025741248736014292    0.01914334767497496
HFC                        0.04555766969466912     0.2518273993750109
BC on Snow              -0.0030519220621472187  -0.005937017140460517
```

```
                                ECS = 5K
                                    2040                    2100
ssp585
CH4                   0.09529302290656273     0.24813212274858323
Aerosols              0.10172415398104348     0.21148571908213415
Tropospheric Ozone    0.03307925176935772    0.024600501084583216
HFC                    0.0585446977071766      0.3236153005543126
BC on Snow          -0.003921926993890548  -0.0076294699904560365


                                ECS = 2K                        \
                                    2040                    2100
historical
CH4                  0.0077132387149825565    0.02703927122654534
Aerosols             -0.009908627912094015   -0.04251408931871051
Tropospheric Ozone    0.005241636725860588    0.01849257773823193
HFC                  0.0007444353141619498  0.0017742750627926067
BC on Snow                             nan                    nan

                               ECS = 3.4K                       \
                                    2040                    2100
historical
CH4                   0.012962933505788199   0.045442425407349996
Aerosols             -0.016652522954926197    -0.0714495341401904
Tropospheric Ozone    0.008809138527872185   0.031078780837636932
HFC                  0.0012511042161961299  0.0029818615123738887
BC on Snow                             nan                    nan

                                ECS = 5K
                                    2040                    2100
historical
CH4                   0.016658249392053515      0.058396600975961
Aerosols              -0.02139962225881925   -0.09181750088603652
Tropospheric Ozone    0.011320340913645699    0.03993834279587727
HFC                  0.0016077538343877845  0.0038318944321908757
BC on Snow                             nan                    nan
```

2.7.2 Make table with all scenarios:

[40]:
```
iterables = [list(ECS2ecsf.keys()), years]
iterables2 = [scenarios_fl, [var.split('|')[-1] for var in variables_erf_comp]]

def setup_table2():#scenario_n=''):
    _i = pd.MultiIndex.from_product(iterables, names=['', ''])
    _r = pd.MultiIndex.from_product(iterables2, names=['', ''])
```

```
    table = pd.DataFrame(columns=_r, index = _i).transpose()
    return table
```

[55]:
```
tab = setup_table2()#scenario_n=scn)

for scn in scenarios_fl:
    for var in variables_erf_comp:
        tabvar = var.split('|')[-1]
        dtvar = new_varname(var,name_deltaT)
        print(dtvar)
        for key in ECS2ecsf:
            for year in years:
                # compute difference between year and ref year
                _da_y = dic_ds[key][dtvar].sel(scenario=scn,␣
 ↪time=slice(year,year))#.squeeze()
                _da_refy = dic_ds[key][dtvar].sel(scenario=scn,␣
 ↪time=slice(ref_year,ref_year)).squeeze()
                #_tab_da = dic_ds[key][dtvar].sel(scenario=scn,␣
 ↪time=slice(year,year))-  dic_ds[key][dtvar].sel(scenario=scn,␣
 ↪time=slice(ref_year,ref_year)).squeeze()
                _tab_da = _da_y - _da_refy

                tab.loc[(scn, tabvar), (key,year)] =_tab_da.squeeze().
 ↪mean('climatemodel').values#[0]
```

```
Delta T|Anthropogenic|CH4
Delta T|Anthropogenic|Aerosols
Delta T|Anthropogenic|Tropospheric Ozone
Delta T|Anthropogenic|F-Gases|HFC
Delta T|Anthropogenic|Other|BC on Snow
Delta T|Anthropogenic|CH4
Delta T|Anthropogenic|Aerosols
Delta T|Anthropogenic|Tropospheric Ozone
Delta T|Anthropogenic|F-Gases|HFC
Delta T|Anthropogenic|Other|BC on Snow
Delta T|Anthropogenic|CH4
Delta T|Anthropogenic|Aerosols
Delta T|Anthropogenic|Tropospheric Ozone
Delta T|Anthropogenic|F-Gases|HFC
Delta T|Anthropogenic|Other|BC on Snow
Delta T|Anthropogenic|CH4
Delta T|Anthropogenic|Aerosols
Delta T|Anthropogenic|Tropospheric Ozone
Delta T|Anthropogenic|F-Gases|HFC
Delta T|Anthropogenic|Other|BC on Snow
Delta T|Anthropogenic|CH4
Delta T|Anthropogenic|Aerosols
```

```
Delta T|Anthropogenic|Tropospheric Ozone
Delta T|Anthropogenic|F-Gases|HFC
Delta T|Anthropogenic|Other|BC on Snow
Delta T|Anthropogenic|CH4
Delta T|Anthropogenic|Aerosols
Delta T|Anthropogenic|Tropospheric Ozone
Delta T|Anthropogenic|F-Gases|HFC
Delta T|Anthropogenic|Other|BC on Snow
Delta T|Anthropogenic|CH4
Delta T|Anthropogenic|Aerosols
Delta T|Anthropogenic|Tropospheric Ozone
Delta T|Anthropogenic|F-Gases|HFC
Delta T|Anthropogenic|Other|BC on Snow
```

```
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
/home/sarambl/miniconda3/envs/rcmip_ipcc/lib/python3.7/site-
packages/xarray/core/nanops.py:142: RuntimeWarning: Mean of empty slice
  return np.nanmean(a, axis=axis, dtype=dtype)
```

[56]:
```
tab
```

[56]:
```
                                               ECS = 2K  \
                                                   2040


ssp119               CH4                 -0.02659828770048701
                     Aerosols             0.15646387941855683
                     Tropospheric Ozone  -0.04992508208229368
                     HFC                  0.003468253587250494
                     BC on Snow          -0.011329101981495735
ssp126               CH4                 -0.017367724889572122
                     Aerosols             0.12215597107108145
                     Tropospheric Ozone  -0.033763352537327304
                     HFC                  0.011032221399586888
                     BC on Snow          -0.009436533713336538
```

```
ssp245                     CH4                    0.028937393882524302
                           Aerosols                0.03637900641138267
                           Tropospheric Ozone     0.0009328311281484147
                           HFC                     0.018234694544699594
                           BC on Snow            -0.003402782920874044
ssp370                     CH4                     0.05457162376258964
                           Aerosols               -0.011068885443324872
                           Tropospheric Ozone      0.024602751780866523
                           HFC                     0.01704878795819055
                           BC on Snow             0.0036842324966297967
ssp370-lowNTCF-aerchemmip CH4                      0.05457162366753363
                           Aerosols                0.06273291382163072
                           Tropospheric Ozone    -0.0032062710739075963
                           HFC                     0.01704878793732071
                           BC on Snow            -0.0037433274391409396
ssp585                     CH4                     0.044123353916243016
                           Aerosols                0.047101148762349374
                           Tropospheric Ozone      0.01531662537912159
                           HFC                     0.02710784418483706
                           BC on Snow            -0.0018159626749880552
historical                 CH4                    0.0077132387149825565
                           Aerosols               -0.009908627912094015
                           Tropospheric Ozone      0.005241636725860588
                           HFC                    0.0007444353141619498
                           BC on Snow                                nan

                                                                        \
                                                                  2100

ssp119                     CH4                     -0.1296912754447551
                           Aerosols                 0.2249195956185493
                           Tropospheric Ozone      -0.10048092297791049
                           HFC                    -0.0029761684916363817
                           BC on Snow              -0.01697901215240332
ssp126                     CH4                     -0.1231558283831311
                           Aerosols                 0.22774103852286798
                           Tropospheric Ozone      -0.09404727045262026
                           HFC                     -0.00132423401564886
                           BC on Snow              -0.01532641975381759
ssp245                     CH4                    -0.004182704112309194
                           Aerosols                  0.1367591718072312
                           Tropospheric Ozone     -0.039034660403500676
                           HFC                     0.038451376778719744
                           BC on Snow             -0.012488796472324282
ssp370                     CH4                     0.21565799113002856
                           Aerosols               -0.007421477076560101
                           Tropospheric Ozone      0.06349719049159727
```

```
                          HFC                    0.06493327819133399
                          BC on Snow             0.006754058664053657
ssp370-lowNTCF-aerchemmip CH4                      0.21565799026157
                          Aerosols               0.14244876622095556
                          Tropospheric Ozone     0.012046389288997983
                          HFC                     0.0649332767375719
                          BC on Snow             -0.00704176174526431
ssp585                    CH4                     0.11489216246985463
                          Aerosols                0.0979238452792276
                          Tropospheric Ozone     0.011390724974023542
                          HFC                     0.14984300008060603
                          BC on Snow            -0.0035326595202287737
historical                CH4                     0.02703927122654534
                          Aerosols               -0.04251408931871051
                          Tropospheric Ozone      0.01849257773823193
                          HFC                    0.0017742750627926067
                          BC on Snow                              nan

                                                          ECS = 3.4K  \
                                                                2040

ssp119                    CH4                    -0.04470130480462069
                          Aerosols                0.26295450457415265
                          Tropospheric Ozone     -0.08390451057176351
                          HFC                     0.005828775990740371
                          BC on Snow             -0.019039783558255186
ssp126                    CH4                    -0.02918834373076379
                          Aerosols                0.2052963468190799
                          Tropospheric Ozone      -0.0567429727053181
                          HFC                     0.018540843568887466
                          BC on Snow              -0.0158591174954173
ssp245                    CH4                     0.04863242622082048
                          Aerosols                0.06113886248604996
                          Tropospheric Ozone    0.0015677237971163881
                          HFC                     0.030645380185388666
                          BC on Snow             -0.005718745441164742
ssp370                    CH4                      0.0917135273880785
                          Aerosols               -0.018602461467488916
                          Tropospheric Ozone      0.041347590445410684
                          HFC                     0.028652335655970435
                          BC on Snow              0.006191751952510926
ssp370-lowNTCF-aerchemmip CH4                     0.09171352722832657
                          Aerosols                0.10542945973064936
                          Tropospheric Ozone    -0.005388485987327574
                          HFC                      0.0286523356208964
                          BC on Snow             -0.006291067407225456
ssp585                    CH4                     0.07415407768433238
```

	Aerosols	0.07915858461200927
	Tropospheric Ozone	0.025741248736014292
	HFC	0.04555766969466912
	BC on Snow	-0.0030519220621472187
historical	CH4	0.012962933505788199
	Aerosols	-0.016652522954926197
	Tropospheric Ozone	0.008809138527872185
	HFC	0.0012511042161961299
	BC on Snow	nan

		2100
ssp119	CH4	-0.2179602423824401
	Aerosols	0.37800175385322743
	Tropospheric Ozone	-0.16886907968150738
	HFC	-0.005001773662750117
	BC on Snow	-0.02853506985308847
ssp126	CH4	-0.20697671538153598
	Aerosols	0.3827434943996489
	Tropospheric Ozone	-0.15805662942987894
	HFC	-0.002225518763942189
	BC on Snow	-0.025757709244058458
ssp245	CH4	-0.007029487519546129
	Aerosols	0.22983860813230494
	Tropospheric Ozone	-0.06560197679979962
	HFC	0.06462170546081415
	BC on Snow	-0.020988775820408107
ssp370	CH4	0.36243662387632175
	Aerosols	-0.012472596455663742
	Tropospheric Ozone	0.106713909495384
	HFC	0.10912741049646246
	BC on Snow	0.01135092748863771
ssp370-lowNTCF-aerchemmip	CH4	0.3624366224167831
	Aerosols	0.23940058809757553
	Tropospheric Ozone	0.02024526260736541
	HFC	0.10912740805325775
	BC on Snow	-0.011834443693562069
ssp585	CH4	0.19308872932196103
	Aerosols	0.16457163351109735
	Tropospheric Ozone	0.01914334767497496
	HFC	0.2518273993750109
	BC on Snow	-0.005937017140460517
historical	CH4	0.045442425407349996
	Aerosols	-0.0714495341401904
	Tropospheric Ozone	0.031078780837636932
	HFC	0.0029818615123738887

```
                           BC on Snow                          nan

                                                          ECS = 5K  \
                                                               2040

ssp119                     CH4                  -0.05744421069915064
                           Aerosols               0.3379143859685943
                           Tropospheric Ozone   -0.10782299096099926
                           HFC                 0.0074903727663812964
                           BC on Snow          -0.024467414165359597
ssp126                     CH4                  -0.03750900280333449
                           Aerosols               0.2638197398037043
                           Tropospheric Ozone   -0.07291857125932286
                           HFC                  0.023826242414316925
                           BC on Snow          -0.020380042392300957
ssp245                     CH4                   0.06249596853716284
                           Aerosols              0.07856758799112298
                           Tropospheric Ozone   0.002014631485887075
                           HFC                   0.039381393541404436
                           BC on Snow          -0.007348976042039757
ssp370                     CH4                   0.11785810759372976
                           Aerosols             -0.02390542559623008
                           Tropospheric Ozone    0.05313446011989424
                           HFC                   0.03682019604658643
                           BC on Snow           0.007956821513633937
ssp370-lowNTCF-aerchemmip CH4                    0.11785810738843767
                           Aerosols              0.13548401159956747
                           Tropospheric Ozone  -0.006924570228058991
                           HFC                   0.03682019600151392
                           BC on Snow          -0.008084448613810082
ssp585                     CH4                   0.09529302290656273
                           Aerosols              0.10172415398104348
                           Tropospheric Ozone    0.03307925176935772
                           HFC                    0.0585446977071766
                           BC on Snow          -0.003921926993890548
historical                 CH4                  0.016658249392053515
                           Aerosols            -0.02139962225881925
                           Tropospheric Ozone   0.011320340913645699
                           HFC                 0.0016077538343877845
                           BC on Snow                          nan


                                                               2100

ssp119                     CH4                    -0.2800937051430452
                           Aerosols                0.4857579099290342
                           Tropospheric Ozone     -0.2170082290929777
```

	HFC	-0.006427618643534087
	BC on Snow	-0.03666950153066572
ssp126	CH4	-0.2659791274586253
	Aerosols	0.4918513683687795
	Tropospheric Ozone	-0.20311349664292128
	HFC	-0.0028599426649754825
	BC on Snow	-0.033100404639423535
ssp245	CH4	-0.009033368577154454
	Aerosols	0.2953582113555412
	Tropospheric Ozone	-0.08430299281060225
	HFC	0.08304327760575213
	BC on Snow	-0.026972001506768793
ssp370	CH4	0.46575566145192465
	Aerosols	-0.01602813300184842
	Tropospheric Ozone	0.13713461672709976
	HFC	0.14023612932577073
	BC on Snow	0.014586712247842122
ssp370-lowNTCF-aerchemmip	CH4	0.4657556595763185
	Aerosols	0.30764600461407887
	Tropospheric Ozone	0.026016536563311144
	HFC	0.14023612618608688
	BC on Snow	-0.015208063389011895
ssp585	CH4	0.24813212274858323
	Aerosols	0.21148571908213415
	Tropospheric Ozone	0.024600501084583216
	HFC	0.3236153005543126
	BC on Snow	-0.0076294699904560365
historical	CH4	0.058396600975961
	Aerosols	-0.09181750088603652
	Tropospheric Ozone	0.03993834279587727
	HFC	0.0038318944321908757
	BC on Snow	nan

2.8 Save output

[57]:
```
tab.to_csv(PATH_DT_OUTPUT)
```