Figures Brief Temperature Change

https://www.fao.org/3/cb9051en/cb9051en.pdf

```
# TITLE: Temperature Change data dissemination brief https://www.fao.org/3/cb9051en/cb9
# 051en.pdf
# AUTHOR: FAO
# STARTED ON: 03/2022
# VERSION: v1.0
# PURPOSE: Reproducing Figure 2; Figure 3; Figure 4; Figure 7 in the brief

# LOADING LIBRARIES -----


library("plyr")
library("dplyr")
library("tidyr")
library("stringr")
library("grid")
library("ggplot2")
library("magrittr")
library("ggthemes")



# LOADING THE FAOSTAT TEMPERATURE CHANGE DATA -----

## Access data from https://www.fao.org/faostat/en/#data/ET
## Bulk download Environment_Temperature_change_E_All_Data_(Normalized).zip (data in lo
## ng format)

### Specify the URL where the ET data file is located
urlET <- "https://fenixservices.fao.org/faostat/static/bulkdownloads/Environment_Temper
ature_change_E_All_Data_(Normalized).zip"

### Specify the directory where the ET file should be saved
pathToDest <- "C:/Users/Downloads"
destETfile <-paste0(pathToDest, "/Environment_Temperature_change_E_All_Data_(Normalized
).zip")
### This is a generic path, location to store the data should be specified

### Apply download.file function in R
download.file(urlET, destETfile)

### Unzip the bulk download in the same directory where the zip file was downloaded
ETpath = pathToDest
###ETpath = "C:/Users/Downloads"
```

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ETbulk <- unzip(destETfile , exdir=ETpath)

### Read the csv file with all Temperature Change data
ETdata <- read.csv(paste0(ETpath,"/Environment_Temperature_change_E_All_Data_(Normalize
d).csv")) %>%
  as_tibble()
### Depending on the regional settings of your machine, the symbol for Celsius degree #
### s (°C) may generate an error in the code above.
### The issue may be solved specifying a different encoding as follows:
### ETdata <- read.csv(paste0(ETpath,"/Environment_Temperature_change_E_All_Data_(Norma
### lized).csv"), encoding="latin1") %>% as_tibble()

### Select and rename variables
ETforPlots <- rename(ETdata, AreaCode=Area.Code, AreaName=Area, ElementCode=Element.Cod
e, ItemCode=Months.Code) %>% select(c(AreaCode, AreaName, Year, ItemCode, ElementCode, V
alue)) %>%
### Filtering for yearly values - Meteorological year (7020) - used for generating figu
### res
 filter(ItemCode==7020)


# PREPARING FIGURE 2  ------

## Figure 2: Mean annual temperature change over land expressed as anomalies by country

fig2data <- ETforPlots %>%
  filter(AreaCode < 300) %>%
### Sub-setting for countries and territories - no regional aggregates
  spread(ElementCode, Value) %>%
  rename(st_dev = `6078`, temp = `7271`) %>%
  group_by(Year) %>%
### Below to exclude countries that did not exist in the period 1951-1980 or didn't hav
### e sufficient (at least 20) records
  filter(!is.na(st_dev)) %>%
### Records with yearly temperature warmer (>= +2sd);  cooler (<= -2sd); within the n
### ormal +-2sd
  mutate(var2sigma = ifelse((temp > 0) & (temp >= (st_dev * 2)), 1,
                            ifelse((temp < 0) & (temp <= (st_dev * -2)), -1, 0))) %>%
### Number of countries by year and typology of temperature change
  group_by(Year) %>%
  mutate(CountRecds = length(AreaName)) %>%
### Grouping and preparing for plotting
  group_by(Year, CountRecds) %>%
  mutate(class = ifelse((var2sigma == 1), "2",
                        ifelse((var2sigma == -1), "1", "3"))) %>%
  ungroup()


## Plot Figure 2
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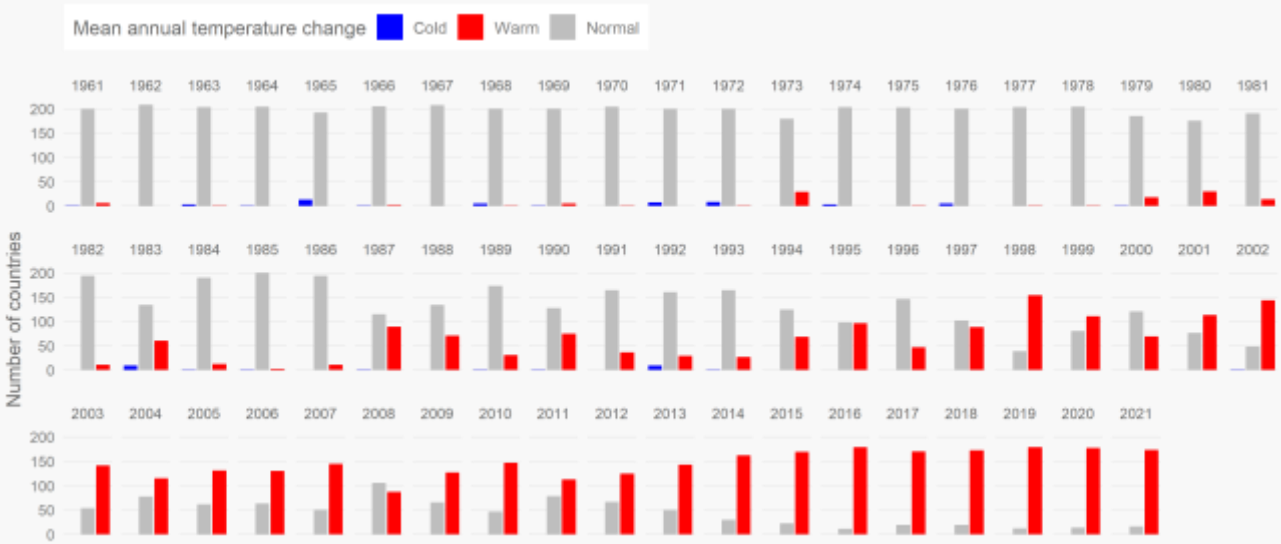
```
fig2_plot <- ggplot(fig2data, aes(x=var2sigma)) +
  geom_bar(aes(fill=class)) + facet_wrap( Year~., nrow= 3) +
  scale_fill_manual(values = c("blue","red","grey"), labels = c("Cold", "Warm", "Normal
")) +
  theme(panel.grid.minor = element_blank()) + theme_gdocs() +
  theme(legend.position = "top", legend.direction = "horizontal", legend.justification
= "left") +
  labs(x="", y="Number of countries", fill = "Mean annual temperature change") +
  theme(axis.text.x = element_blank(), axis.ticks = element_blank(), axis.text.y = elem
ent_text(size = 9)) +
  theme(plot.background=element_blank()) +
  theme(panel.grid.major.y = element_line(size = 0.15, linetype = 'solid', colour = "li
ghtgrey"),
        panel.grid.major.x = element_blank()) + theme(strip.text.x = element_text(size
= 9)) +
  theme(panel.spacing.y=unit(1, "lines")) + theme(axis.line.x = element_blank()) + them
e(legend.text = element_text(size = 10)) +
  theme(axis.title.y = element_text(size = 12)) + theme(axis.title.y=element_text(margi
n = margin(t=0, r=4, b=0, l=-5)))


fig2_plot
```




```
### ggsave(paste0(pathToDest,'/Figure2.png'), width =11, height = 5)
### To save locally the image as png


# PREPARING FIGURE 3 and FIGURE 4 ------

## Temperature Change data for the regional aggregate "Latin America and the Caribbean"
## are not directly available in the FAOSTAT domain. The temperature change for this re
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```
## gional aggregate is computed by weighting the temperature changes values by the area
## of the sub-regions in LAC (South America, Central America, the Caribbean). Correspon
## ding country and regional area values are taken from the FAOSTAT Land USE (RL) https
## ://www.fao.org/faostat/en/#data/RL.
## See the README_Methodological_Note (https://fenixservices.fao.org/faostat/static/doc
uments/ET/ET_e.pdf)

LAC.ET <- ETforPlots %>%
### Filter for sub-regions in Latin America and the Caribbean: Central America (5204);
### Caribbean (5206); South America (5207) AND Filter for temperature change values (El
### ementCode=7271)
  filter(AreaCode %in% c(5204, 5206, 5207) & Year > 1990, ElementCode==7271)

### Downloading FAOSTAT Land Use data from https://www.fao.org/faostat/en/#data/RL
### Bulk download https://fenixservices.fao.org/faostat/static/bulkdownloads/Inputs_Lan
### dUse_E_All_Data_(Normalized).zip (data in long format)
### Specify the URL where the LAND USE data file is located
urlRL <- "https://fenixservices.fao.org/faostat/static/bulkdownloads/Inputs_LandUse_E_A
ll_Data_(Normalized).zip"
### Specify the directory where the RL file should be saved
pathToDest <- "C:/Users/Downloads"
destRLfile <-paste0(pathToDest, "/Inputs_LandUse_E_All_Data_(Normalized).zip")
### This is a generic path, location to store the data should be specified

### Apply download.file function in R
download.file(urlRL, destRLfile)
### Unzip the bulk download in the same directory where the zip file was downloaded
RLpath = pathToDest
RLbulk <- unzip(destRLfile, exdir=RLpath)
### Read the csv file with all Land Use data
RLdata <- read.csv(paste0(RLpath,"/Inputs_LandUse_E_All_Data_(Normalized).csv")) %>% as
_tibble() %>%
### Rename columns
rename(AreaCode=Area.Code, AreaName=Area, ElementCode=Element.Code, ItemCode=Item.Code)

## Select the sub-regions in LAC, Years from 1991 (included) onward and the values for
## Country areas


LAC.RL <- RLdata %>%
  filter(AreaCode %in% c(5204, 5206, 5207) & Year >= 1991 & ItemCode==6600 & ElementCod
e==5110) %>% select(c(AreaCode, AreaName, Year, Value))

## Below to prepare an extended RL.LAC dataset with area values for 2020 and 2021 (due
## to different dissemination cycles, these data are currently not available in RL FAOS
## TAT)

## Figure 3: Regional trends in mean annual temperature changes measured over land

### Using 2019 for 2020
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```
LAC.RL.2020 <-
  filter(LAC.RL, Year == 2019) %>%
  mutate(Year = 2020)
### Using 2019 for 2021
LAC.RL.2021 <-
  filter(LAC.RL, Year == 2019) %>%
  mutate(Year = 2021)
### Binding all sub-regional values
LAC.RL.full <- bind_rows(LAC.RL, LAC.RL.2020, LAC.RL.2021)


temp.LAC <-
### Join the two datasets (temperature change and country area)
  left_join(LAC.ET,LAC.RL.full, by=c("AreaCode", "AreaName", "Year")) %>%
  rename(Value=Value.x, Areaha=Value.y) %>%
  select(-c(AreaCode, AreaName, ItemCode, ElementCode)) %>%
  filter(!is.na(Value), !is.na(Areaha)) %>%
  group_by(Year) %>%
### Compute the values weighted by country area
  summarise(meanLAC = weighted.mean(Value, Areaha), .groups='keep') %>%
  ungroup() %>%
### Save the name of the region
  mutate(AreaCode=5205, AreaName="Latin America and the Caribbean") %>%
  rename(Value=meanLAC)

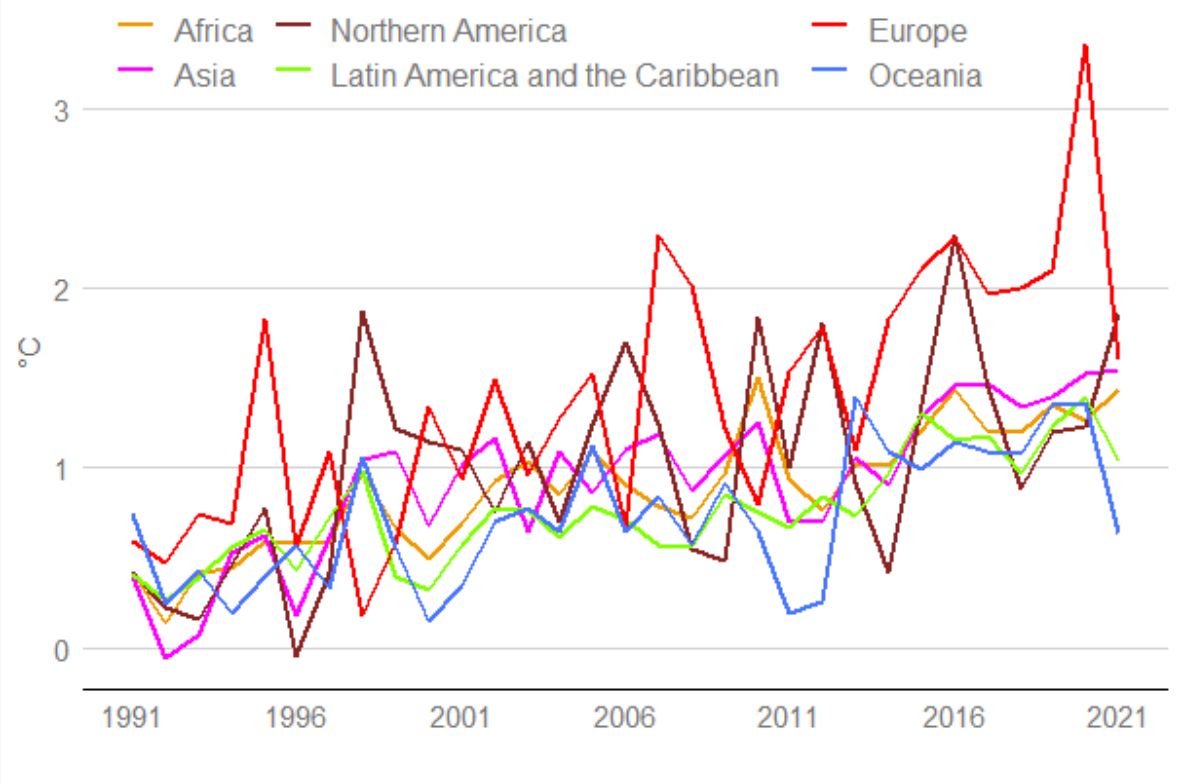
## Import Temperature Change data for the other regions Africa (5100); Northern America
## (5203); Asia (5300); Europe (5400); Oceania (5500)
othRegions.ET <- filter(ETforPlots, AreaCode %in% c(5100, 5203, 5300, 5400, 5500) & Yea
r >= 1991) %>% filter(ElementCode==7271) %>% select(-c(ElementCode, ItemCode))

## Binding the two datasets. Important: This is also used as input for Figure 4
regions <- rbind(othRegions.ET, temp.LAC) %>% mutate(AreaName =
         factor(AreaName, levels=c("Africa", "Asia", "Northern America", "Latin America
and the Caribbean", "Europe", "Oceania")))

## Plot Figure 3

fig3.plot <- ggplot(regions, aes(x=Year, y=Value, color=AreaName)) +
  geom_line(size=1.05)  + theme_gdocs() + scale_color_manual(values=c("orange2", "magent
a", "brown4", "chartreuse", "red", "royalblue1")) + theme(panel.grid.major.y = element_l
ine(size = 0.1, linetype = 'solid', colour = "lightgrey"),panel.grid.major.x = element_
blank()) + theme(legend.position = c(0, 0.95), legend.direction = "horizontal",legend.j
ustification = "left", legend.text = element_text(margin = margin(t = 2))) +
  labs(x="", y="°C") + theme(legend.title = element_blank()) + theme(legend.background =
element_rect(fill = "transparent")) + theme(plot.background=element_blank()) +
  scale_x_continuous(breaks=seq(1991, 2021, by=5)) + theme(axis.title=element_text(size=
11), axis.text = element_text(size= 11))
```

```
fig3.plot
```




```
### ggsave(paste0(pathToDest,'/Figure3.png'), width = 8, height = 4.5)
### To save locally the image as png

## Figure 4: Mean annual temperature changes measured over the land, global and regiona
## l trends by recent decades

### Average for the earlier decade (2002-2011)
avg_regions2002_2011 <- filter(regions, Year > 2001 & Year < 2012) %>%
  group_by(AreaCode, AreaName) %>%
  summarise(avg2002_11 = mean(Value), .groups="keep") %>%
  ungroup()
### Average for the most recent decade (2012-2021)
avg_regions2012_2021 <- filter(regions, Year >= 2012) %>%
  group_by(AreaCode, AreaName) %>%
  summarise(avg2012_21 = mean(Value), .groups="keep") %>%
  ungroup()

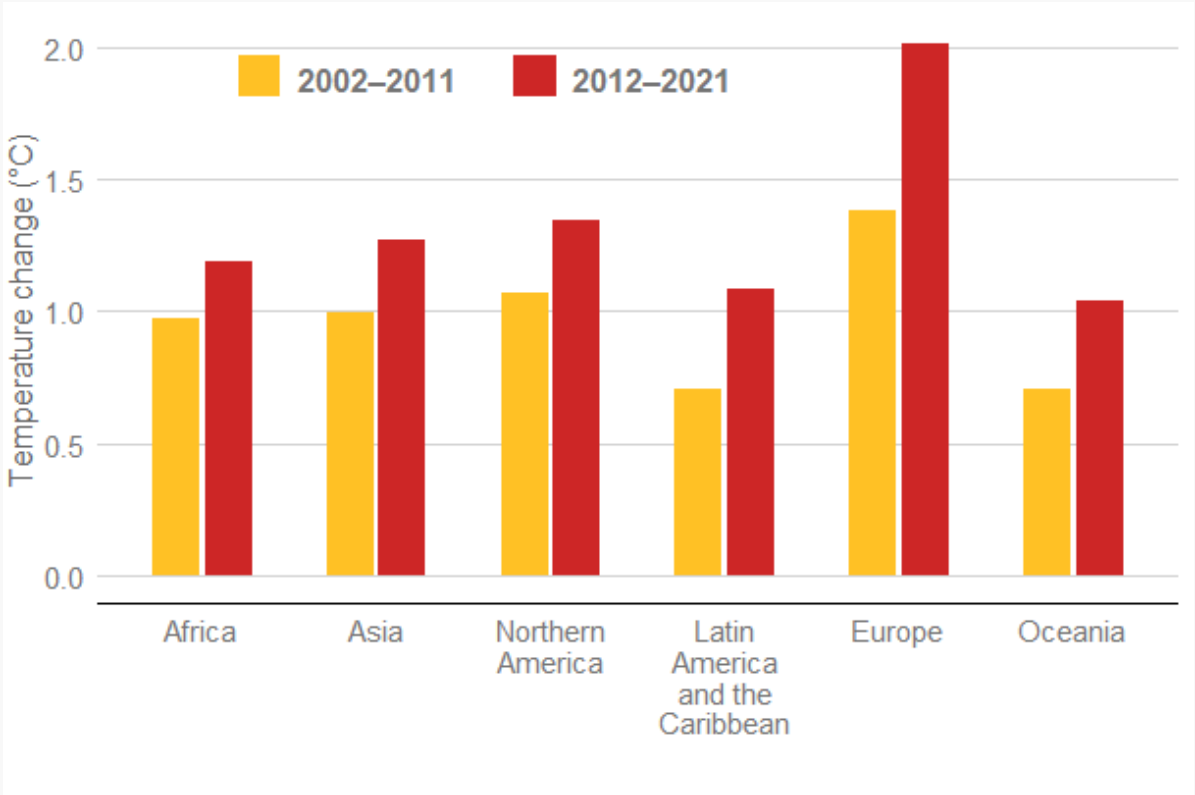
fig4.data <- full_join(avg_regions2002_2011, avg_regions2012_2021, by=c("AreaCode", "Ar
eaName")) %>% gather(average, Value, 3:4)

## Plot Figure 4

fig4.plot <- fig4.data %>%
```

```
  mutate(AreaName = factor(AreaName, levels=c("World", "Africa", "Asia", "Northern Amer
ica", "Latin America and the Caribbean", "Europe", "Oceania"))) %>%
  ggplot(aes(x=AreaName, y=Value, fill=average)) +
  geom_bar(stat="identity", width=.6, position=position_dodge2())  + theme_gdocs() +
  scale_fill_manual(values=c("goldenrod1", "firebrick3"), labels = c("2002-2011", "2012
-2021")) +
  theme(panel.grid.major.y = element_line(size = 0.15, linetype = 'solid', colour = "li
ghtgrey"),
        panel.grid.major.x = element_blank()) +
  theme(legend.position = c(.1, .9), legend.direction = "horizontal", legend.justificat
ion = "left", legend.text = element_text(margin = margin(t = 2), face="bold")) +
  labs(x="", y="Temperature change (°C)") + theme(legend.title = element_blank()) +
  theme(legend.background = element_rect(fill = "transparent")) + theme(plot.background
=element_blank()) +
  theme(axis.title.y=element_text(margin = margin(t=0, r=3, b=0, l=-5))) +
  theme(axis.ticks = element_blank(), axis.text = element_text(size = 11)) +
  ### below to avoid labels to overlap
  scale_x_discrete(labels = function(x) stringr::str_wrap(x, width = 10))

fig4.plot
```




```
### ggsave(paste0(pathToDest,'/Figure4.png'), width =9, height = 4.5)
### To save locally the image as png


# PREPARING FIGURE 7  ------
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```
## Figure 7: Number of countries and territories with record warming

### Find year when the MAX value (warmest year) of each country/territory occurs
maxYear <- ETforPlots %>%
### The number of countries and territories varies across the 60 years of the analysis;
### Countries and territories that did not exist during the period of climatology refer
### ence (1951-1980) are excluded (std is null)
  spread(ElementCode, Value) %>%
  filter(complete.cases(.)) %>%
  gather(ElementCode, Value, 5:6) %>%
### Sub-set for Temperature change (ElementCode==7271) and for countries/territories on
### ly (FAOSTAT AreaCode < 300)
  filter(AreaCode < 300 & ElementCode==7271) %>%
  select(c(AreaCode, Year, Value))

### Summarize to get the year to which corresponds the maximum value
YearMax <- ddply(maxYear, .(AreaCode), summarise, Year=Year[which.max(Value)])
### Summarize to get the maximum value (highest warming record by country)
ValueMax <- maxYear %>%
  group_by(AreaCode) %>%
  summarise(warmest = max(Value)) %>%
  ungroup() %>%
  filter(!is.na(warmest))

### Bind data: years with max value for each country/territory
MaxValueYear <- left_join(ValueMax, YearMax, by="AreaCode")

### Prepare the data to plot
fig7.data <- MaxValueYear  %>%
  group_by(Year) %>%
  summarise(count = n()) %>%
  mutate(Year = as.factor(Year)) %>%
  complete(Year)

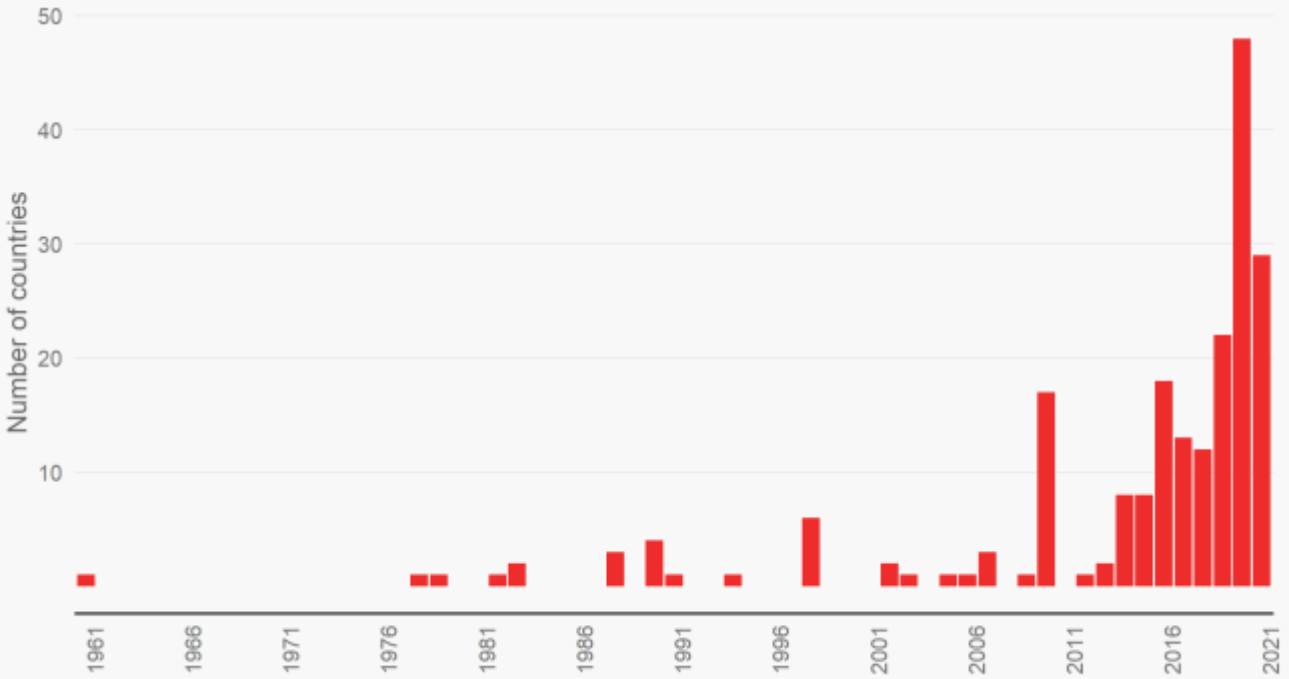
### Prepare a vector with all years in the period 1961-2021
YearsAll <- c(1961:2021, 0:0) %>% as_tibble() %>%
  mutate(ToFill = 0) %>% dplyr::rename(Year = value) %>%
  mutate(Year = as.factor(Year))

## Plot Figure 7

### Merge with the number of record countries by year
fig7.plot <- left_join(YearsAll, fig7.data, by="Year") %>%
  mutate(count = ifelse(is.na(count), 0, count)) %>%
  select(Year, count) %>%
  filter(Year!=0) %>%
  ggplot(aes(y=count, x=Year)) +
  geom_col(show.legend=F, fill = "firebrick2") + theme_gdocs() +
  theme(plot.background=element_blank()) +
```

```
  theme(panel.grid.major.y = element_line(size = 0.15, linetype = 'solid', colour = "li
ghtgrey"),
        panel.grid.major.x = element_blank()) +
  labs(y="Number of countries", x="") +
  theme(axis.ticks = element_blank(), axis.text = element_text(size = 10)) +
  theme(axis.title.y=element_text(margin = margin(t=0, r=3, b=0, l=-5))) +
  scale_x_discrete(breaks=c(1961, 1966, 1971, 1976, 1981, 1986, 1991, 1996, 2001, 2006,
                            2011, 2016, 2021)) +
  theme(plot.caption = element_text(hjust=1, size=10)) +
  scale_y_continuous(breaks=c(10, 20, 30, 40, 50)) + theme(axis.text.x=element_text(ang
le=90))

fig7.plot
```




```
### ggsave(paste0(pathToDest,'/Figure7.png'), width =8, height = 4.5)
### To save locally the image as png
```