library(ncdf4)

library(tidyverse)

library(raster)

library(here)

library(lubridate) # for date functions

library(scales) # generating scales for plotting etc.

library(ggplot2)

library(dplyr)

library(latex2exp) # for writing the degree Celsius

library(sf)

library(magick)

########################

# Files ################

pathSST<-"/Users/andreworca/Desktop/\_wAAD/\_r/MEASO/ACCESS/SO\_1900-2100/Temperature/Means/"

filesSST<-c(

"MonthlyMeans\_1900-1909.nc"

,"MonthlyMeans\_1910-1919.nc"

,"MonthlyMeans\_1920-1929.nc"

,"MonthlyMeans\_1930-1939.nc"

,"MonthlyMeans\_1940-1949.nc"

,"MonthlyMeans\_1950-1959.nc"

,"MonthlyMeans\_1960-1969.nc"

,"MonthlyMeans\_1970-1979.nc"

,"MonthlyMeans\_1980-1989.nc"

,"MonthlyMeans\_1990-1999.nc"

,"MonthlyMeans\_2000-2009.nc"

,"MonthlyMeans\_2010-2014.nc"

,"MonthlyMeans\_2015-2024.nc"

,"MonthlyMeans\_2025-2034.nc"

,"MonthlyMeans\_2035-2044.nc"

,"MonthlyMeans\_2045-2054.nc"

,"MonthlyMeans\_2055-2064.nc"

,"MonthlyMeans\_2065-2074.nc"

,"MonthlyMeans\_2075-2084.nc"

,"MonthlyMeans\_2085-2094.nc"

,"MonthlyMeans\_2095-2100.nc"

) # end file list

SSTfiles<-as.data.frame(list(

path = sapply(filesSST,function(p,d) paste(d,p,sep=""), pathSST)

,year0 = as.numeric(sapply(filesSST,function(p) substr(p,14,17)))

,year1 = as.numeric(sapply(filesSST,function(p) substr(p,19,22)))

))

SSTfilesYrs<-do.call(rbind,lapply(seq(1,nrow(SSTfiles),1)

,function(i,f){

cbind(seq(f[i,2],f[i,3],1)

,rep(i,(f[i,3]-f[i,2]+1)))},SSTfiles))

pathSIC<-"/Users/andreworca/Desktop/\_wAAD/\_r/MEASO/ACCESS/SO\_1900-2100/SIC/Means/"

filesSIC<-c(

"MonthlyMeans\_SIC\_1850-2014.nc"

,"MonthlyMeans\_SIC\_2015-2100.nc"

) # end file list

SICfiles<-as.data.frame(list(

path = sapply(filesSIC,function(p,d) paste(d,p,sep=""), pathSIC)

,year0 = as.numeric(sapply(filesSIC,function(p) substr(p,18,21)))

,year1 = as.numeric(sapply(filesSIC,function(p) substr(p,23,26)))

))

SICfilesYrs<-do.call(rbind,lapply(seq(1,nrow(SICfiles),1)

,function(i,f){

cbind(seq(f[i,2],f[i,3],1)

,rep(i,(f[i,3]-f[i,2]+1)))},SICfiles))

pathGWL<-"/Users/andreworca/Desktop/\_wAAD/\_r/MEASO/ACCESS/SO\_1900-2100/GWL/"

filesGWL<-c(

"tas\_Amon\_ACCESS-ESM1-5\_r1i1p1f1\_gn\_185001-230012\_gwl20.nc"

,"tas\_Amon\_ACCESS-ESM1-5\_r1i1p1f1\_gn\_185001-230012\_gwl30.nc"

,"tas\_Amon\_ACCESS-ESM1-5\_r1i1p1f1\_gn\_185001-230012\_ymonmean.nc"

) # end file list

############################################

# input Global Warming Level (GWL)

ncfname <- paste(pathGWL,filesGWL[2],sep="")

ncin <- nc\_open(ncfname)

print(ncin)

# read in dimensions

lon<-ncvar\_get(ncin,"lon")

nlon<-dim(lon)

lat<-ncvar\_get(ncin,"lat")

nlat<-dim(lat)

# depth<-ncvar\_get(ncin,"lev")

# ndepth<-dim(depth)

t<-ncvar\_get(ncin,"time")

nt<-dim(t)

tunits<-ncatt\_get(ncin,"time","units") # days since 1850-01-01

Year<-year(as.Date(t,origin="1850-01-01"))

# read in variable array

ncVar<-"tas"

ncData<-ncvar\_get(ncin,ncVar)

NAvalue<-ncatt\_get(ncin,ncVar,"\_FillValue")[[2]]

ncVarUnits<-ncatt\_get(ncin,ncVar,"units")

nc\_close(ncin)

rGWL <- brick(ncfname, stopIfNotEqualSpaced = F)

#reset minima and maxima of dimensions of each raster in order to enable use of 'area'

xmin(rGWL)<-0

xmax(rGWL)<-360

ymin(rGWL)<-(-90)

ymax(rGWL)<-90

# calculate weighted means

CellArea<-area(rGWL[[1]])

rGWL\_wt\_vals<-rGWL\*CellArea

GWL<-cellStats(rGWL\_wt\_vals,sum)/cellStats(CellArea,sum)

GWL<-GWL-GWL[1]

plot(Year,GWL,type="l") # plot GWL as a check

#Reproject to South Polar Stereographic (EPSG:3976)

#Define projection

south\_stereo <- "+proj=stere +lat\_0=-90 +lat\_ts=-70 +lon\_0=0 +k=1 +x\_0=0 +y\_0=0 +datum=WGS84 +units=m +no\_defs"

# latitude circle for plotting

pLat<- -60

pLonInc<-0.1

pCircle<-st\_linestring(cbind(seq(-180,180,pLonInc),rep(pLat,(360/pLonInc+1))))

pCircle<-st\_sfc(pCircle,crs=4326)

pCircle<-st\_transform(pCircle,south\_stereo)

pCircle<-as.data.frame(st\_coordinates(pCircle))

############################################

# Routine

############################################

SIC\_file<-0 # SIC file not loaded yet

SST\_file<-0 # SST file not loaded yet

doYears<-seq(2000,2100,1)

doMonths<-seq(1,12,1)

printPlot<-TRUE

savePlot<-TRUE

outputDir<-"/Users/andreworca/Desktop/\_wAAD/\_r/MEASO/ACCESS/Output Animation"

################################

#do loop

for (y in doYears){

for (m in doMonths){

# determine which file the year is in

whichSSTfile<-SSTfilesYrs[which(SSTfilesYrs[,1]==y),2]

if(SST\_file!=whichSSTfile){

SST\_file<-whichSSTfile

sst<-brick(SSTfiles[SST\_file,1], stopIfNotEqualSpaced = F)

sstDate<-as.vector(sapply(names(sst),function(d) paste(substr(d,2,5),substr(d,7,8),substr(d,10,11),sep="-")))

sstYears<-year(sstDate)

sstMonths<-month(sstDate)

sst\_reproj <- projectRaster(sst, crs =south\_stereo) # reproject to polar

}

whichSICfile<-SICfilesYrs[which(SICfilesYrs[,1]==y),2]

if(SIC\_file!=whichSICfile){

SIC\_file<-whichSICfile

sic<-brick(SICfiles[SIC\_file,1], stopIfNotEqualSpaced = F)

sicDate<-as.vector(sapply(names(sic),function(d) paste(substr(d,2,5),substr(d,7,8),substr(d,10,11),sep="-")))

sicYears<-year(sicDate)

sicMonths<-month(sicDate)

sic\_reproj <- projectRaster(sic, crs =south\_stereo) # reproject to polar

}

# subset raster

p<-which(sstYears==y & sstMonths==m)

pName<-names(sst\_reproj)[p]

sst\_df\_reproj <- as.data.frame(sst\_reproj[[pName]], xy = T)

aData<-sst\_df\_reproj

maxSST<-10

aData[(!is.na(aData[,3]) & aData[,3]>maxSST),3] <- maxSST

# colour ramp for just sst

pColours <- c("#2c7bb6","#f7f7f7","#ca0020","black","black")

pValues <- rescale(c(-2,2,4,5,maxSST),to = c(0,1), from=c(-2,maxSST))

minSIC<-25

sic\_df\_reproj <- as.data.frame(sic\_reproj[[pName]], xy = T)

mData<-merge(aData,sic\_df\_reproj,by=c("x","y"))

useSIC <- (!is.na(mData[,4]) & mData[,4]>=minSIC & mData[,4]<=100)

aData<-mData[,c(1:3)]

aData[useSIC,3]<-mData[useSIC,4]

names(aData)<-c("x","y",pName)

pColours <- c("#2c7bb6","#f7f7f7","#ca0020","black","black","blue","darkblue","darkblue")

pValues <- rescale(c(-2,2,4,5,(minSIC-0.1),minSIC,80,100),to = c(0,1), from=c(-2,100))

pYear<-year(sstDate[p])

pGWL<-as.vector(GWL[which(Year==pYear)])

pGWLcolour<-ifelse(pGWL<=1.5,"blue",ifelse(pGWL>1.5 & pGWL <=2,"red","darkred"))

pGWL\_txt<-paste(format(round(pGWL, 1), nsmall = 1),"\u00B0C",sep="")

# location of annotations

names(pCircle)<-names(aData)

aPlot<- ggplot(aData,aes\_string("x", "y", fill = pName)) +

geom\_raster()+

scale\_fill\_gradientn(

colours=pColours

,values=pValues

,na.value = "white")+

theme\_minimal()+

labs(fill = "Scale") +

theme(legend.position="none",aspect.ratio=1

,axis.text.x = element\_blank()

,axis.text.y = element\_blank()

,axis.ticks = element\_blank()

,axis.title.x = element\_blank()

,axis.title.y = element\_blank()

) + # end theme

ggtitle(paste(pYear,month(sstDate[p],label=TRUE,abbr=FALSE),sep=" : ")) +

annotate("text", x=max(aData[,"x"])/10,y=0,

label=pGWL\_txt,size = 5,color = pGWLcolour) +

annotate("text", x=max(aData[,"x"])/10,y=max(aData[,"y"])/7.5,

label="GWL",size = 3,color = pGWLcolour)

if(printPlot) print(aPlot)

if(savePlot) ggsave(paste(outputDir,"/",pName,".png",sep=""))

#####################

} # end do month

} # end do year

###############################################################################

###############################################################################

# create animation

outputDir<-"/Users/andreworca/Desktop/\_wAAD/\_r/MEASO/ACCESS/Output animation"

imgs <- list.files(outputDir, full.names = TRUE)

img\_list <- lapply(imgs, image\_read)

## join the images together

img\_joined <- image\_join(img\_list)

## animate at 2 frames per second

img\_animated <- image\_animate(img\_joined, fps = 20)

## view animated image

img\_animated

## save to disk

image\_write(image = img\_animated,

path = "COP26.gif")

###############################################################################

# generating mean raster for a given month for a range of GWL

###############################################################################

#vGWL<-c(0,1.5,2,4)

vGWL<-c(4)

GWLmonth <- 2

for(g in 1:length(vGWL)){

pGWL<-vGWL[g] # value to be plotted

GWLrange <- c((pGWL-0.3),pGWL)

pGWLcolour<-ifelse(pGWL<=1.5,"blue",ifelse(pGWL>1.5 & pGWL <=2,"red","darkred"))

GWLyears <- Year[which(GWL>=GWLrange[1] & GWL<=GWLrange[2])] # do as sequence of years from 1900 to 1950 for first one

useSSTyear<- SSTfilesYrs[,1] %in% GWLyears

SIC\_file<-0 # SIC file not loaded yet

SST\_file<-0 # SST file not loaded yet

doYears<-SSTfilesYrs[useSSTyear,1]

if(pGWL==0) doYears<-c(1900:1950)

m<-GWLmonth

printPlot<-TRUE

savePlot<-FALSE

outputDir<-"/Users/andreworca/Desktop/\_wAAD/\_r/MEASO/ACCESS"

################################

#do loop to combine rasters into a stack

rStack\_sst<-NULL

rStack\_sic<-NULL

for (y in doYears){

# determine which file the year is in

whichSSTfile<-SSTfilesYrs[which(SSTfilesYrs[,1]==y),2]

if(SST\_file!=whichSSTfile){

SST\_file<-whichSSTfile

sst<-brick(SSTfiles[SST\_file,1], stopIfNotEqualSpaced = F)

sstDate<-as.vector(sapply(names(sst),function(d) paste(substr(d,2,5),substr(d,7,8),substr(d,10,11),sep="-")))

sstYears<-year(sstDate)

sstMonths<-month(sstDate)

}

whichSICfile<-SICfilesYrs[which(SICfilesYrs[,1]==y),2]

if(SIC\_file!=whichSICfile){

SIC\_file<-whichSICfile

sic<-brick(SICfiles[SIC\_file,1], stopIfNotEqualSpaced = F)

sicDate<-as.vector(sapply(names(sic),function(d) paste(substr(d,2,5),substr(d,7,8),substr(d,10,11),sep="-")))

sicYears<-year(sicDate)

sicMonths<-month(sicDate)

}

# subset raster

p<-which(sstYears==y & sstMonths==m)

pName<-names(sst)[p]

if(is.null(rStack\_sst)){

rStack\_sst<-sst[[pName]]

rStack\_sic<-sic[[pName]]

} else {

rStack\_sst<-stack(rStack\_sst,sst[[pName]])

rStack\_sic<-stack(rStack\_sic,sic[[pName]])

}

} # end doYears

# mean of cells

rMean\_sst<-mean(rStack\_sst)

rMean\_sic<-mean(rStack\_sic)

# plotting

sst\_reproj <- projectRaster(rMean\_sst, crs =south\_stereo) # reproject to polar

sic\_reproj <- projectRaster(rMean\_sic, crs =south\_stereo) # reproject to polar

sst\_df\_reproj <- as.data.frame(sst\_reproj, xy = T)

aData<-sst\_df\_reproj

aData[(!is.na(aData[,3]) & aData[,3]>maxSST),3] <- maxSST

# colour ramp for just sst

pColours <- c("#2c7bb6","#f7f7f7","#ca0020","black","black")

pValues <- rescale(c(-2,2,4,5,maxSST),to = c(0,1), from=c(-2,maxSST))

sic\_df\_reproj <- as.data.frame(sic\_reproj, xy = T)

mData<-merge(aData,sic\_df\_reproj,by=c("x","y"))

useSIC <- (!is.na(mData[,4]) & mData[,4]>=minSIC & mData[,4]<=100)

aData<-mData[,c(1:3)]

aData[useSIC,3]<-mData[useSIC,4]

names(aData)<-c("x","y",pName)

pColours <- c("#2c7bb6","#f7f7f7","#ca0020","black","black","blue","darkblue","darkblue")

pValues <- rescale(c(-2,2,4,5,(minSIC-0.1),minSIC,80,100),to = c(0,1), from=c(-2,100))

MonthName<-unique(sstMonths)[m]

aPlot<- ggplot(aData,aes\_string("x", "y", fill = pName)) +

geom\_raster()+

scale\_fill\_gradientn(

colours=pColours

,values=pValues

,na.value = "white")+

theme\_minimal()+

labs(fill = "Scale") +

theme(legend.position="none",aspect.ratio=1

,axis.text.x = element\_blank()

,axis.text.y = element\_blank()

,axis.ticks = element\_blank()

,axis.title.x = element\_blank()

,axis.title.y = element\_blank()

) + # end theme

ggtitle(paste("Mean : ",month(sstDate[p],label=TRUE,abbr=FALSE),sep="")) +

annotate("text", x=max(aData[,"x"])/10,y=0,

label=paste(format(round(pGWL, 1), nsmall = 1),"\u00B0C",sep=""),size = 5,color = pGWLcolour) +

annotate("text", x=max(aData[,"x"])/10,y=max(aData[,"y"])/7.5,

label="GWL",size = 3,color = pGWLcolour)

names(pCircle)<-names(aData)

aPlot<-aPlot+geom\_line(data=pCircle)

if(printPlot) print(aPlot)

if(savePlot) ggsave(paste(outputDir,"/",paste("Mean\_",month(sstDate[p],label=TRUE,abbr=TRUE),"\_",pGWL,sep=""),".png",sep=""))

} # end gwl vector