STA 442 A3

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Introduction

In this paper, we would like to discuss the changes of CO2 concentrations during the fall of the Berlin wall in November 1989, and the global lockdown during the COVID-19 pandemic starting in February 2020.

Methods

$$Y_i \sim \Gamma(\lambda_i, \theta_i)$$

$$log[\lambda(t)] = X_{it}\beta + f(t)$$

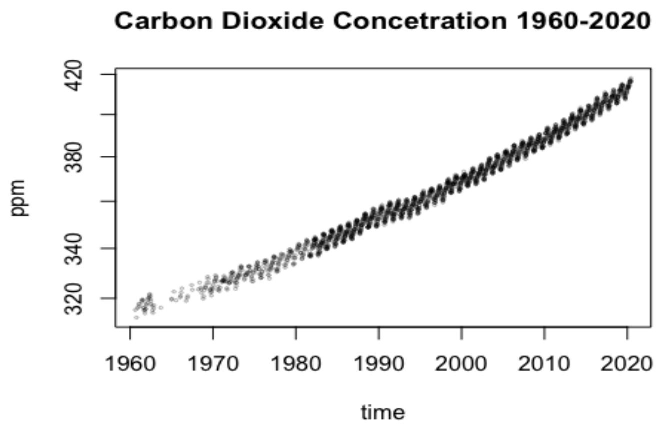
- $X_{i0} = 1$
- $X_{i1} = sin(2\pi t_i/365.25)$
- $X_{i2} = cos(2\pi t_i/365.25)$
- $X_{i3} = sin(2\pi t_i/182.625)$
- $X_{i4} = cos(2\pi t_i/182.625)$

- Y_i is the response variable that measures CO2 concentration, following a gamma distribution with Gamma(λ_i, θi), $sin(2\pi t_i)$, and $cos(2\pi t_i)$ represent the yearly fluctuations and $sin(\pi t_i)$, $cos(\pi t_i)$ represent the 6 months fluctuations, θ_i is the scalar for the gamma distribution, and f(t) is the seasonally adjusted trend following random walk 2 random effect.
- Prior for RW: slope of log rate changes by 0.1 from one year to the next.

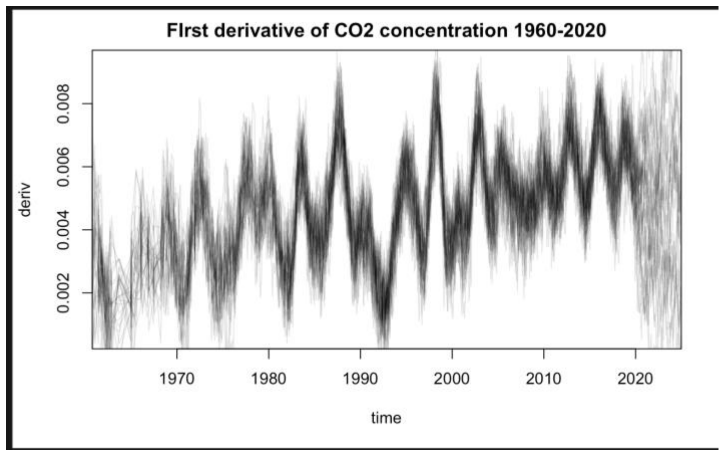
Result

- To see the change of the CO2 concentration, we first approximated the first derivative of the time trend between the whole timeline and focus on the derivative graph of 1985-1995 which, overall, has increasing trend. As you can see that there is drastic decrease from 1990 to 1993. It is sufficient visual evidence that the fall of the Berlin wall in 1989 induces the fall in industrial production so that the CO2 concentration gets on decreasing trend.
- Now we see the first derivative graph between 2018-2022. We use INLA to estimate the data after June 2020. With the confidence interval, we are not convinced that the shutting down will cause decreasing in the CO2 concentration. However, the plot still shows that the more downward trend.

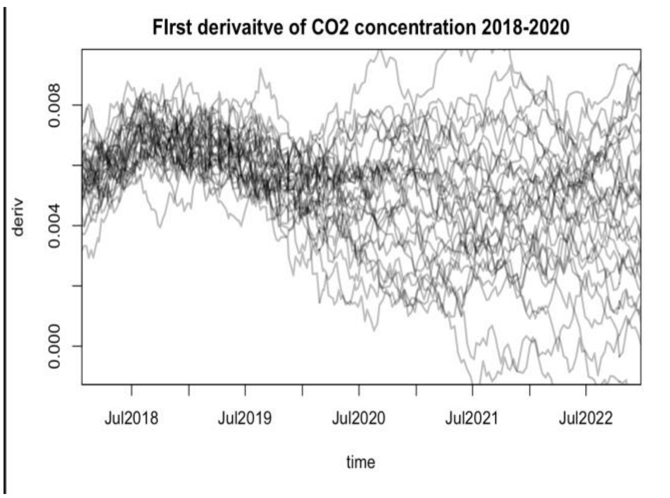
Plot



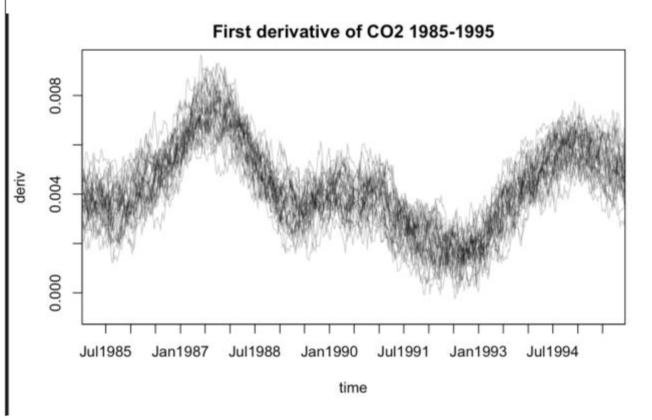
Carbon Dioxide Concetration 1960-2020
ppm
420
380
340
320
1960
1970
1980
1990
2000
2010
2020
time



FIrst derivative of CO2 concentration 1960-2020
deriv
0.002
0.004
0.006
0.008
1970
1980
1990
2000
2010
2020
time



FIrst derivaitve of CO2 concentration 2018-2020
deriv
0.000
0.004
0.008
Jul2018
Jul2019
Jul2020
Jul2021
Jul2022
time



First derivative of CO2 1985-1995
deriv
0.000
0.004
0.008
Jul1985
Jan1987
Jul1988
Jan1990
Jul1991
Jan1993
Jul1994
time

Appendix

```
cUrl = paste0("http://scrippsco2.ucsd.edu/assets/data/atmospheric/", "stations/flask_co2/daily/daily_flask_co2_mlo.csv")
cFile = basename(cUrl)
if (!file.exists(cFile)) download.file(cUrl, cFile)
co2s = read.table(cFile, header = FALSE, sep = ",",
skip = 69, stringsAsFactors = FALSE, col.names = c("day", "time", "junk1", "junk2", "Nflasks", "quality", "co2"))
co2s$date = strptime(paste(co2s$day, co2s$time), format = "%Y-%m-%d %H:%M", tz = "UTC")
# remove low-quality measurements
co2s = co2s[co2s$quality == 0, ]
plot(co2s$date, co2s$co2, log = "y", cex = 0.3, col = "#00000040", xlab = "time", ylab = "ppm")
```

```
plot(co2s[co2s$date > ISOdate(2015, 3, 1, tz = "UTC"), c("date", "co2")], log = "y", type = "o", xlab = "time", ylab = "ppm", cex = 0.5)

co2s$day = as.Date(co2s$date)
toAdd = data.frame(day = seq(max(co2s$day) + 3, as.Date("2025/1/1"),
by = "10 days"), co2 = NA)
co2ext = rbind(co2s[, colnames(toAdd)], toAdd)
timeOrigin = as.Date("2000/1/1")
co2ext$timeInla = round(as.numeric(co2ext$day - timeOrigin)/365.25,
2)

co2ext$cos12 = cos(2 * pi * co2ext$timeInla)

co2ext$sin12 = sin(2 * pi * co2ext$timeInla)

co2ext$cos6 = cos(2 * 2 * pi * co2ext$timeInla)

co2ext$sin6 = sin(2 * 2 * pi * co2ext$timeInla)

library('INLA', verbose=FALSE)

mm = get("inla.models", INLA:::inla.get.inlaEnv())

if(class(mm) == 'function') mm = mm()

mm$latent$rw2$min.diff = NULL

assign("inla.models", mm, INLA:::inla.get.inlaEnv())

co2res = inla(co2 ~ sin12 + cos12 + sin6 + cos6 + f(timeInla, model = 'rw2',
```

```
                                                                prior='pc.prec', param = c(0.1, 0.5))
, data = co2ext, family='gamma', control.family = list(hyper=list(prec=list(
                                                                  prior='pc.prec', param=c(0.1, 0.5))
)),

                 control.inla = list(strategy='gaussian'),

                 control.predictor = list(compute=TRUE, link=1), control.compute = list(conf
ig=TRUE), verbose=FALSE)

qCols = c('0.5quant','0.025quant','0.975quant')

Pmisc::priorPost(co2res)$summary[,qCols]

co2res$summary.fixed[,qCols] if (!requireNamespace("BiocManager", quietly = TRUE))
    install.packages("BiocManager")

BiocManager::install("Biobase")aas

sampleMean = do.call(cbind, Biobase::subListExtract(sampleList, "latent"))

sampleDeriv = apply(sampleMean, 2, diff)/diff(co2res$summary.random$timeInla$ID)

matplot(co2ext$day, co2res$summary.fitted.values[, qCols], type = "l", col = "black", lty
 = c(1, 2, 2), log = "y", xlab = "time", ylab = "ppm")

Stime = timeOrigin + round(365.25 * co2res$summary.random$timeInla$ID)

matplot(Stime[-1], sampleDeriv, type = "l", lty=1, xaxs = "i", col = "#00000020", xlab =
"time", ylab = "deriv",ylim = quantile(sampleDeriv, c(0.01, 0.995)), main= "FIrst derivat
ive of CO2 concentration 1960-2020")



forX = as.Date(c("2018/1/1", "2023/1/1"))

forX = seq(forX[1], forX[2], by = "6 months")

toPlot = which(Stime > min(forX) & Stime < max(forX))

matplot(Stime[toPlot], sampleDeriv[toPlot, ], type = "l",

lty = 1, lwd = 2, xaxs = "i", col = "#00000050",

xlab = "time", ylab = "deriv", xaxt = "n", ylim = quantile(sampleDeriv[toPlot,

], c(0.01, 0.995)),main = "FIrst derivaitve of CO2 concentration 2018-2020")

axis(1, as.numeric(forX), format(forX, "%b%Y"))

forY = as.Date(c("1985/1/1", "1996/1/1"))

forY = seq(forY[1], forY[2], by = "6 months")

toPlot1 = which(Stime > min(forY) & Stime < max(forY))

matplot(Stime[toPlot1], sampleDeriv[toPlot1, ], type = "l",

lty = 1, lwd = 1, xaxs = "i", col = "#00000040",
```

```
xlab = "time", ylab = "deriv", xaxt = "n", ylim = quantile(sampleDeriv[toPlot,
], c(0.01, 0.995)), main = "First derivative of CO2 1985-1995")
axis(1, as.numeric(forY), format(forY, "%b%Y"))
```