TROPICS_Climatology

November 18, 2021

```
In [1]: import os, sys
        import numpy as np
        import h5netcdf

        import xarray as xr
        import xarray.ufuncs as xu
        import pandas as pd

        from matplotlib import pyplot as plt
        from matplotlib import colors
        import cartopy.crs as ccrs
        import cartopy

        plt.rc("figure", figsize=(18,8))
        plt.rc("font", size=14)
        ccrs.PlateCarree()

        from dask.distributed import Client, LocalCluster
        cluster = LocalCluster(processes=False, n_workers=1, threads_per_worker=8)
        client = Client(cluster)
        client
```

```
/home/durandy/miniconda3/envs/towel/lib/python3.9/site-packages/distributed/node.py:160: UserWa
Perhaps you already have a cluster running?
Hosting the HTTP server on port 45145 instead
  warnings.warn(
```

```
Out[1]: <Client: 'inproc://137.129.155.67/53079/1' processes=1 threads=8, memory=78.61 GiB>
```

1 Méthodes

1.1 Comparaison entre la climatologie NO-Smothed et la climatologie Smothed

1.1.1 Notation

Décompostion d'un variable On peut décomposer une variable X de cette façon :

$$X = \overline{x} + x^{*}\overline{x} \text{ est la moyenne et } x^{*} \text{ est l'anomalie.} \quad (1)$$

Méthode de calcul pour $\overline{x}$

$\overline{x} = \frac{\sum_{i=1}^{n_j} x_i}{n_j}$ j de 1 à 12 ou de 1 à 4, μ la moyenne mensuelle ou saisonière, n le nombre de pas de temps $n_j = nbAnn$ (2)

et

$< \overline{x}_y >_h = FiltreHarmonique(\overline{x})$ $\overline{x}$ est la moyenne brute, y la période et h le nombre d'harmonique gardée. (3)

2 Objectifs

On souhaite vérifier la climatologie pour différente valeurs de h et de y, plus spécifiquempent pour la période Toucan de 2012 à 2016.

In [2]:
```
indir_smot = '/cnrm/tropics/commun/DATACOMMUN/WAVE/NO_SAVE/DATA/SMOTHED_CLIM/'
indir_brut = '/cnrm/tropics/commun/DATACOMMUN/WAVE/NO_SAVE/DATA/RAW_CLIM/'
output_fig = '/cnrm/tropics/commun/DATACOMMUN/WAVE/RAPPORT/FIGURES/CLIM/'

var = 'tcwv'

ds_brut = xr.open_mfdataset(indir_brut+'clim_tcwv_brut_ERA5_3H_2012_2016.nc', chunks =
ds_smot = xr.open_mfdataset(indir_smot+'*'+var+'*2020.nc', chunks = {'time' : 1}, paral
ds_smot_3h = xr.open_mfdataset(indir_smot+'*'+var+'*2020_3harm.nc', chunks = {'time' :
ds_smot = ds_smot_3h
ds_smot_4h = xr.open_mfdataset(indir_smot+'*'+var+'*2020_4harm.nc', chunks = {'time' :

ds_brut = ds_brut.sel(latitude = slice(40.1,-40.1))
ds_smot = ds_smot.sel(latitude = slice(40.1,-40.1))

ds_smot_T_3h = xr.open_dataset(indir_smot + 'clim_tcwv_smooth_ERA5_3H_2012_2016_3harm.n
ds_smot_T_4h = xr.open_dataset(indir_smot + 'clim_tcwv_smooth_ERA5_3H_2012_2016_4harm.n
ds_smot_T_5h = xr.open_dataset(indir_smot + 'clim_tcwv_smooth_ERA5_3H_2012_2016_5harm.n
```

In [13]:
```
### Suppresion du biais entre les deux climatologies, (30 ans et Toucan)
# _mean_diff_ds = ds_smot_T_3h.mean('time') - ds_smot_3h.mean('time')
# _ds_smot_T_3h = (ds_smot_T_3h - _mean_diff_ds).load()
# _ds_smot_T_3h.to_netcdf(indir_smot + 'clim_tcwv_smooth_ERA5_3H_2012_2016_3harm_with
```

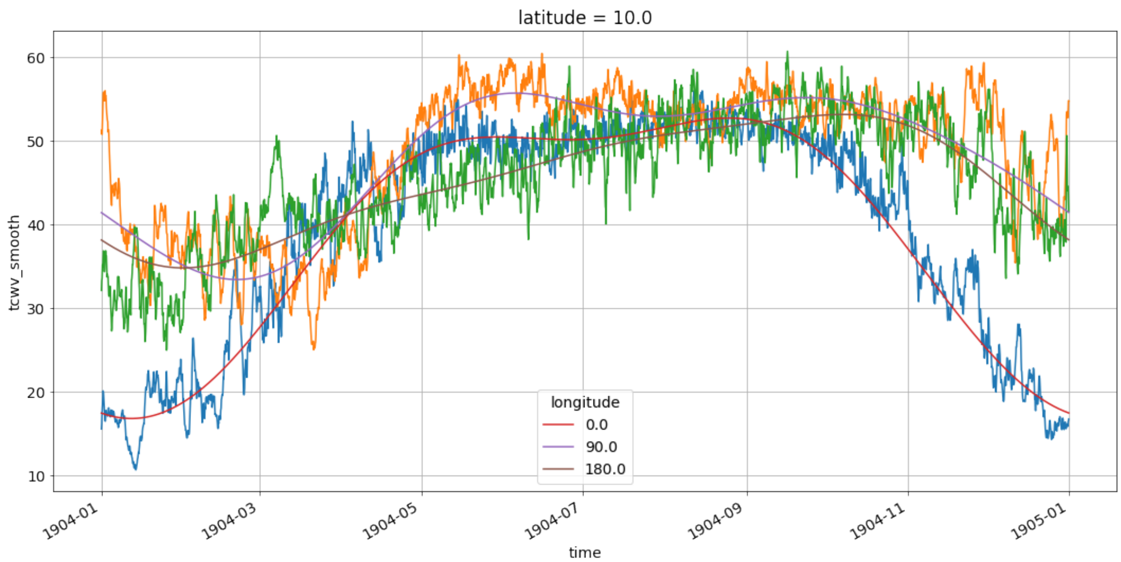
3 Verification 1D entre les données brutes et les données smoothed

Cette vérification est faite sur trois points du globe, Afrique, Océan Indien et Océan Pacifique

$$Y_{plot} = \overline{x_{2012-2016}} Y_{plot} = < \overline{x}_y >_h \quad (4)$$

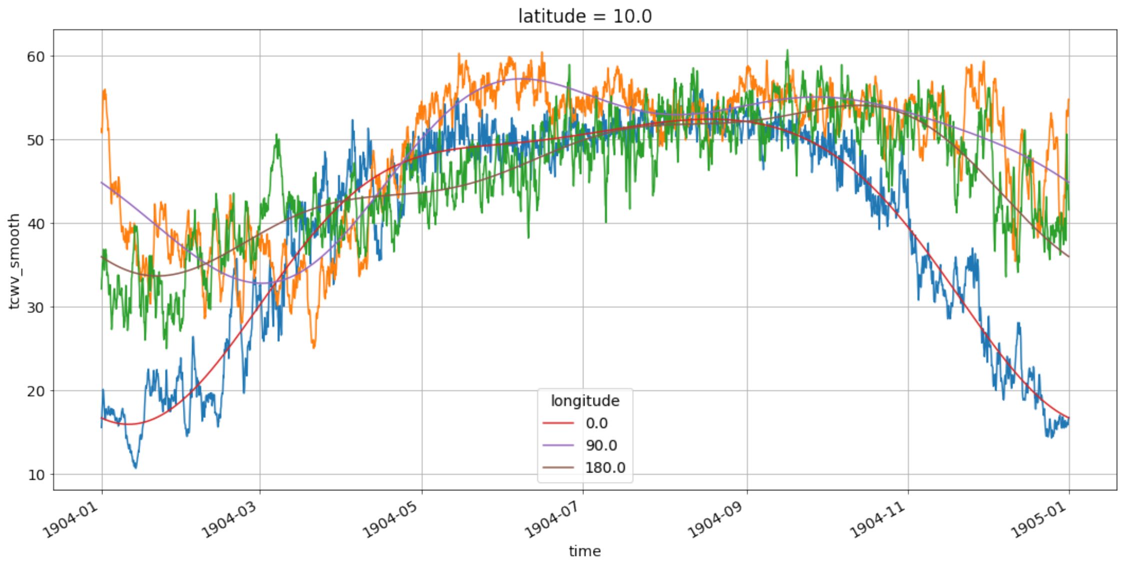
$$< \overline{x}_{30} >_3 = FiltreHarmonique(\overline{x}) \quad (5)$$

In [3]:
```
latitude = 10
longitude = [0, 90, 180]

plt.figure()
ds_brut['tcwv'].sel(latitude = latitude, longitude = longitude).plot(hue='longitude')
ds_smot['tcwv_smooth'].sel(latitude = latitude, longitude = longitude).plot(hue='longi
plt.grid()
# plt.legend()
plt.show()
```



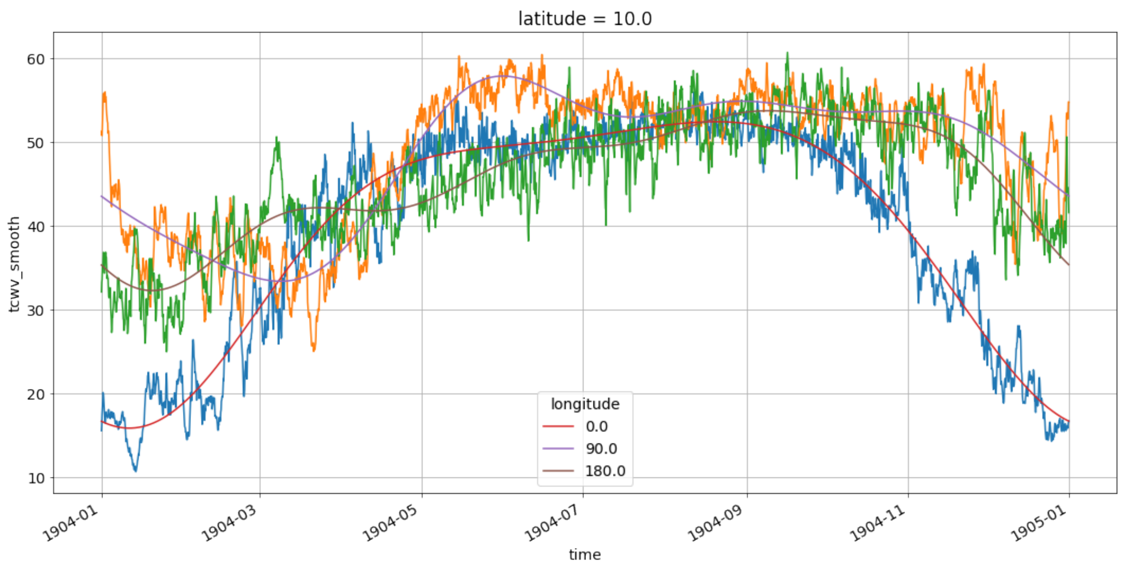
$$< \overline{x}_T >_3 = FiltreHarmonique(\overline{x}) \quad (6)$$

In [4]:
```
latitude = 10
longitude = [0, 90, 180]

plt.figure()
ds_brut['tcwv'].sel(latitude = latitude, longitude = longitude).plot(hue='longitude')
ds_smot_T_3h['tcwv_smooth'].sel(latitude = latitude, longitude = longitude).plot(hue='l
plt.grid()
# plt.legend()
plt.show()
```



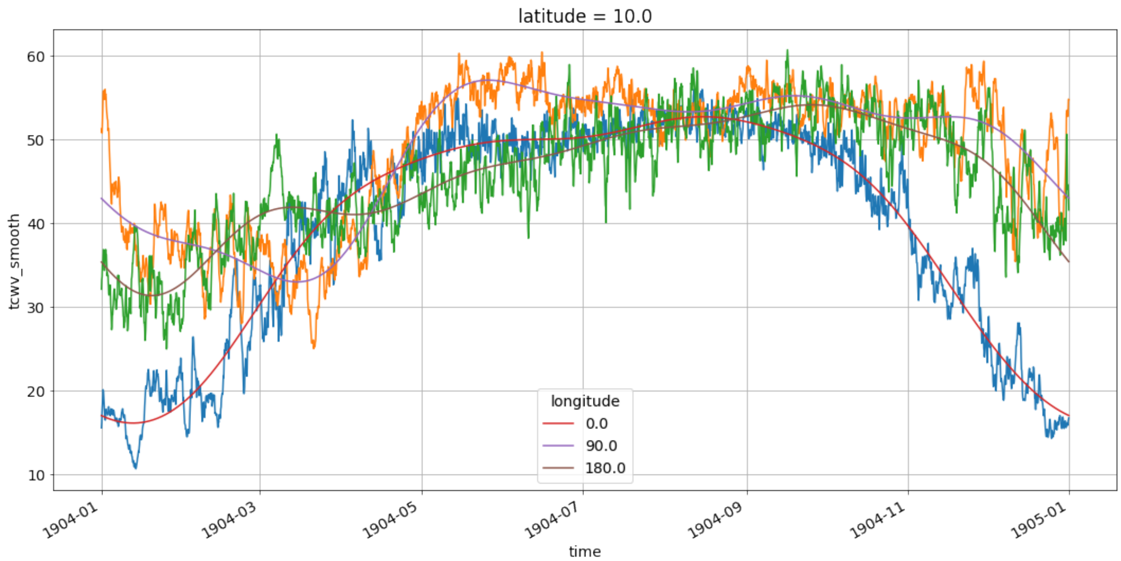
$$< \overline{x}_T >_4 = FiltreHarmonique(\overline{x}) \tag{7}$$

In [5]:
```
latitude = 10
longitude = [0, 90, 180]

plt.figure()
ds_brut['tcwv'].sel(latitude = latitude, longitude = longitude).plot(hue='longitude')
ds_smot_T_4h['tcwv_smooth'].sel(latitude = latitude, longitude = longitude).plot(hue='
plt.grid()
# plt.legend()
plt.show()
```



$$< \overline{x}_T >_5 = FiltreHarmonique(\overline{x}) \quad (8)$$

```
In [6]: latitude = 10
        longitude = [0, 90, 180]

        plt.figure()
        ds_brut['tcwv'].sel(latitude = latitude, longitude = longitude).plot(hue='longitude')
        ds_smot_T_5h['tcwv_smooth'].sel(latitude = latitude, longitude = longitude).plot(hue='l
        plt.grid()
        # plt.legend()
        plt.show()
```



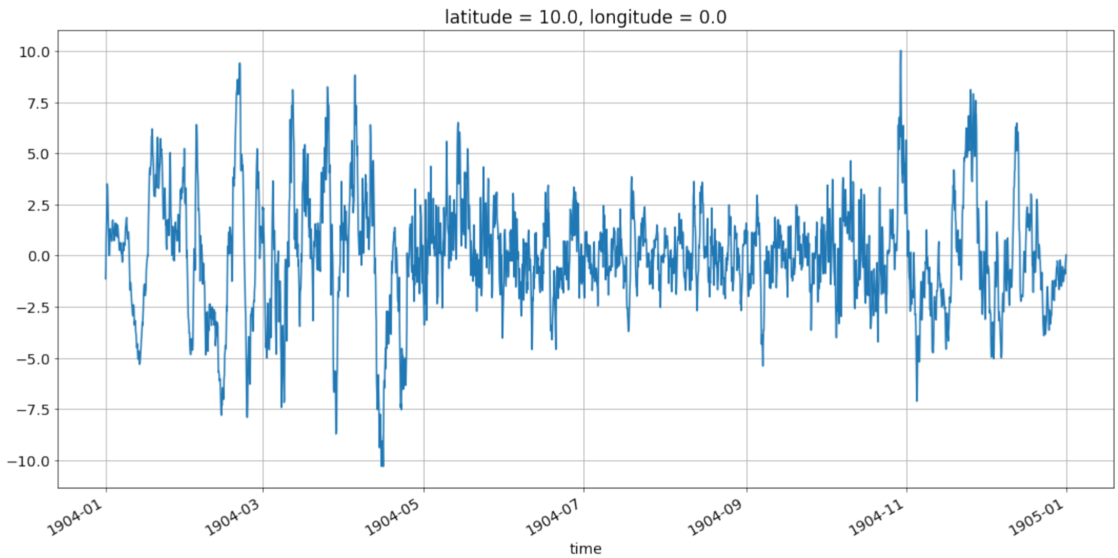
On plot la différence entre la climatologie brute et la climatologie smoothed

$$Y_{plot} = \overline{x} - < \overline{x}_y >_h \quad (9)$$

$$Y_{plot} = \overline{x} - < \overline{x}_T >_3 \quad (10)$$

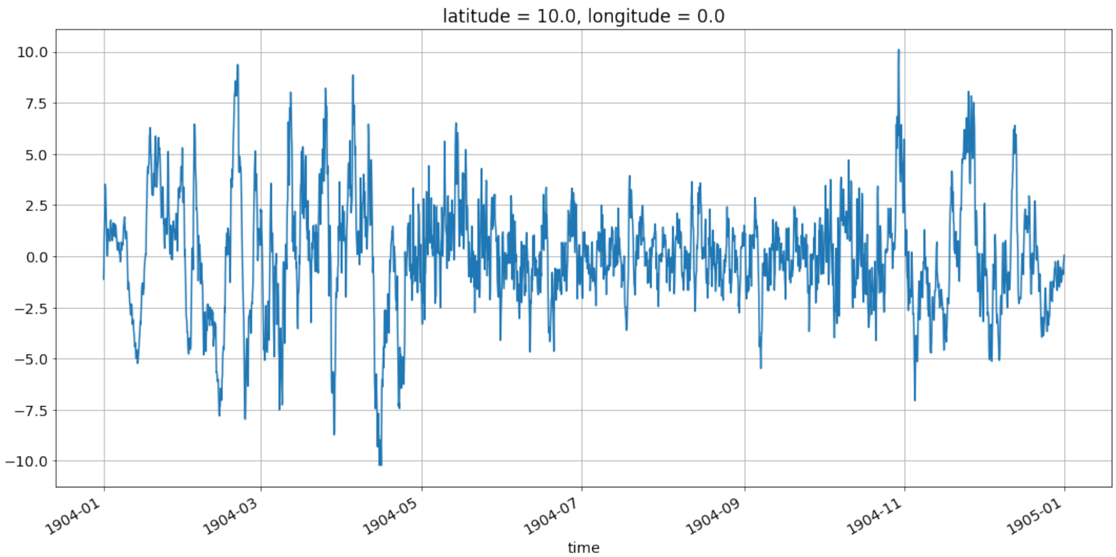
```
In [7]: latitude = 10
        longitude = 0
        brut = ds_brut['tcwv'].sel(latitude = 10, longitude = longitude, method = 'nearest').co

        diff = brut - ds_smot_T_3h['tcwv_smooth'].sel(latitude = latitude, longitude = longitu

        plt.figure()
```

```
diff.plot(hue='longitude')
plt.grid()
# plt.legend()
plt.show()
```



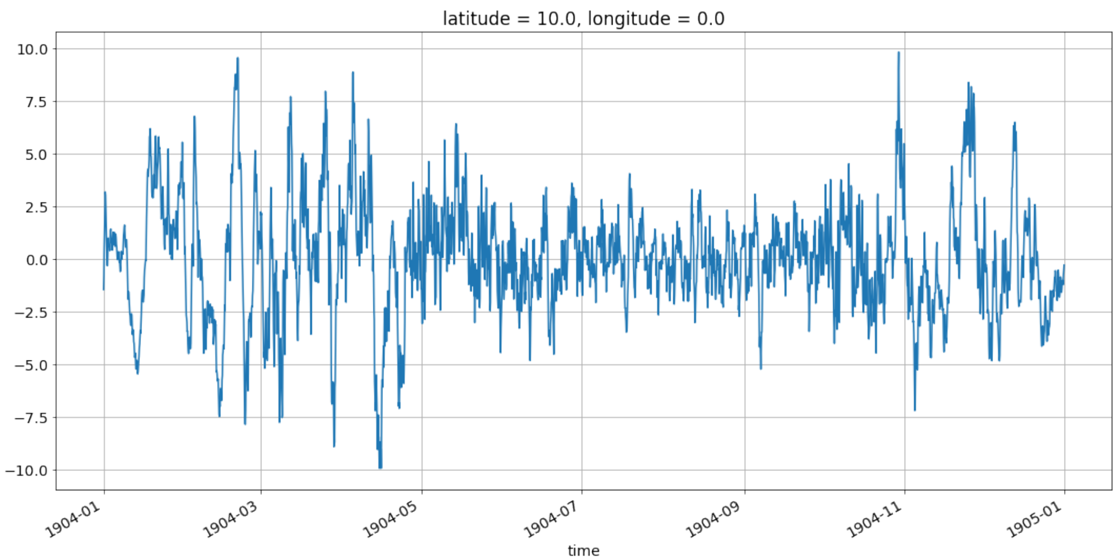
$$Y_{plot} = \overline{x} - < \overline{x}_T >_4 \tag{11}$$

```
In [8]: diff = brut - ds_smot_T_4h['tcwv_smooth'].sel(latitude = latitude, longitude = longitu

        plt.figure()
        diff.plot(hue='longitude')
        plt.grid()
        # plt.legend()
        plt.show()
```



$$Y_{plot} = \overline{x} - < \overline{x}_T >_5 \tag{12}$$

In [9]:
```
diff = brut - ds_smot_T_5h['tcwv_smooth'].sel(latitude = latitude, longitude = longitu

plt.figure()
diff.plot(hue='longitude')
plt.grid()
# plt.legend()
plt.show()
```



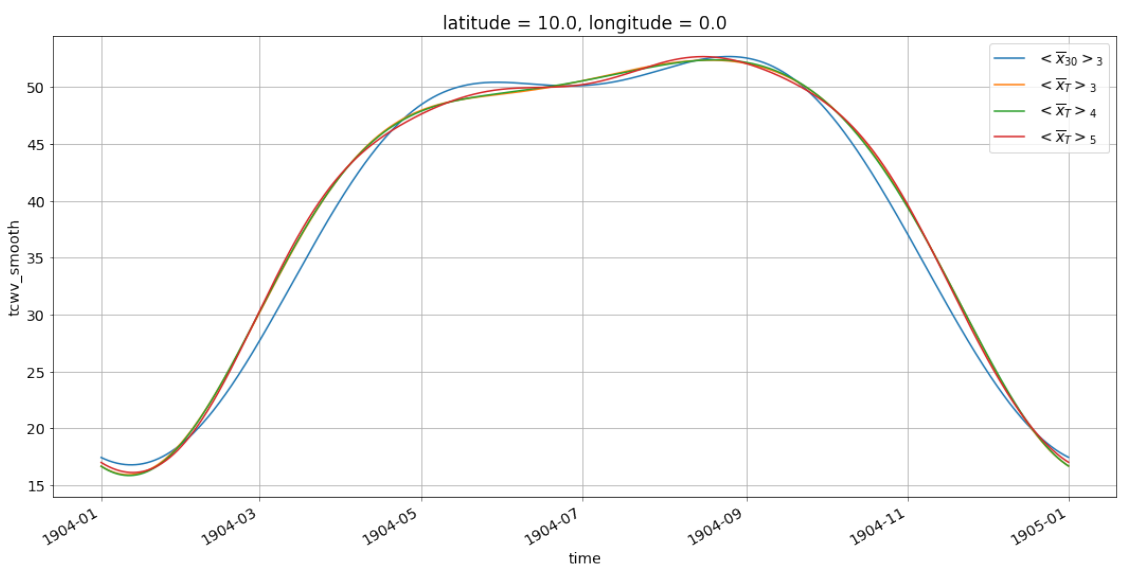
3.1 Comparaison entre les différentes climatologies

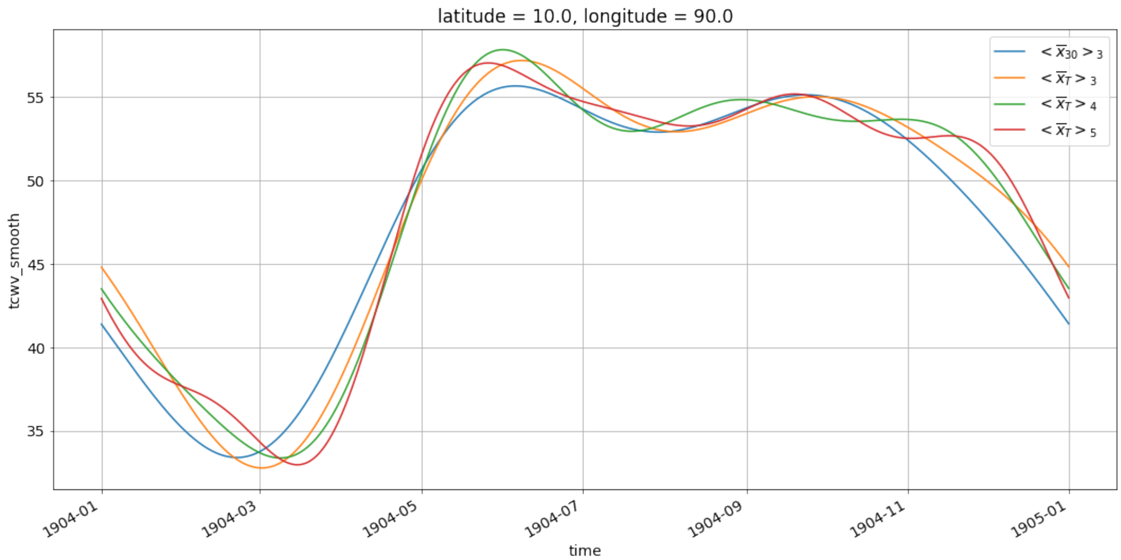
On plot sur un même graphe les différentes climatologies

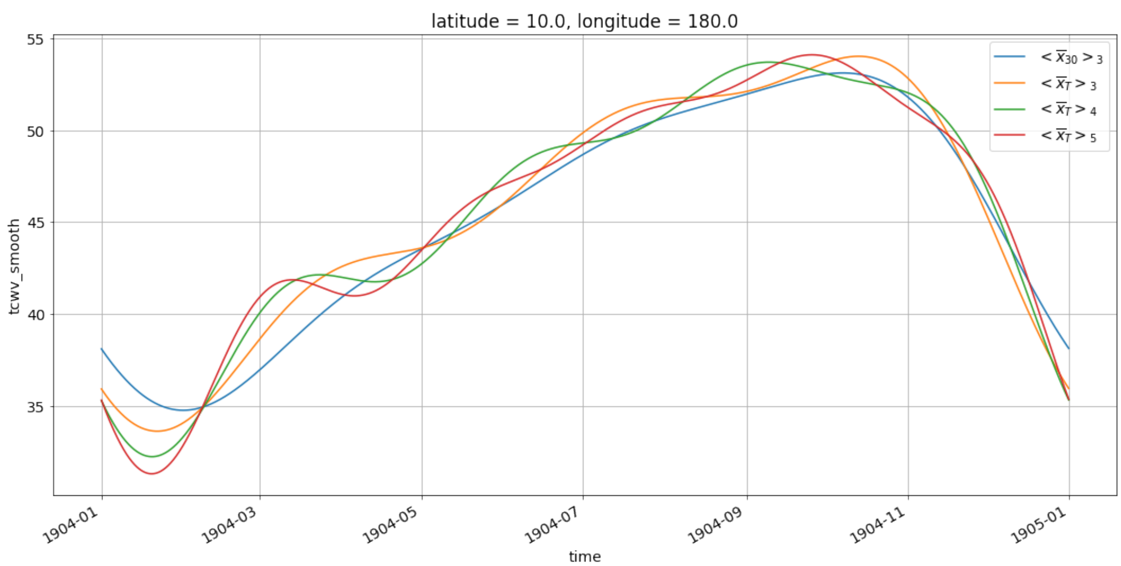
$$Y_{plot} =< \overline{x}_{30} >_3 Y_{plot} =< \overline{x}_T >_3 Y_{plot} =< \overline{x}_T >_4 Y_{plot} =< \overline{x}_T >_5 \tag{13}$$

```
In [10]: plt.figure()
         latitude = 10
         longitude = [0, 90, 180]
         for x in longitude :
             plt.figure()
             ds_smot_3h['tcwv_smooth'].sel(latitude = latitude, longitude = x).plot(label = '$
         #     ds_smot_4h['tcwv_smooth'].sel(latitude = latitude, longitude = x).plot(label =
             ds_smot_T_3h['tcwv_smooth'].sel(latitude = latitude, longitude = x).plot(label =
             ds_smot_T_4h['tcwv_smooth'].sel(latitude = latitude, longitude = x).plot(label =
             ds_smot_T_5h['tcwv_smooth'].sel(latitude = latitude, longitude = x).plot(label =
             plt.grid()
             plt.legend()
             plt.show()
```

```
<Figure size 1296x576 with 0 Axes>
```





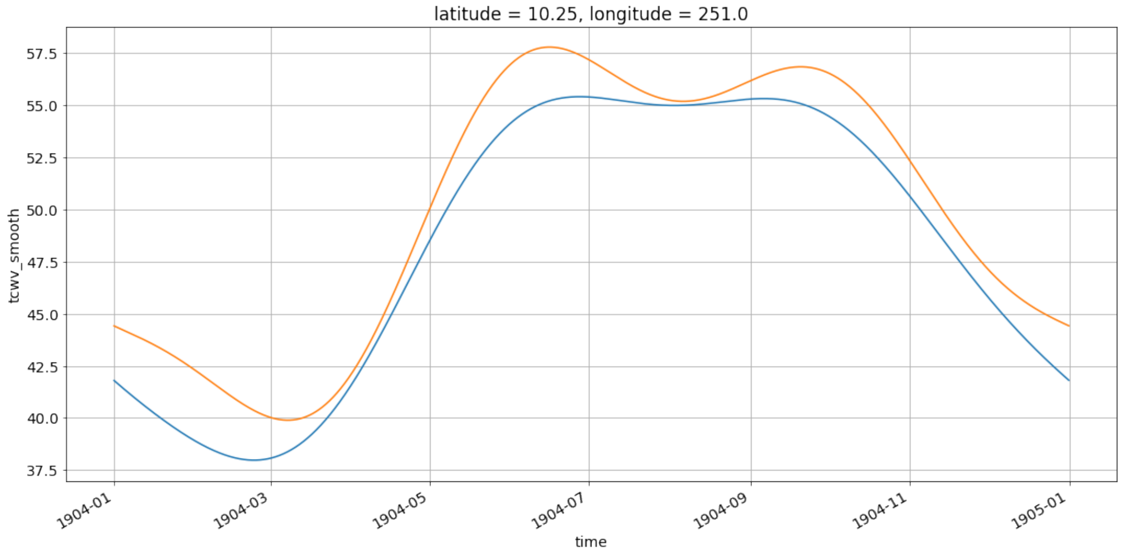


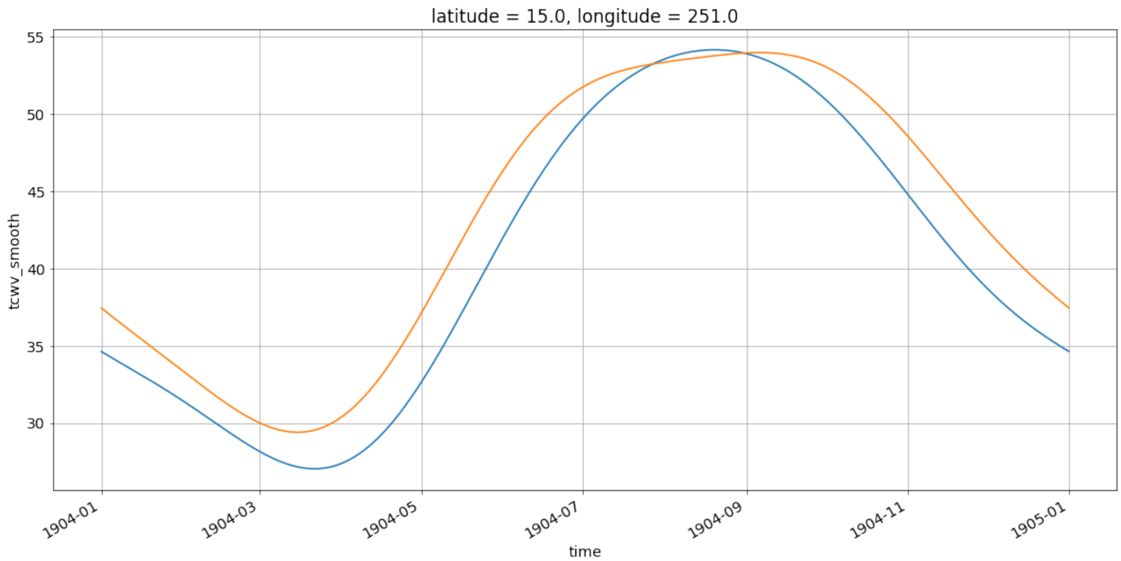
4 Comparaison des climatologies entre celle de 30 ans et celle de TOUCAN.

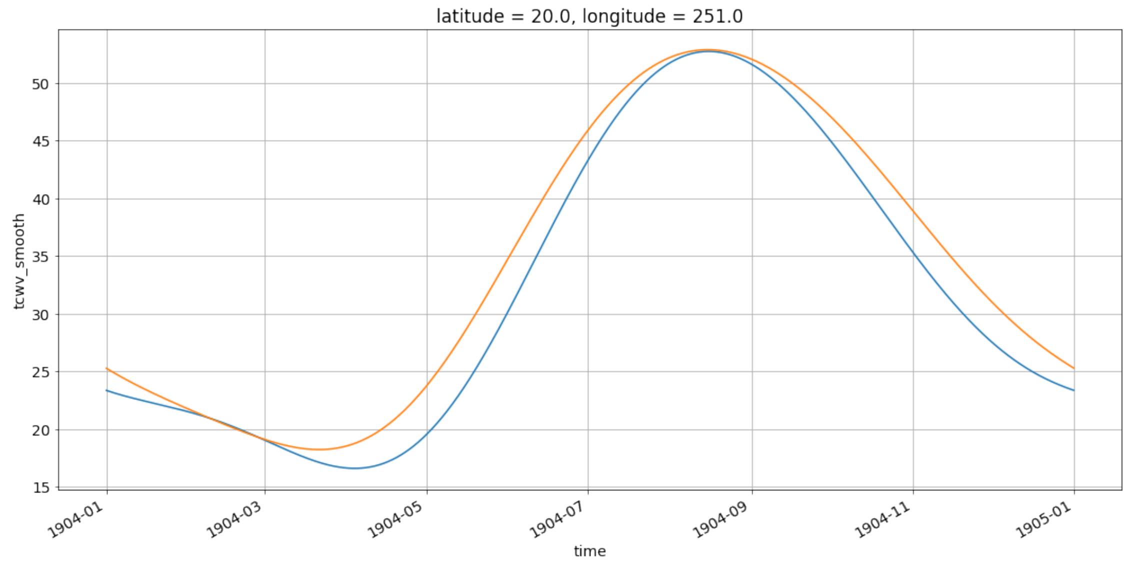
4.1 Elle est réalisé au large de la Californie, au lieu ou il y avait le plus de différence. On remarque qu'il existe un biais.

In [4]:
```
latitude = [10.3, 15, 20]
longitude = 251
```

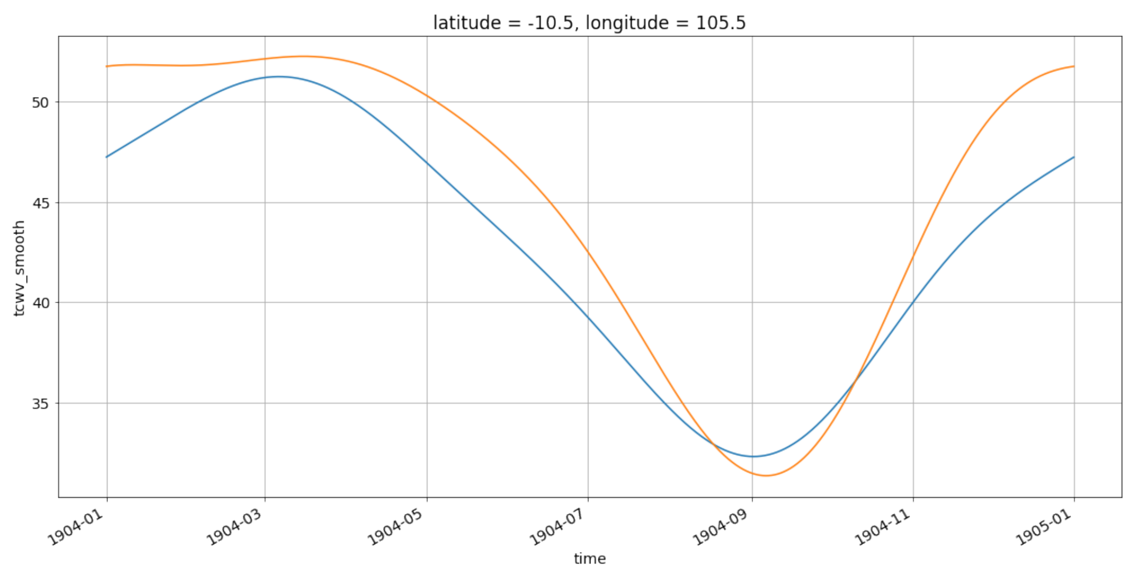
```
for i in latitude :
    plt.figure()
    ds_smot['tcwv_smooth'].sel(latitude = i, longitude = longitude, method = 'nearest')
    ds_smot_T_3h['tcwv_smooth'].sel(latitude = i, longitude = longitude, method = 'nea

    # ds_smot_T_5h['tcwv_smooth'].sel(latitude = latitude, longitude = longitude).plot
    plt.grid()
    # plt.legend()
    plt.show()
```

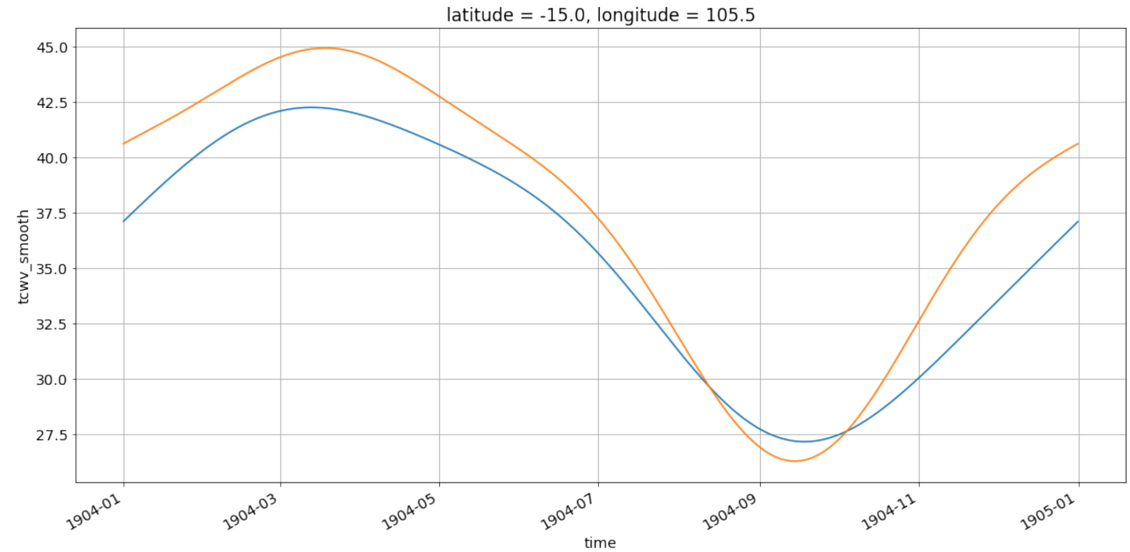


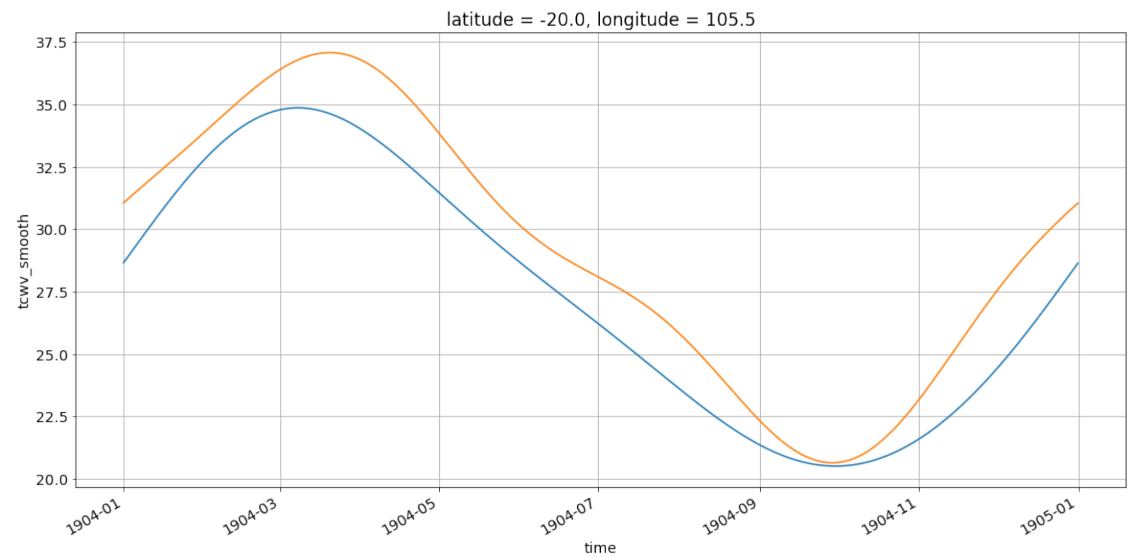




In [12]:
```
latitude = [-10.53, -15, -20] #First Christmas Isle
longitude = 105.62

for i in latitude :
    plt.figure()
    ds_smot['tcwv_smooth'].sel(latitude = i, longitude = longitude, method = 'nearest
    ds_smot_T_3h['tcwv_smooth'].sel(latitude = i, longitude = longitude, method = 'nea

    # ds_smot_T_5h['tcwv_smooth'].sel(latitude = latitude, longitude = longitude).plo
    plt.grid()
    # plt.legend()
    plt.show()
```





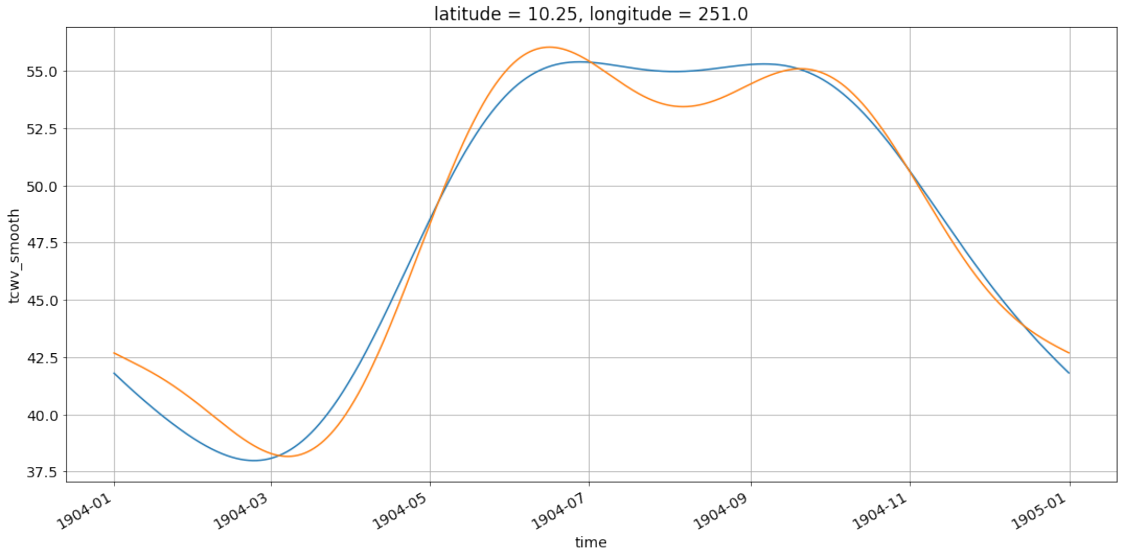


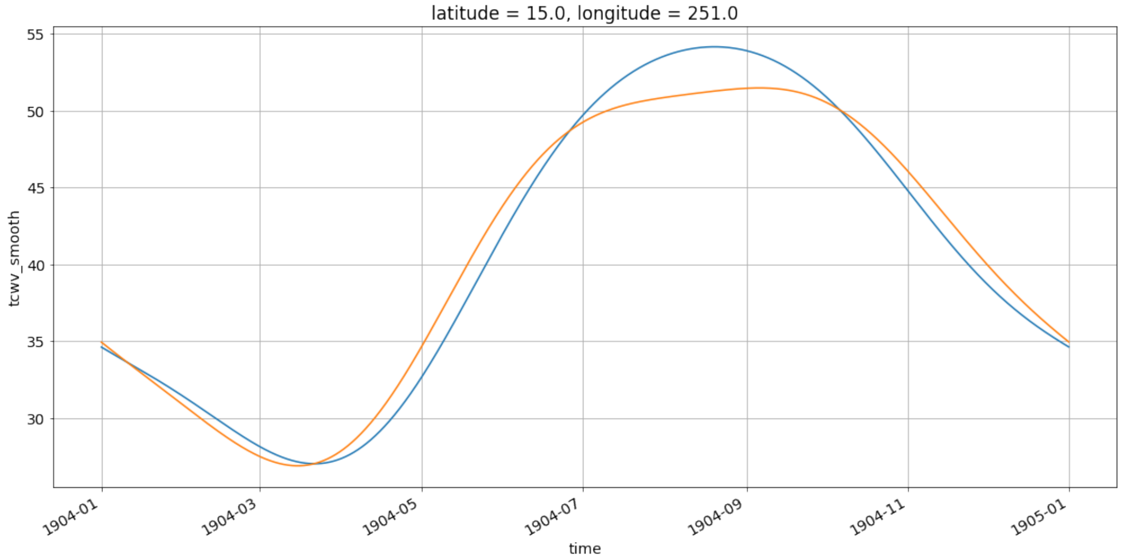
5 On soustrais le biais sur la climatologie de la période TOUCAN

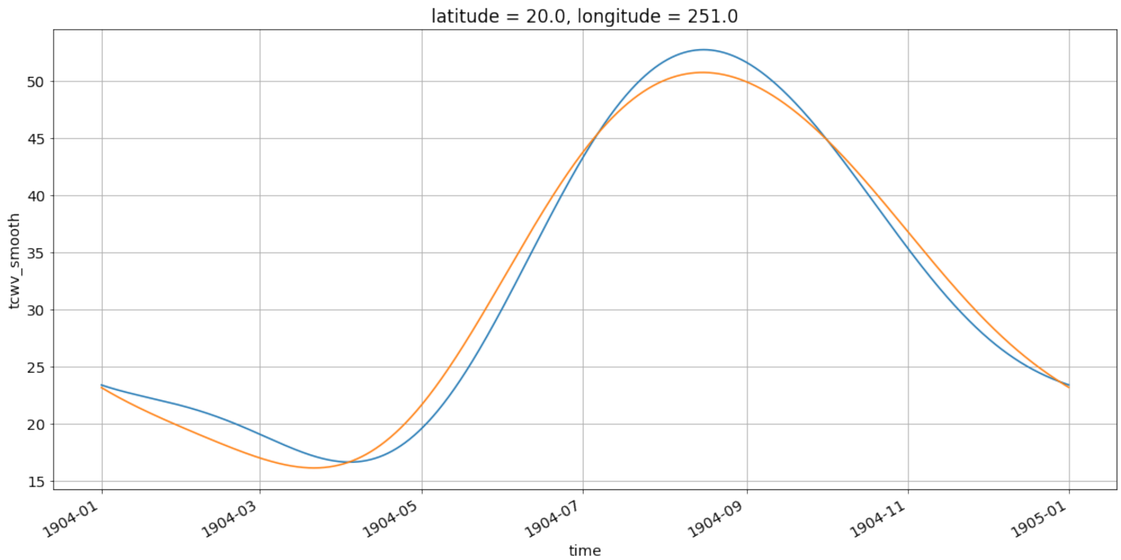
$$< \overline{x}_T >_3 = < \overline{x}_T >_3 - biais \tag{14}$$

In [8]:
```
latitude = [10.3, 15, 20]
longitude = 251
```

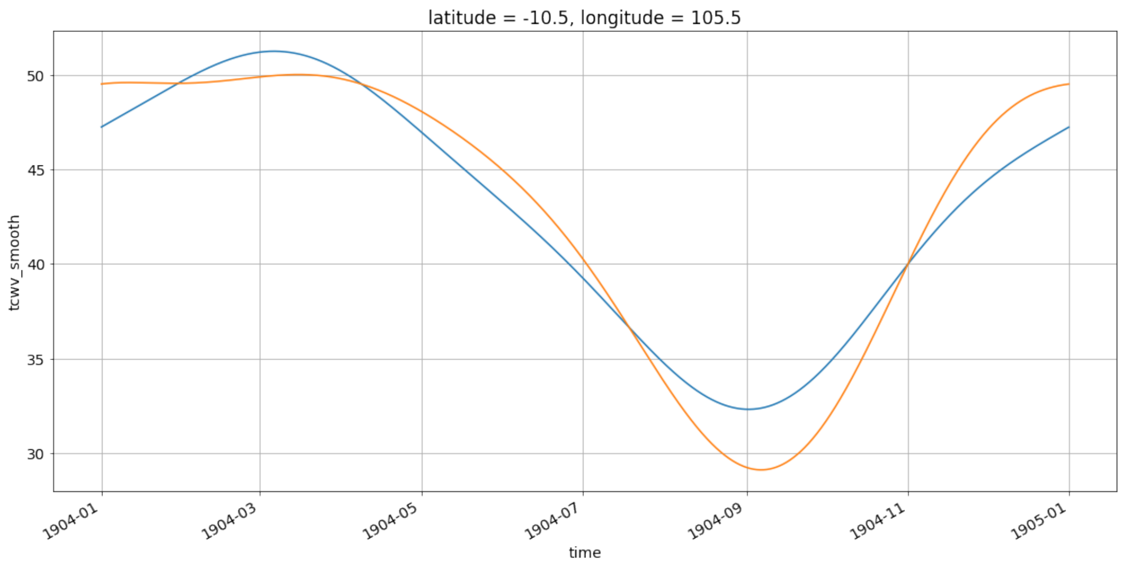
```
for i in latitude :
    plt.figure()
    ds_smot['tcwv_smooth'].sel(latitude = i, longitude = longitude, method = 'nearest')
    _ds_smot_T_3h['tcwv_smooth'].sel(latitude = i, longitude = longitude, method = 'nea

    # ds_smot_T_5h['tcwv_smooth'].sel(latitude = latitude, longitude = longitude).plot
    plt.grid()
    # plt.legend()
    plt.show()
```

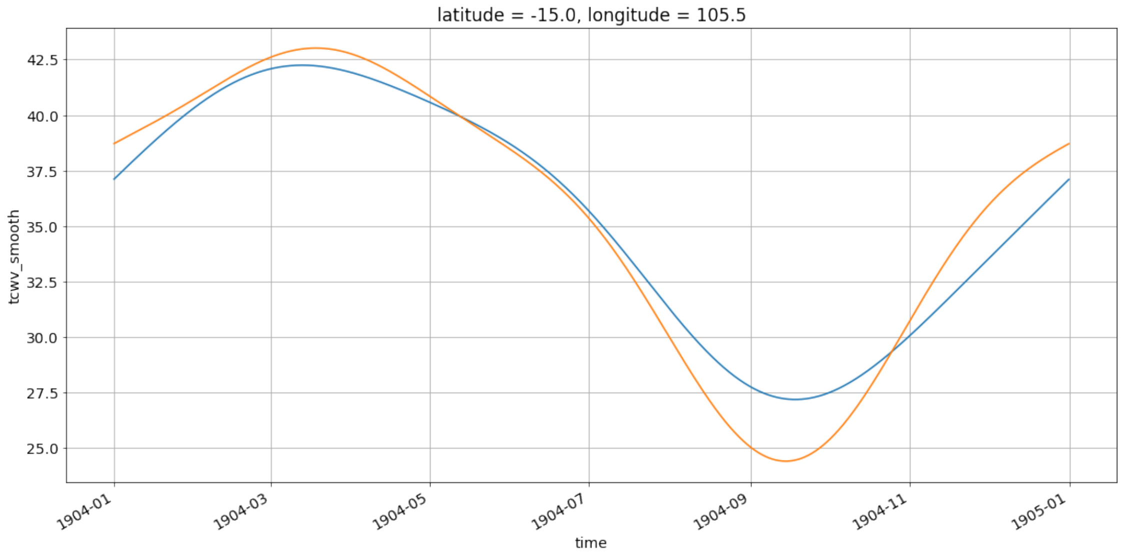


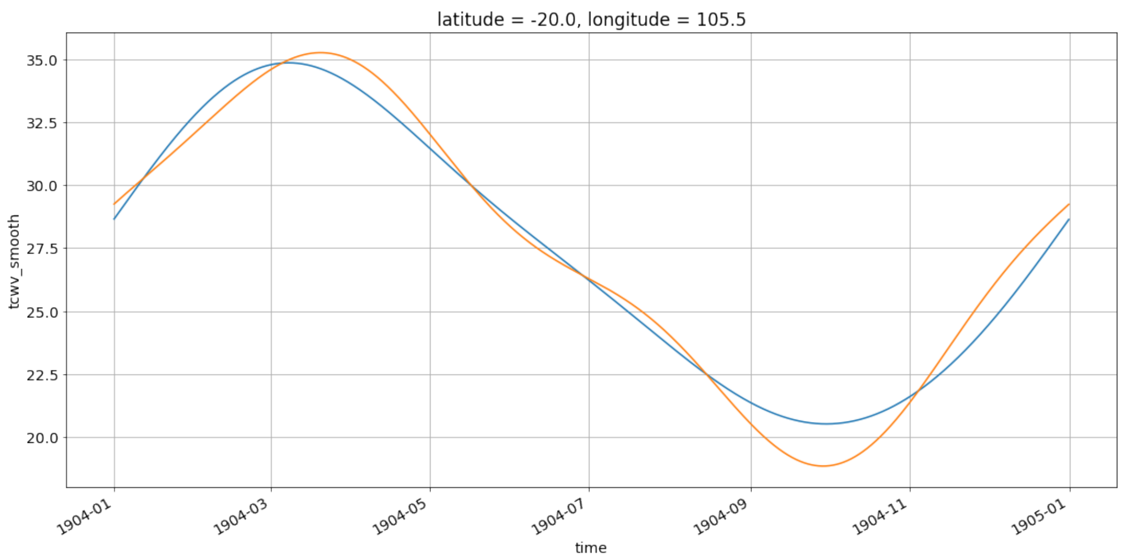





```
In [11]: latitude = [-10.53, -15, -20] #First Christmas Isle
         longitude = 105.62

         for i in latitude :
             plt.figure()
             ds_smot['tcwv_smooth'].sel(latitude = i, longitude = longitude, method = 'nearest
             _ds_smot_T_3h['tcwv_smooth'].sel(latitude = i, longitude = longitude, method = 'ne

             # ds_smot_T_5h['tcwv_smooth'].sel(latitude = latitude, longitude = longitude).plo
             plt.grid()
             # plt.legend()
             plt.show()
```





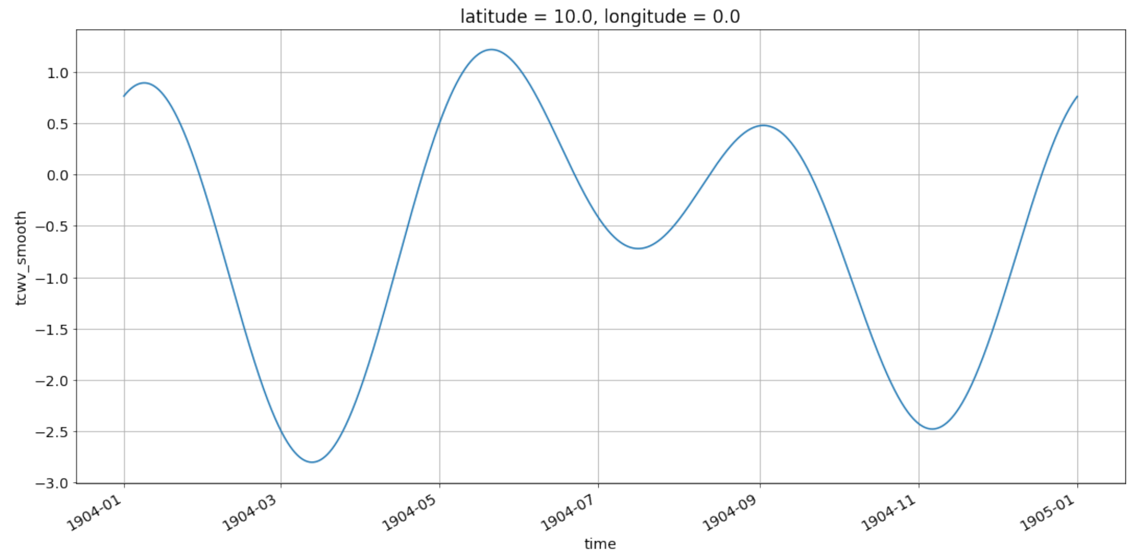


6 PWc - PWl

$$Y_{plot} = < \overline{x}_{30} >_3 - < \overline{x}_T >_h \tag{15}$$

$$Y_{plot} = < \overline{x}_{30} >_3 - < \overline{x}_T >_3 \tag{16}$$

```
In [11]: latitude = 10
         longitude = 0

         ds_smot_S = ds_smot.sel(latitude = latitude, longitude = longitude, method = 'nearest

         diff = ds_smot_S['tcwv_smooth'] - ds_smot_T_3h['tcwv_smooth'].sel(latitude = latitude

         plt.figure()
         diff.plot.line()
         plt.grid()
         # plt.legend()
         plt.show()
         diff
```



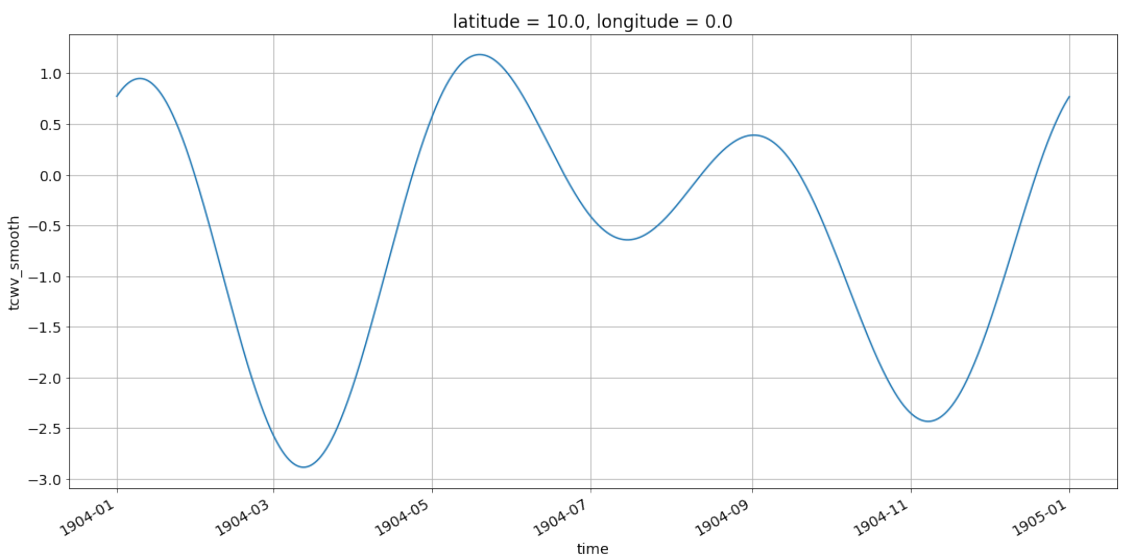

```
Out[11]: <xarray.DataArray 'tcwv_smooth' (time: 2928)>
         dask.array<subtract, shape=(2928,), dtype=float64, chunksize=(1,), chunktype=numpy.nda
         Coordinates:
             latitude   float32 10.0
             longitude  float32 0.0
           * time       (time) datetime64[ns] 1904-01-01 ... 1904-12-31T21:00:00
```

```
In [ ]: latitude = 10
        longitude = 0

        ds_smot_S = ds_smot.sel(latitude = latitude, longitude = longitude, method = 'nearest')

        diff = ds_smot_S['tcwv_smooth'] - _ds_smot_T_3h['tcwv_smooth'].sel(latitude = latitude

        plt.figure()
```

```
diff.plot.line()
plt.grid()
# plt.legend()
plt.show()
diff
```

$$Y_{plot} = < \overline{x}_{30} >_3 - < \overline{x}_T >_4 \tag{17}$$

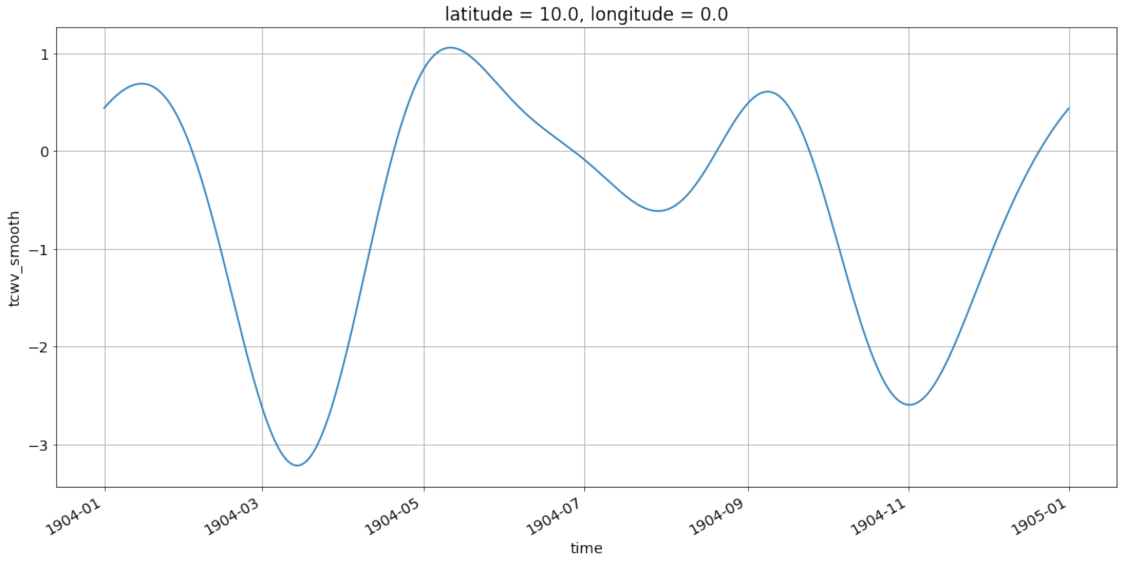
```
In [12]: latitude = 10
         longitude = 0

         diff = ds_smot_S['tcwv_smooth'] - ds_smot_T_4h['tcwv_smooth'].sel(latitude = latitude

         plt.figure()
         diff.plot(hue='longitude')
         plt.grid()
         # plt.legend()
         plt.show()
```



$$Y_{plot} = < \overline{x}_{30} >_3 - < \overline{x}_T >_5 \tag{18}$$

```
In [13]: latitude = 10
         longitude = 0

         diff = ds_smot_S['tcwv_smooth'] - ds_smot_T_5h['tcwv_smooth'].sel(latitude = latitude

         plt.figure()
         diff.plot(hue='longitude')
```

```
plt.grid()
# plt.legend()
plt.show()
```

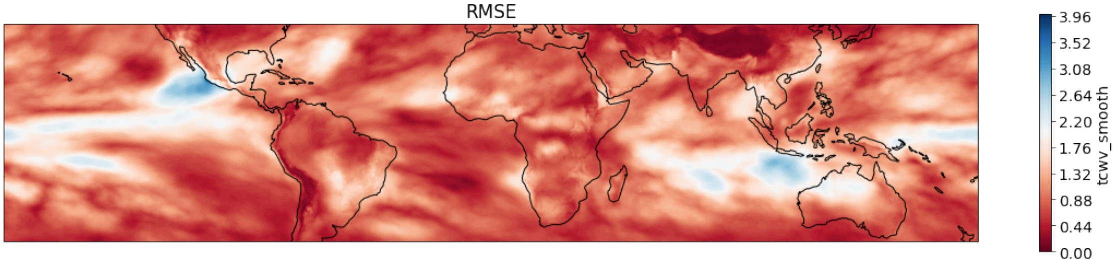


7 Verification 2D

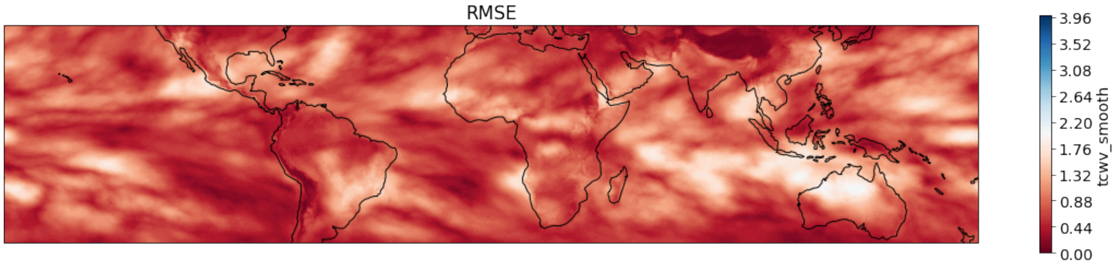
$$RMSE = \sqrt{\frac{\sum_{i=1}^{n_j} (< \overline{x}_{30} >_3 - < \overline{x}_T >_3)^2}{n_j}} \tag{19}$$

j de 1 à 12 ou de 1 à 4, μ la moyenne mensuelle ou saisonière, n le nombr

```
In [9]: err2 = xu.square(ds_smot - ds_smot_T_3h)
        err_tot = err2.sum('time')
        RMSE = xu.sqrt(err_tot/ds_smot.time.size)
        RMSE

        varPlot = RMSE['tcwv_smooth'].load()

        plt.figure(figsize=(20,4))
        ax = plt.axes(projection=ccrs.PlateCarree())
        p = varPlot.plot.contourf(levels = 101, vmax = 4,vmin = 0, cmap='RdBu')
        #                                                      cbar_kwargs=colorbar)
        ax.coastlines()
        plt.title("RMSE")
        plt.show()
```



In [10]:
```
err2 = xu.square(ds_smot - _ds_smot_T_3h)
err_tot = err2.sum('time')
RMSE = xu.sqrt(err_tot/ds_smot.time.size)
RMSE

varPlot = RMSE['tcwv_smooth'].load()

plt.figure(figsize=(20,4))
ax = plt.axes(projection=ccrs.PlateCarree())
p = varPlot.plot.contourf(levels = 101, vmax = 4,vmin = 0, cmap='RdBu')
#                                                 cbar_kwargs=colorbar)
ax.coastlines()
plt.title("RMSE")
plt.show()
```



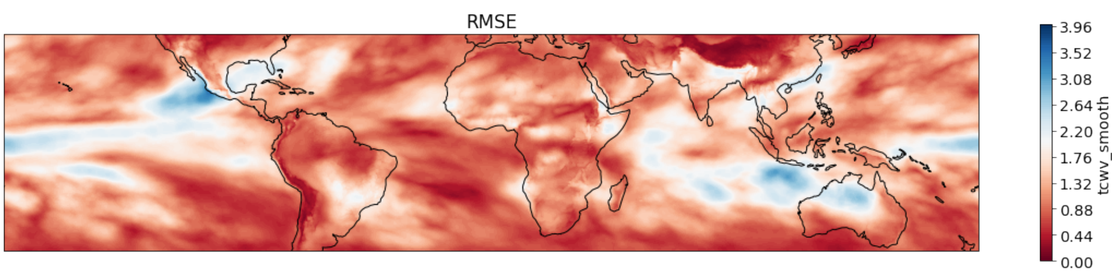
$$RMSE = \sqrt{\frac{\sum_{i=1}^{n_j} (<\overline{x}_{30}>_3 - <\overline{x}_T>_4)^2}{n_j}} j \text{ de 1 à 12 ou de 1 à 4, } \mu \text{ la moyenne mensuelle ou saisonière, n le nombre} \tag{20}$$

In [16]:
```
err2 = xu.square(ds_smot - ds_smot_T_4h)
err_tot = err2.sum('time')
```

```
        RMSE = xu.sqrt(err_tot/ds_smot.time.size)
        RMSE
```

```
Out[16]: <xarray.Dataset>
         Dimensions:      (latitude: 321, longitude: 1440)
         Coordinates:
           * latitude     (latitude) float32 40.0 39.75 39.5 39.25 ... -39.5 -39.75 -40.0
           * longitude    (longitude) float32 0.0 0.25 0.5 0.75 ... 359.2 359.5 359.8
         Data variables:
             tcwv_smooth  (latitude, longitude) float64 dask.array<chunksize=(321, 1440), meta=
```

```
In [17]: varPlot = RMSE['tcwv_smooth'].load()

         plt.figure(figsize=(20,4))
         ax = plt.axes(projection=ccrs.PlateCarree())
         p = varPlot.plot.contourf(levels = 101, vmax = 4,vmin = 0, cmap='RdBu')
         #                                                        cbar_kwargs=colorbar)
         ax.coastlines()
         plt.title("RMSE")
         plt.show()
```



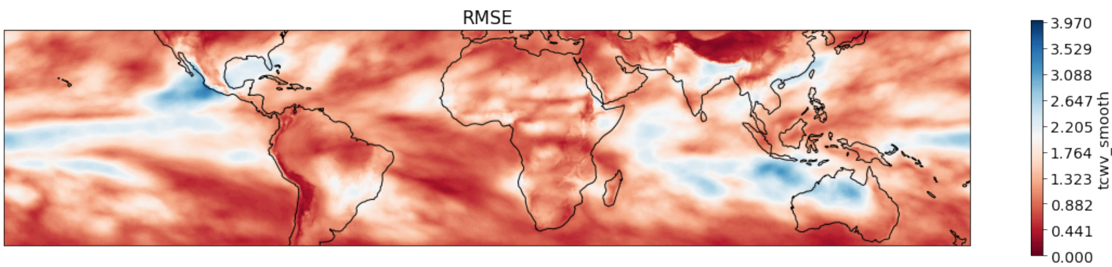
$$RMSE = \sqrt{\frac{\sum_{i=1}^{n_j} (< \bar{x}_{30} >_3 - < \bar{x}_T >_5)^2}{n_j}} j \text{ de 1 à 12 ou de 1 à 4, } \mu \text{ la moyenne mensuelle ou saisonière, n le nombre} \quad (21)$$

```
In [18]: err2 = xu.square(ds_smot - ds_smot_T_5h)
         err_tot = err2.sum('time')
         RMSE = xu.sqrt(err_tot/ds_smot.time.size)
         RMSE
```

```
Out[18]: <xarray.Dataset>
         Dimensions:      (latitude: 321, longitude: 1440)
```

```
Coordinates:
  * latitude     (latitude) float32 40.0 39.75 39.5 39.25 ... -39.5 -39.75 -40.0
  * longitude    (longitude) float32 0.0 0.25 0.5 0.75 ... 359.2 359.5 359.8
Data variables:
    tcwv_smooth  (latitude, longitude) float64 dask.array<chunksize=(321, 1440), meta=
```

```
In [19]: varPlot = RMSE['tcwv_smooth'].load()

         plt.figure(figsize=(20,4))
         ax = plt.axes(projection=ccrs.PlateCarree())
         p = varPlot.plot.contourf(levels = 101, vmax = 4.01,vmin = 0, cmap='RdBu')
         #                                                cbar_kwargs=colorbar)
         ax.coastlines()
         plt.title("RMSE")
         plt.show()
```



7.1 Carte global de PW en moyenne mensuelle

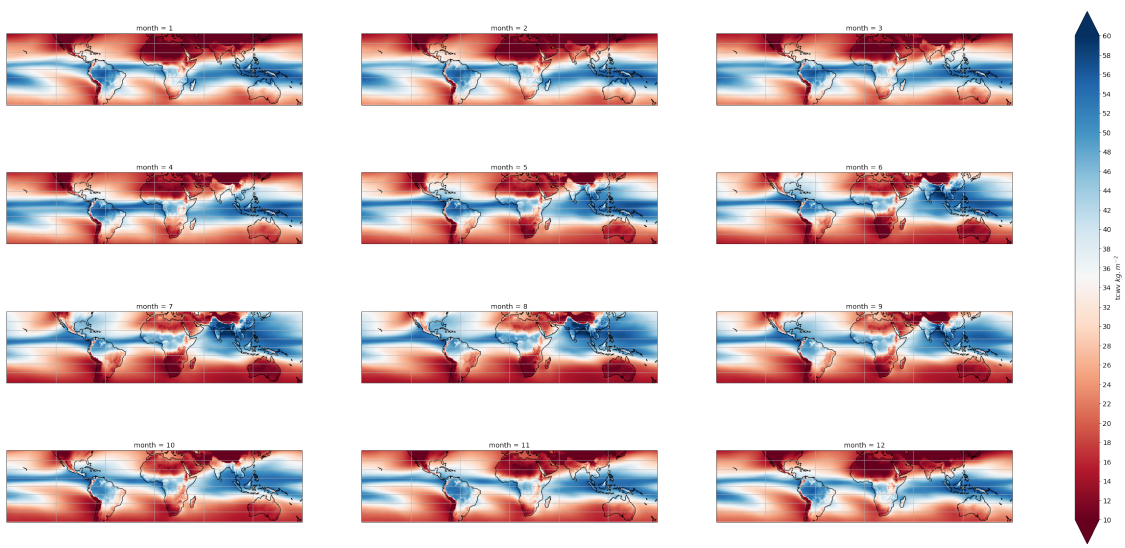
$$\overline{tcwv^*}_j = \frac{\sum_{i=1}^{n_j}(<\overline{x}_{30}>_3)_i}{n_j} = \mu_j^* j \text{ de 1 à 12 ou de 1 à 4, } \mu \text{ la moyenne mensuelle ou saisonière, n le nombre de pas d} \quad (22)$$

```
In [20]: ds_MMS = ds_smot.groupby('time.month').mean('time').load()
         ds_MSS = ds_smot.groupby('time.season').mean('time').load()

         ds_MMS_T = ds_smot_T_3h.groupby('time.month').mean('time').load()
         ds_MSS_T = ds_smot_T_3h.groupby('time.season').mean('time').load()

In [21]: #### Parameter for plotting
         colorbar = {'label': 'tcwv $kg.m^{-2}$',
                     'orientation': 'vertical' , 'ticks': np.arange(10.,60.1,2),
                     'extend' : 'both'}
         vmax = 60.
```

```
        vmin = 10.
        cmap ='RdBu'
        size = 5

        map_proj = ccrs.Mercator(central_longitude=0.0,
                                 min_latitude=-40.0,
                                 max_latitude=40.0,
                                 globe=None)
```

```
In [22]: # plt.figure(figsize = (30,10))
        p = ds_MMS['tcwv_smooth'].plot(transform=ccrs.PlateCarree(),  # the data's projection
                                       col = 'month', col_wrap =3,
                                       aspect = 3, size = size,
                                       vmin = vmin, vmax = vmax, cmap=cmap,# multiplot settin
                                       subplot_kws={'projection': map_proj},
                                       cbar_kwargs=colorbar)
        for ax in p.axes.flat:
            ax.coastlines()
            ax.gridlines()

        plt.savefig(output_fig+'atlas_meanMonth_clim.png')
```

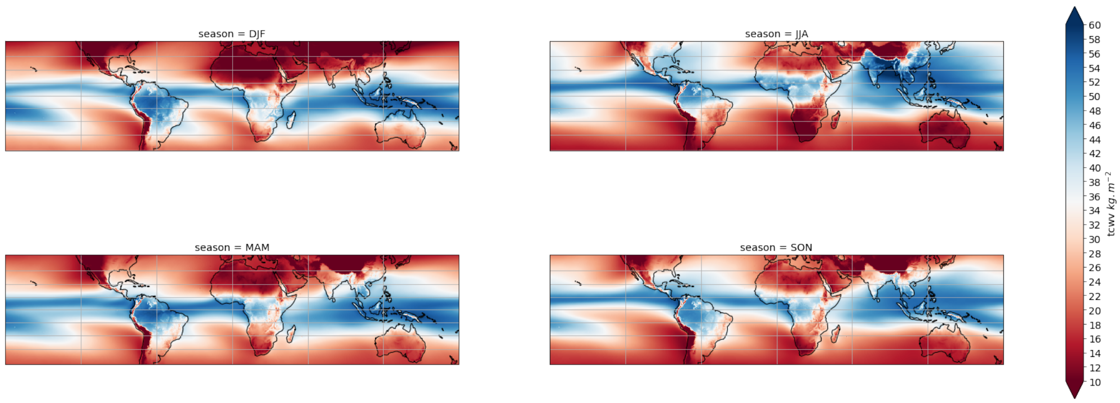
```
/home/durandy/miniconda3/envs/towel/lib/python3.9/site-packages/xarray/plot/facetgrid.py:394: U
  self.fig.tight_layout()
```



Carte global de PW en moyenne saisonière

```
In [23]: p = ds_MSS['tcwv_smooth'].plot(transform=ccrs.PlateCarree(),  # the data's projection
                                       col = 'season', col_wrap =2,
```

```
                                        aspect = 3, size = size,
                                        vmin = vmin, vmax = vmax, cmap=cmap,# multiplot settin
                                        subplot_kws={'projection': map_proj},
                                        cbar_kwargs=colorbar)
for ax in p.axes.flat:
    ax.coastlines()
    ax.gridlines()

plt.savefig(output_fig+'atlas_meanSeason_clim.png')
```



8 Calcul et carte de variance pour la variable tcwv

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{n_j}((<\overline{x}_{30}>_3)_i - \mu_j^*)^2}{n_j}} j \text{ de 1 à 12 ou de 1 à 4, } \mu_j \text{ la moyenne climatologique, n le nombre de pas de temps} \quad (23)$$

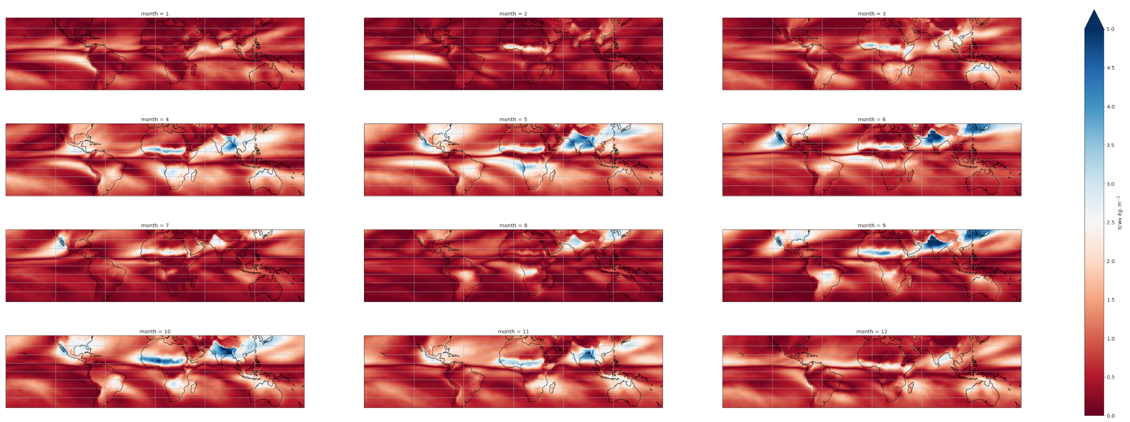
```
In [24]: ds_std_smot = ds_smot.std('time')
         ds_std_smot_M = ds_smot.groupby('time.month').std('time').load()
         ds_std_smot_S = ds_smot.groupby('time.season').std('time').load()

         ds_std_brut = ds_brut.std('time')
         ds_std_brut_M = ds_brut.groupby('time.month').std('time')
         ds_std_brut_S= ds_brut.groupby('time.season').std('time')



         #### Parameter for plotting
         colorbar = {'label': 'tcwv $kg.m^{-2}$',
                     'orientation': 'vertical' , 'ticks': np.arange(0.,5.1,0.5),
                     'extend' : 'max'}
         vmax = 5.
```

```
vmin = 0.
cmap ='RdBu'
size = 5
aspect = 4
```

Atlas de la variance sur les douze mois

```
In [25]: p = ds_std_smot_M['tcwv_smooth'].plot(transform=ccrs.PlateCarree(),  # the data's pro
                                               col = 'month', col_wrap =3,
                                               aspect = aspect, size = size,
                                               vmin = 0., vmax = vmax, cmap=cmap,# multiplot settings
                                               subplot_kws={'projection': map_proj},
                                               cbar_kwargs=colorbar)
         for ax in p.axes.flat:
             ax.coastlines()
             ax.gridlines()

         # plt.show()
         plt.savefig(output_fig+'atlas_varMonth_clim.png')
```

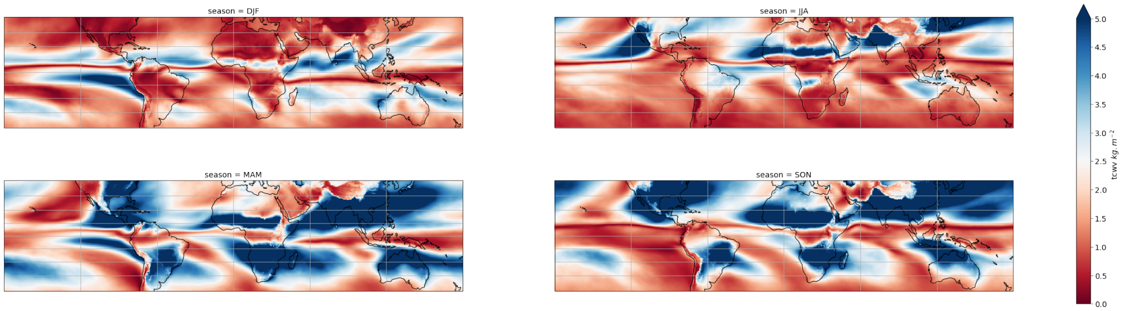
```
/home/durandy/miniconda3/envs/towel/lib/python3.9/site-packages/xarray/plot/facetgrid.py:394: U
  self.fig.tight_layout()
```



Atlas de la variance saisonière

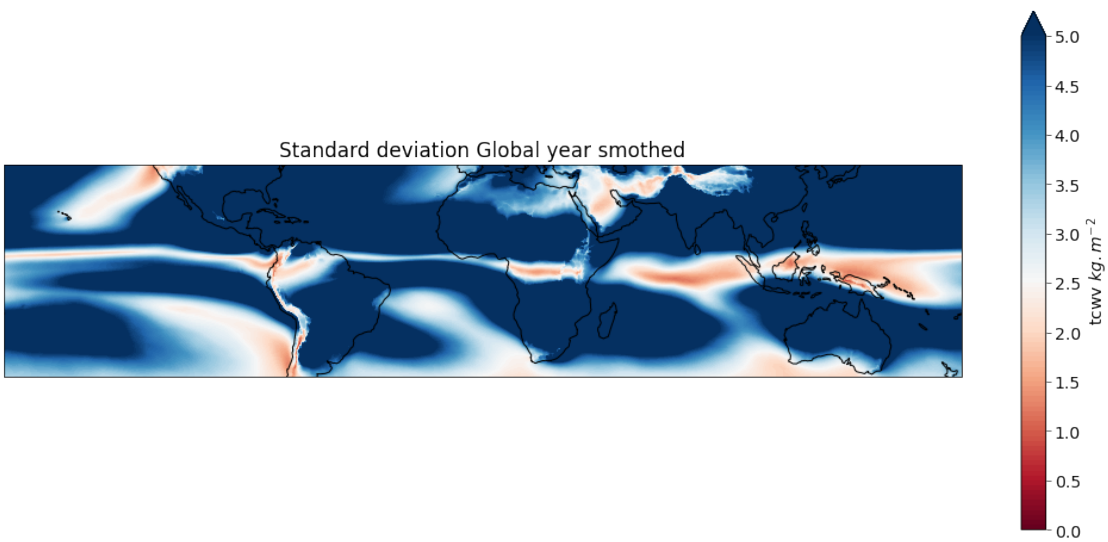
```
In [26]: # plt.figure(figsize = (30,10))
         p = ds_std_smot_S['tcwv_smooth'].plot(transform=ccrs.PlateCarree(),  # the data's pro
                                               col = 'season', col_wrap =2,
                                               aspect = aspect, size = size,
                                               vmin = vmin, vmax = vmax, cmap=cmap,# multiplot settin
                                               subplot_kws={'projection': map_proj},
                                              cbar_kwargs=colorbar)
```

```
for ax in p.axes.flat:
    ax.coastlines()
    ax.gridlines()
plt.savefig(output_fig+'atlas_varSeason_clim.png')
```



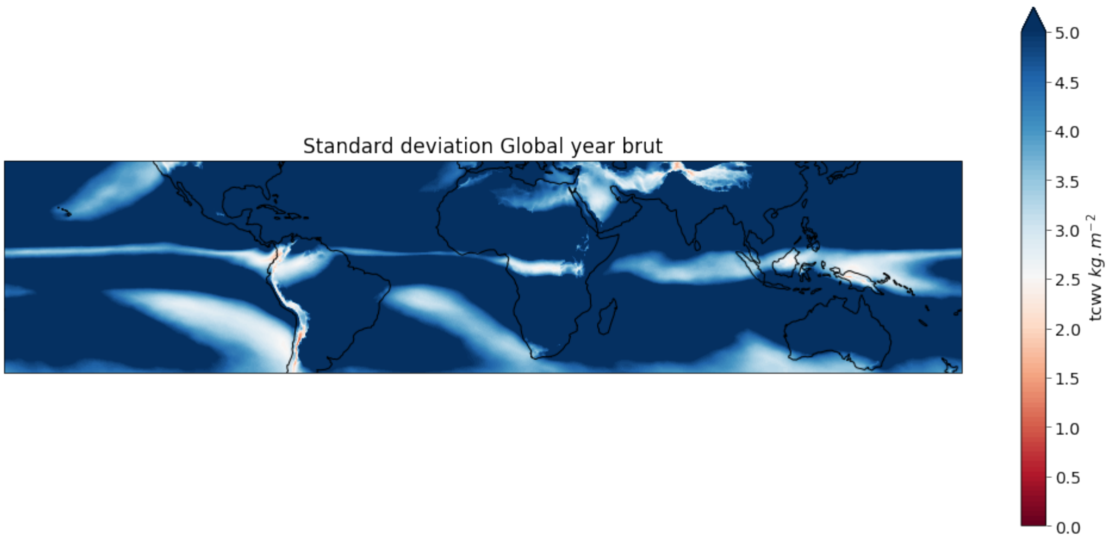
Variance sur l'année

```
In [27]: plt.figure()
         ax = plt.axes(projection=ccrs.PlateCarree())
         p = ds_std_smot['tcwv_smooth'].plot.contourf(levels = 101, vmax = vmax,vmin = vmin, c
                                                      cbar_kwargs=colorbar)
         ax.coastlines()
         plt.title("Standard deviation Global year smothed")
         plt.show()
```

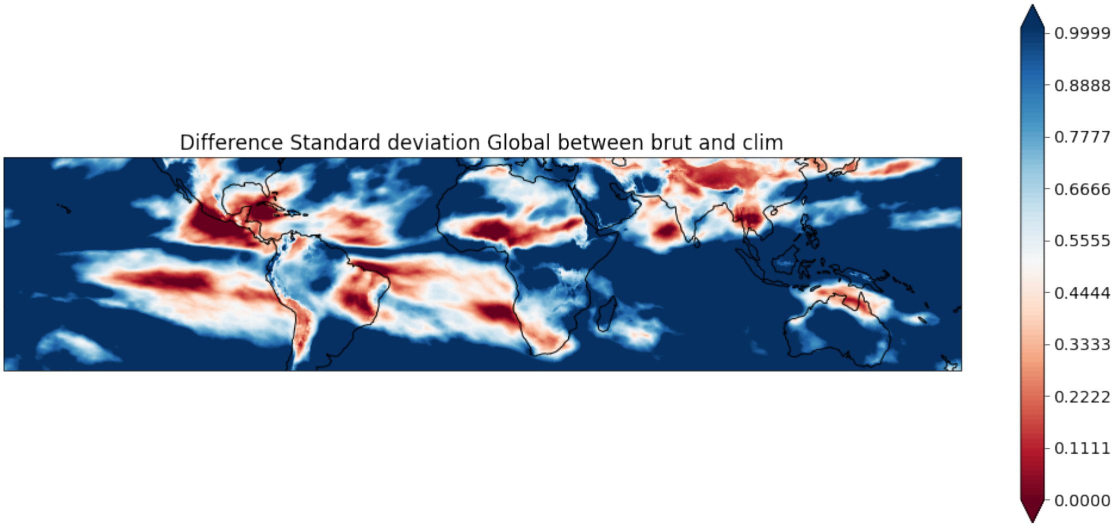



```
In [28]: plt.figure()
         ax = plt.axes(projection=ccrs.PlateCarree())
```

```
p = ds_std_brut['tcwv'].plot.contourf(levels = 101, vmax = vmax, vmin = vmin, cmap='Rd
                                                     cbar_kwargs=colorbar)
ax.coastlines()
plt.title("Standard deviation Global year brut")
plt.show()
```




```
In [29]: diff = ds_std_brut['tcwv']-ds_std_smot['tcwv_smooth']

         plt.figure()
         ax = plt.axes(projection=ccrs.PlateCarree())
         p = diff.plot.contourf(levels = 101, vmax = 1.01, vmin = vmin, cmap='RdBu'
                               )
         ax.coastlines()
         plt.title("Difference Standard deviation Global between brut and clim")
         plt.show()
```



In [30]:
```
# plt.figure()
# ax = plt.axes(projection=ccrs.PlateCarree())
# p = ds_MMS['tcwv_smooth'].sel(month = 9).plot.contourf(levels = 101, vmax = 60.,vmi
#                                                          cbar_kwargs={'label': 'tcwv $
#                         'orientation': 'vertical' , 'ticks': np.arange(0.,61,5)
#                          , 'extend' : 'both'})
# ax.coastlines()
# plt.title("Septembre")
# plt.show()
```