tropospheric-temperature

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Evaluation of tropospheric temperatures

This script compares tropospheric temperatures (TLT) simulated from gloal climate models (CMIP5) and data from satellites (MSU).

R Markdown

This is an R Markdown document. Markdown is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. For more details on using R Markdown see http://rmarkdown.rstudio.com.

```
library(esd)
```

```
## Loading required package: ncdf4
```

```
## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'
```

```
## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric
```

```
##
## Attaching package: 'esd'
```

```
## The following object is masked from 'package:base':
##
##     subset.matrix
```

CMIP5 simulations

functions extracting the TLT

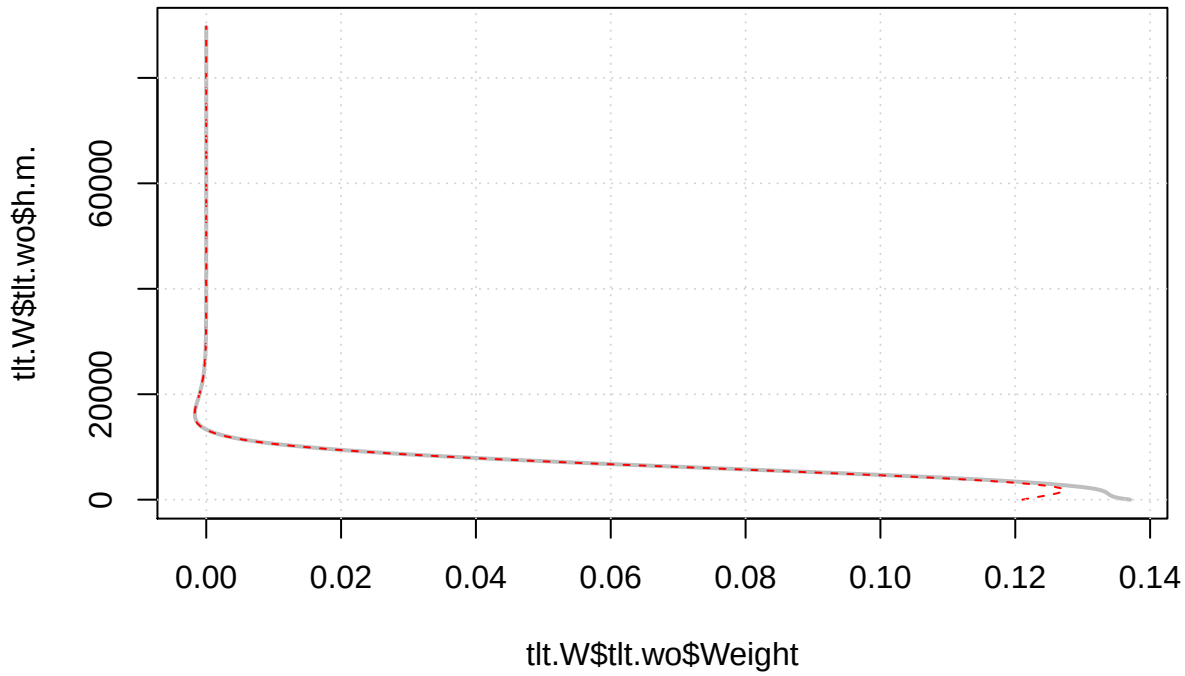
Vertical weigthing functions

Retrieve the weighting loads for the different heights corresponding to the TLT temperature. More on the vertical weighting function from http://www.remss.com/measurements/upper-air-temperature and http://tropic.ssec.wisc.edu/real-time/amsu/explanation.html.

```
if (!file.exists('tlt.W.rda')) {
  colnames <- c('level','h(m)','T(K)','P(pa)','PV(pa)','Weight')
  ## Weighting over land:
  ## Surface Weight                                    0.15104
  tlt.wl <- read.table('http://data.remss.com/msu/weighting_functions/std_atmosphere_wt_function_chan_tl
                col.names = colnames)
  attr(tlt.wl,'Surface Weight') <- 0.15104
  ## Weighting over ocean
  ## Surface Weight                                    0.11863
```

```
  tlt.wo <- read.table('http://data.remss.com/msu/weighting_functions/std_atmosphere_wt_function_chan_tl
                col.names=colnames)
  attr(tlt.wo,'Surface Weight') <- 0.11863
  tlt.W <- list(tlt.wl=tlt.wl,tlt.wo=tlt.wo)
  save(tlt.W,file='tlt.W.rda')
} else load('tlt.W.rda')
```

```
plot(tlt.W$tlt.wo$Weight,tlt.W$tlt.wo$h.m.,type='l',lwd=2,col='grey')
lines(tlt.W$tlt.wl$Weight,tlt.W$tlt.wl$h.m.,col='red',lty=2)
grid()
```

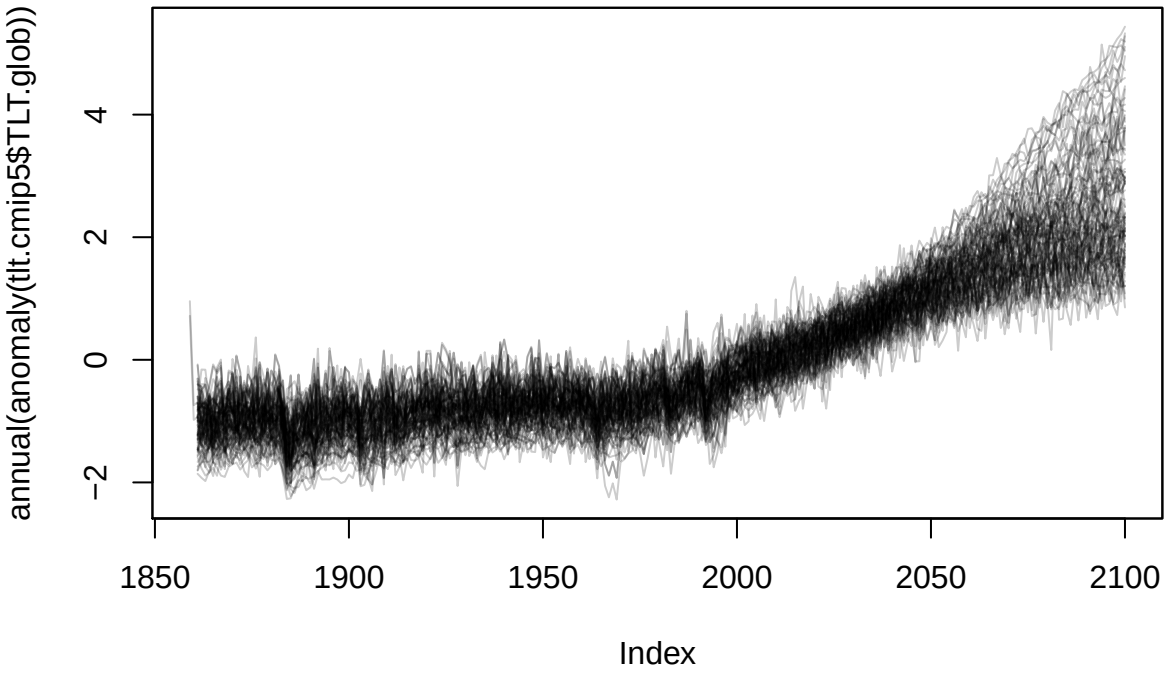


The air temperature needs to be weighted according to surface area (latitude) and height before it is aggregated to a product that is comparable to that of the satellite TLT.

```
## Estimate area weighted mean temperature
areamean <- function(x,W.lat,d) {
  y <- x*c(W.lat)
  dim(y) <- c(d[1],d[2])
  z <- colSums(y,na.rm=TRUE)/sum(W.lat[,1],na.rm=TRUE)
  return(z)
}

ta2tlt <- function(fname,tlt.W,xlat=c(-90,90),varid='ta') {
  require(ncdf4)
  ncid <- nc_open(fname)
  X <- ncvar_get(ncid,varid)
  lat <- ncvar_get(ncid,'lat')
  plev <- ncvar_get(ncid,'plev')
  tim <- ncvar_get(ncid,'time')
  tunit <- ncatt_get(ncid,'time','units')
  model.id <- ncatt_get(ncid,0,'model_id')
  rcp <- ncatt_get(ncid,0,'experiment')
  ## Different GCMs use different calendars: 365-day, Gregorian, ets.
```

```
  calendar <- ncatt_get(ncid,'time','calendar')
  nc_close(ncid)
  ## Extract selected latitude band
  iy <- (lat >= min(xlat)) & (lat <= max(xlat))
  lat <- lat[iy]
  X <- X[iy,,]
  d <- dim(X)

  ## Area weights - latitude
  W.lat <- matrix(rep(cos(pi*lat/180),d[2]),d[1],d[2])
  ## Prepare for fast matrix operations
  dim(X) <- c(d[1]*d[2],d[3])
  ## Z contains the global mean temperature at different vertical levels
  Z <- apply(X,2,'areamean',W.lat,d)

  ## Estimate the TLT-temperature based on the TLT weights
  data(etopo5)
  etopo5 <- subset(etopo5,is=list(lat=xlat))
  ## Weighted average of land and ocean
  nl <- sum(etopo5 >=0)/length(etopo5); no <- sum(etopo5 <0)/length(etopo5)
  W0 <- no*tlt.W$tlt.wo$Weight + nl*tlt.W$tlt.wl$Weight
  W <- approx(tlt.W$tlt.wo$P.pa.,W0,plev,rule=2)$y

  tlt <- apply(Z,2,function(x,W) sum(x*W,na.rm=TRUE)/sum(W,na.rm=TRUE),W)

  ## Use the first time stamp and the time orgigin to set the first date, and then
  ## Assume every month since that (there are monthly mean data after all)
  t1 <- as.Date(tim[1],origin = sub('days since ','',tunit$value))
  TLT <- zoo(tlt, order.by=seq(t1,by='month',length.out=length(tim)))
  attr(TLT,'model_id') <- model.id
  attr(TLT,'rcp') <- rcp
  if (sum(is.finite(tlt))==0) browser()
  return(TLT)
}
```

Download CMIP5 data from the KNMI Climate Explorer and estimate the TLT temperature. The data is stored as zonal mean temperature with the dimensions latitude and pressure-level.



Data from satellites

Get the lower tropospheric data from the RSS:

```
if (!file.exists('RSS.glob.rda')) {
  rss.glob <- read.table('http://data.remss.com/msu/graphics/TLT/time_series/RSS_TS_channel_TLT_Global_
  rss.trop <- read.table('http://data.remss.com/msu/graphics/TLT/time_series/RSS_TS_channel_TLT_Tropics
  rss.glob$V3[rss.glob$V3 <= -99] <- NA
  RSS.glob <- zoo(rss.glob$V3,order.by=as.Date(paste(rss.glob$V1,rss.glob$V2,'01',sep='-')))
  rss.trop$V3[rss.trop$V3 <= -99] <- NA
  RSS.trop <- zoo(rss.trop$V3,order.by=as.Date(paste(rss.trop$V1,rss.trop$V2,'01',sep='-')))
  save(RSS.glob,file='RSS.glob.rda')
  save(RSS.trop,file='RSS.trop.rda')
} else {load('RSS.glob.rda'); load('RSS.trop.rda')}
```

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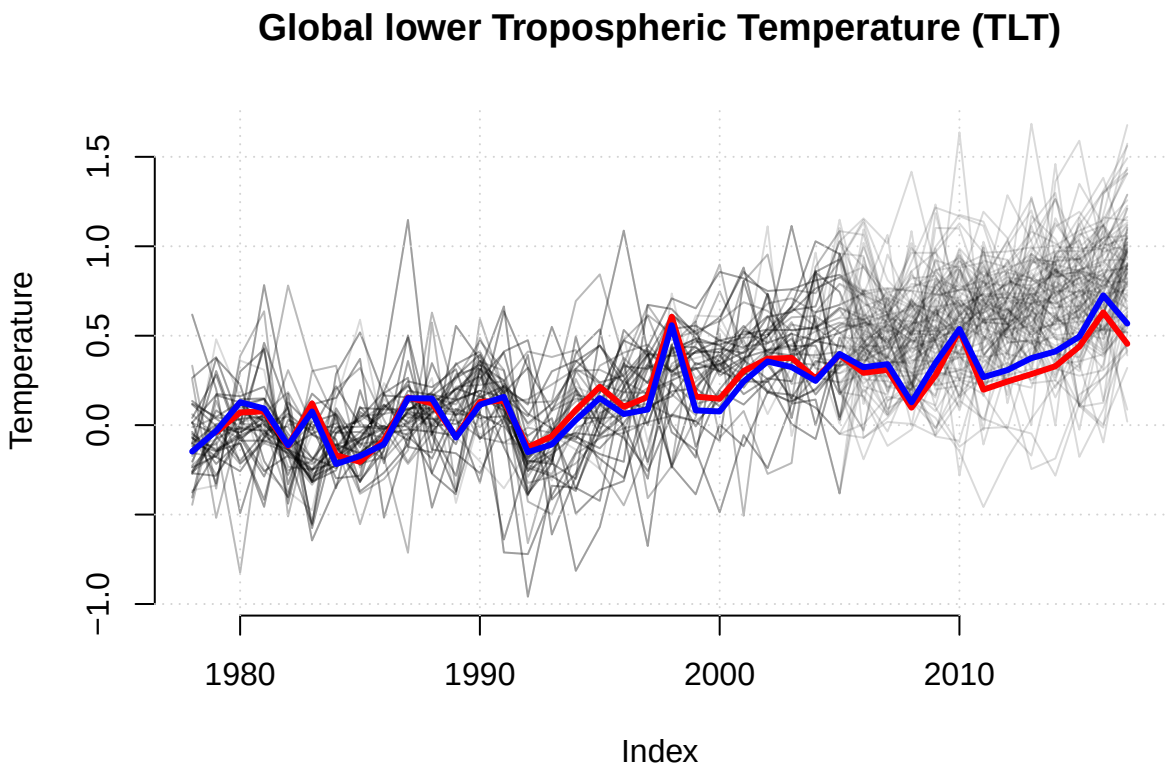
```
if (!file.exists('UAH.glob.rda')) {
  UAH <- readLines('http://www.nsstc.uah.edu/data/msu/t2lt/tltglhmam_5.6.txt')
  writeLines(UAH[-length(UAH)],con='UAHTLT.dat')
  uah <- read.table('UAHTLT.dat',skip=4,header=TRUE)
  UAH.glob <- zoo(uah$GLOBAL,order.by=as.Date(paste(uah$YEAR,uah$MON,'01',sep='-')))
  UAH.trop <- zoo(uah$TRPC,order.by=as.Date(paste(uah$YEAR,uah$MON,'01',sep='-')))
  save(UAH.glob,file='UAH.glob.rda')
  save(UAH.trop,file='UAH.trop.rda')
} else {load('UAH.glob.rda'); load('UAH.trop.rda')}
```

Comapre the data

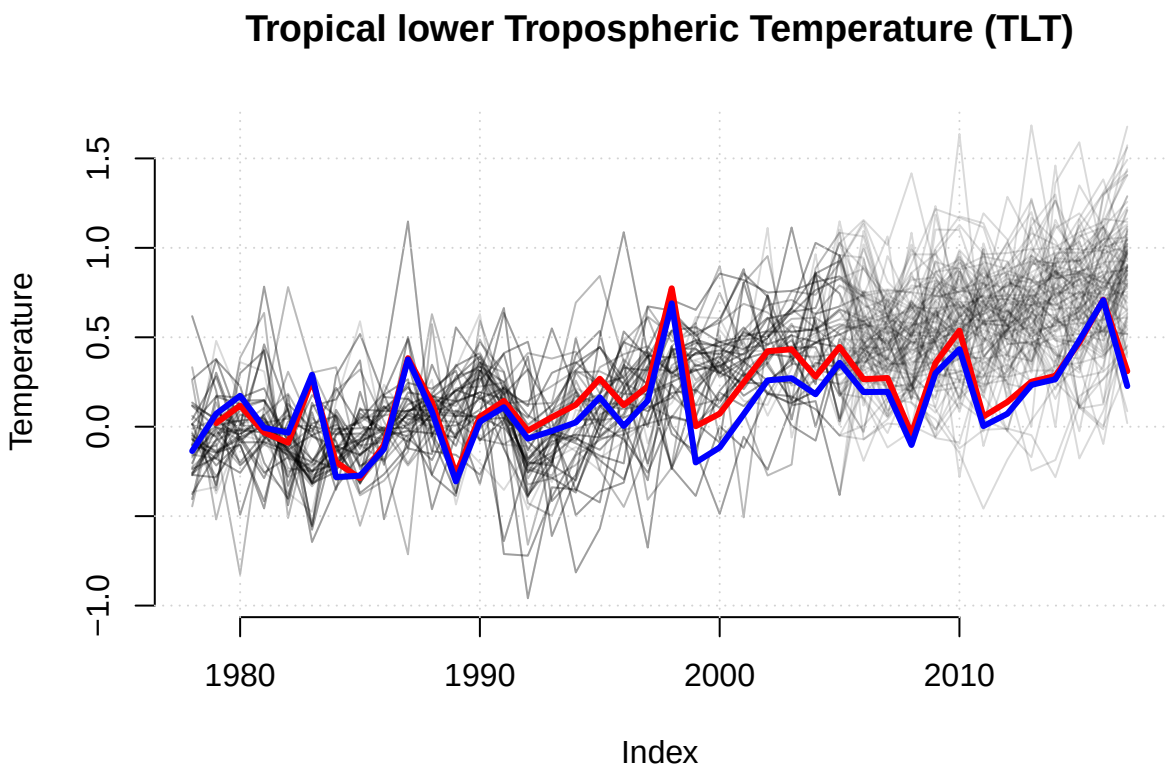
The global mean TLT temperature

```
X <- merge(annual(anomaly(RSS.glob,ref=1979:1990)),
           annual(anomaly(UAH.glob,ref=1979:1990)),
           annual(anomaly(window(tlt.cmip5$TLT.glob,start=start(RSS.glob),end=end(RSS.glob)),ref=1979:19
par(bty='n')
plot(X[,-c(1,2)],plot.type='single',col=rep(rgb(0,0,0,0.15),N),main='Global lower Tropospheric Temperatu
grid()
lines(X[,1],lwd=3,col='red')
lines(X[,2],lwd=3,col='blue')
```



The global mean TLT temperature

```
X <- merge(annual(anomaly(RSS.trop,ref=1979:1990)),
           annual(anomaly(UAH.trop,ref=1979:1990)),
           annual(anomaly(window(tlt.cmip5$TLT.trop,start=start(RSS.trop),end=end(RSS.trop)),ref=1979:19
par(bty='n')
plot(X[,-c(1,2)],plot.type='single',col=rep(rgb(0,0,0,0.15),N),main='Tropical lower Tropospheric Tempera
grid()
lines(X[,1],lwd=3,col='red')
lines(X[,2],lwd=3,col='blue')
```


Tropical lower Tropospheric Temperature (TLT)
Temperature
1.5
1.0
0.5
0.0
−1.0
1980
1990
2000
2010
Index