

Various GLGM examples

Patrick Brown

March 18, 2024

This vignette is a bunch of examples, its primary purpose is to test the glgm function.

The data

```
library("geostatsp")

## Loading required package: Matrix

## Loading required package: terra

## terra 1.7.71

##
## Attaching package: 'terra'

## The following object is masked from 'package:knitr':
##
##      spin

data('swissRain')
swissRain = unwrap(swissRain)
swissAltitude = unwrap(swissAltitude)
swissBorder = unwrap(swissBorder)
swissRain$lograin = log(swissRain$rain)

swissAltitudeCrop = mask(swissAltitude,swissBorder)

    number of cells... smaller is faster but less interesting

if(!exists('fact')) fact = 1
fact

## [1] 1

(Ncell = round(25*fact))
```

```
## [1] 25
```

model with standard formula

```
swissFit = geostatsp::glgm(  
  formula = lograin~ CHE_alt,  
  data = swissRain,  
  grid = Ncell,  
  buffer = 10*1000,  
  covariates=swissAltitudeCrop,  
  family="gaussian",  
  prior = list(  
    sd=c(1,0.5),  
    sdObs = 1,  
    range=c(500000, 0.5)),  
  control.inla = list(strategy='gaussian')  
)
```

parameters

```
if(length(swissFit$parameters)) {  
  knitr::kable(swissFit$parameters$summary[,c(1,3,5)], digits=3)  
} else {  
  print("INLA was not run, install the INLA package to see results")  
}
```

```
## [1] "INLA was not run, install the INLA package to see results"
```

Exceedance probabilities

```
if(length(swissFit$parameters)) {  
  swissExc = excProb(  
    x=swissFit, random=TRUE,  
    threshold=0)  
}  
  
if(length(swissFit$parameters)) {  
  plot(swissExc, breaks = c(0, 0.2, 0.8, 0.95, 1.00001),  
    col=c('green','yellow','orange','red'))  
  
  plot(swissBorder, add=TRUE)  
  
  swissExcP = excProb(  
    swissFit$inla$marginals.predict, 3,  
    template=swissFit$raster)
```

```

plot(swissExcP, breaks = c(0, 0.2, 0.8, 0.95, 1.00001),
     col=c('green','yellow','orange','red'))
plot(swissBorder, add=TRUE)

matplot(
  swissFit$parameters$sd$posterior[, 'x'],
  swissFit$parameters$sd$posterior[, c('y', 'prior')],
  lty=1, col=c('black', 'red'), type='l',
  xlab='sd', ylab='dens', xlim = c(0,5))

matplot(
  swissFit$parameters$range$posterior[, 'x'],
  swissFit$parameters$range$posterior[, c('y', 'prior')],
  lty=1, col=c('black', 'red'), type='l',
  xlab='range', ylab='dens')
}

non-parametric elevation effect

altSeq = exp(seq(
  log(100), log(5000),
  by = log(2)/5))
altMat = cbind(altSeq[-length(altSeq)], altSeq[-1], seq(1,length(altSeq)-1))

swissAltCut = classify(
  swissAltitudeCrop,
  altMat
)
names(swissAltCut) = 'bqrnt'

swissFitNp = geostatsp::glgm(
  formula = lograin ~ f(bqrnt, model = 'rw2', scale.model=TRUE,
    values = 1:length(altSeq),
    prior = 'pc.prec', param = c(0.1, 0.01)),
  data=swissRain,
  grid = Ncell,
  covariates=swissAltCut,
  family="gaussian", buffer=20000,
  prior=list(
    sd=c(u = 0.5, alpha = 0.1),
    range=c(50000,500000),
    sdObs = c(u=1, alpha=0.4)),
  control.inla=list(strategy='gaussian')
)

```

```

if(length(swissFitNp$parameters)) {
  knitr::kable(swissFitNp$parameters$summary, digits=3)

  matplot(
    altSeq,
    exp(swissFitNp$inla$summary.random$bqrnt[,
      c('0.025quant', '0.975quant', '0.5quant')]),
    log='xy',
    xlab='elevation', ylab='rr',
    type='l',
    lty = 1,
    col=c('grey','grey','black')
  )

  swissExcP = excProb(swissFitNp$inla$marginals.predict,
    3, template=swissFitNp$raster)
  plot(swissExcP, breaks = c(0, 0.2, 0.8, 0.95, 1.00001),
    col=c('green','yellow','orange','red'))
  plot(swissBorder, add=TRUE)
}

```

intercept only, named response variable. legacy priors

```

swissFit = geostatsp::glgm("lograin", swissRain, Ncell,
  covariates=swissAltitude, family="gaussian", buffer=20000,
  priorCI=list(sd=c(0.2, 2), range=c(50000,500000), sdObs = 2),
  control.inla=list(strategy='gaussian')
)
if(length(swissFit$parameters))
  knitr::kable(swissFit$parameters$summary[,c(1, 3:5, 8)], digits=4)

```

intercept only, add a covariate just to confuse glgm.

```

swissFit = geostatsp::glgm(
  formula=lograin~1,
  data=swissRain,
  grid=Ncell,
  covariates=swissAltitude,
  family="gaussian", buffer=20000,
  priorCI=list(sd=c(0.2, 2), range=c(50000,500000)),
  control.inla=list(strategy= 'gaussian'),
  control.family=list(hyper=list(prec=list(prior="loggamma", param=c(.1, .1))))
)

if(length(swissFit$parameters)) {

```

```
knitr::kable(swissFit$parameters$summary[,c(1, 3:5, 8)], digits=3)

swissExc = excProb(
  swissFit$inla$marginals.random$space, 0,
  template=swissFit$raster)
plot(swissExc, breaks = c(0, 0.2, 0.8, 0.95, 1.00001),
  col=c('green','yellow','orange','red'))
plot(swissBorder, add=TRUE)

matplot(
  swissFit$parameters$range$posterior[, 'x'],
  swissFit$parameters$range$posterior[, c('y', 'prior')],
  lty=1, col=c('black','red'), type='l',
  xlab='range', ylab='dens')
}
```

covariates are in data

```
newdat = swissRain
newdat$elev = extract(swissAltitude, swissRain, ID=FALSE)
swissLandType = unwrap(swissLandType)
swissFit = geostatsp::glgm(lograin~ elev + land,
  newdat, Ncell,
  covariates=list(land=swissLandType),
  family="gaussian", buffer=40000,
  priorCI=list(sd=c(0.2, 2), range=c(50000,500000)),
  control.inla = list(strategy='gaussian'),
  control.family=list(hyper=list(prec=list(prior="loggamma",
    param=c(.1, .1))))
)

if(length(swissFit$parameters)) {
knitr::kable(swissFit$parameters$summary, digits=3)

plot(swissFit$raster[['predict.mean']])
plot(swissBorder, add=TRUE)

matplot(
  swissFit$parameters$range$posterior[, 'x'],
  swissFit$parameters$range$posterior[, c('y', 'prior')],
  lty=1, col=c('black','red'), type='l',
  xlab='range', ylab='dens')
}
```

formula, named list elements

```

swissFit = geostatsp::glgm(lograin~ elev,
  swissRain, Ncell,
  covariates=list(elev=swissAltitude),
  family="gaussian", buffer=20000,
  priorCI=list(sd=c(0.2, 2), range=c(50000,500000)),
  control.mode=list(theta=c(1.9,0.15,2.6),restart=TRUE),
  control.inla = list(strategy='gaussian'),
  control.family=list(hyper=list(prec=list(prior="loggamma",
    param=c(.1, .1))))
)
if(length(swissFit$parameters))
  swissFit$parameters$summary[,c(1,3,5)]

categorical covariates

swissFit = geostatsp::glgm(
  formula = lograin ~ elev + factor(land),
  data = swissRain, grid = Ncell,
  covariates=list(elev=swissAltitude,land=swissLandType),
  family="gaussian", buffer=20000,
  prior=list(sd=c(0.2, 0.5), range=c(100000,0.5)),
  control.inla=list(strategy='gaussian'),
  control.family=list(hyper=list(
    prec=list(prior="loggamma",
      param=c(.1, .1))))
)
if(length(swissFit$parameters)) {

  knitr::kable(swissFit$parameters$summary[,c(1,3,5)], digits=3)

  plot(swissFit$raster[['predict.mean']])
  plot(swissBorder, add=TRUE)

  matplot(
    swissFit$parameters$range$posterior[, 'x'],
    swissFit$parameters$range$posterior[,c('y','prior')],
    lty=1, col=c('black','red'), type='l',
    xlab='range', ylab='dens')
}

```

put some missing values in covaritates also dont put factor() in formula

```

temp = values(swissAltitude)
temp[seq(10000,12000)] = NA
values(swissAltitude) = temp

```

```

swissFitMissing = geostatsp::glgm(rain ~ elev + land,swissRain, Ncell,
  covariates=list(elev=swissAltitude,land=swissLandType),
  family="gaussian", buffer=20000,
  prior=list(sd=c(0.2, 0.5), range=c(100000,0.5)),
  control.inla = list(strategy='gaussian'),
  control.family=list(hyper=list(prec=list(prior="loggamma",
    param=c(.1, .1))))
)
if(length(swissFitMissing$parameters))
  knitr::kable(swissFitMissing$parameters$summary[,1:5], digits=3)

covariates in data, factors

newdat = swissRain
newdat$landOrig = extract(swissLandType, swissRain, ID=FALSE)
newdat$landRel = relevel(newdat$landOrig, 'Mixed forests')

swissFit = geostatsp::glgm(
  formula = lograin~ elev + landOrig,
  data=newdat,
  covariates=list(elev = swissAltitude),
  grid=geostatsp::squareRaster(swissRain,Ncell),
  family="gaussian", buffer=0,
  prior=list(sd=c(0.2, 0.5), range=c(100000,0.5)),
  control.inla = list(strategy='gaussian'),
  control.family=list(hyper=list(prec=list(prior="loggamma",
    param=c(.1, .1))))
)

swissFitR = geostatsp::glgm(
  formula = lograin~ elev + landRel,
  data=newdat,
  grid=geostatsp::squareRaster(swissRain,Ncell),
  covariates=list(elev = swissAltitude, landRel = swissLandType),
  family="gaussian", buffer=0,
  prior=list(sd=c(0.2, 0.5), range=c(100000,0.5)),
  control.inla = list(strategy='gaussian'),
  control.family=list(hyper=list(prec=list(prior="loggamma",
    param=c(.1, .1))))
)

levels(newdat$landOrig)

## [1] "Water bodies" "Evergreen needleleaf forest"
## [3] "Evergreen broadleaf forest" "Deciduous needleleaf forest"

```

```

## [5] "Deciduous broadleaf forest"      "Mixed forests"
## [7] "Closed shrublands"               "Open shrublands"
## [9] "Woody savannas"                  "Savannas"
## [11] "Grasslands"                     "Permanent Wetlands"
## [13] "Croplands"                      "Urban and built-up"
## [15] "Cropland/natural vegetation mosaic" "Snow and ice"
## [17] "Barren or sparsely vegetated"

levels(newdat$landRel)

## [1] "Mixed forests"                  "Water bodies"
## [3] "Evergreen needleleaf forest"    "Evergreen broadleaf forest"
## [5] "Deciduous needleleaf forest"    "Deciduous broadleaf forest"
## [7] "Closed shrublands"              "Open shrublands"
## [9] "Woody savannas"                 "Savannas"
## [11] "Grasslands"                    "Permanent Wetlands"
## [13] "Croplands"                     "Urban and built-up"
## [15] "Cropland/natural vegetation mosaic" "Snow and ice"
## [17] "Barren or sparsely vegetated"

if(length(swissFit$parameters)) {
  levels(swissFit$inla$.args$data$landOrig)
  levels(swissFitR$inla$.args$data$landRel)
}

if(length(swissFit$parameters)) {
  knitr::kable(swissFit$parameters$summary[,c(1,3,5)], digits=3)
  knitr::kable(swissFitR$parameters$summary[,c(1,3,5)], digits=3)
}

covariates are in data, interactions

newdat = swissRain
newdat$elev = extract(swissAltitude, swissRain, ID=FALSE)

swissFit = geostatsp::glgm(
  formula = lograin~ elev : land,
  data=newdat,
  grid=geostatsp::squareRaster(swissRain,Ncell),
  covariates=list(land=swissLandType),
  family="gaussian", buffer=0,
  prior=list(sd=c(0.2, 0.5), range=c(100000,0.5)),
  control.inla = list(strategy='gaussian'),
  control.family=list(hyper=list(prec=list(prior="loggamma",
    param=c(.1, .1))))
)

```



```

if(length(swissFit$parameters)) {
  knitr::kable(swissFit$parameters$summary[,c(1,3,5)], digits=3)
}

if(length(swissFit$parameters)) {
  plot(swissFit$raster[['predict.mean']])
  plot(swissBorder, add=TRUE)

  matplot(
    swissFit$parameters$range$posterior[, 'x'],
    swissFit$parameters$range$posterior[, c('y', 'prior')],
    lty=1, col=c('black', 'red'), type='l',
    xlab='range', ylab='dens')
}

categorical tests

data('loaloa')
loaloa = unwrap(loaloa)
ltLoa = unwrap(ltLoa)
elevationLoa = unwrap(elevationLoa)
eviLoa = unwrap(eviLoa)

rcl = rbind(
  # wetlands and mixed forests to forest
  c(5,2), c(11,2),
# savannas to woody savannas
  c(9,8),
  # croplands and urban changed to crop/natural mosaic
  c(12,14), c(13,14))
ltLoaR = classify(ltLoa, rcl)
levels(ltLoaR) = levels(ltLoa)

elevationLoa = elevationLoa - 750
elevLow = min(elevationLoa, 0)
elevHigh = max(elevationLoa, 0)

eviLoa2 = (eviLoa - 1e7)/1e6

covList = list(elLow = elevLow, elHigh = elevHigh,
  land = ltLoaR, evi=eviLoa2)

loaFit = geostatsp::glgm(
  y ~ 1 + land + evi + elHigh + elLow +
  f(villageID, prior = 'pc.prec', param = c(log(2), 0.5),

```

```

        model="iid"),
    loaloa,
    Ncell,
    covariates=covList,
    family="binomial", Ntrials = loaloa$N,
    shape=2, buffer=25000,
    prior = list(
        sd=log(2),
        range = 100*1000),
    control.inla = list(strategy='gaussian')
)

if(length(loaFit$parameters)) {
  knitr::kable(loaFit$par$summary[,c(1,3,5)], digits=3)
}

if(length(loaFit$parameters)) {
  plot(loaFit$raster[['predict.exp']])

matplot(
  loaFit$parameters$range$posterior[, 'x'],
  loaFit$parameters$range$posterior[, c('y', 'prior')],
  lty=1, col=c('black', 'red'), type='l',
  xlab='range', ylab='dens')
}

prior for observation standard deviation

swissFit = geostatsp::glgm( formula="lograin", data=swissRain, grid=Ncell,
  covariates=swissAltitude, family="gaussian", buffer=20000,
  prior=list(sd=0.5, range=200000, sdObs=1),
  control.inla = list(strategy='gaussian')
)

```

no data checks

a model with little data, posterior should be same as prior

```

data2 = vect(cbind(c(1,0), c(0,1)),
  atts=data.frame(y=c(0,0), offset=c(-50,-50), x=c(-1,1)),
  crs = '+proj=merc')

```

```

resNoData = res = geostatsp::glgm(
  data=data2, grid=Ncell,

```

```

    formula=y~1 + x+offset(offset),
    prior = list(sd=0.5, range=0.1),
    family="poisson",
    buffer=0.5,
    control.fixed=list(
      mean.intercept=0, prec.intercept=1,
      mean=0,prec=4),
    control.mode = list(theta = c(0.651, 1.61), restart=TRUE),
    control.inla = list(strategy='gaussian')
  )

if(length(res$parameters)) {
# beta
plot(res$inla$marginals.fixed[['x']], col='blue', type='l',
      xlab='beta',lwd=3)
xseq = res$inla$marginals.fixed[['x']][,'x']
lines(xseq, dnorm(xseq, 0, 1/2),col='red',lty=2,lwd=3)
legend("topright", col=c("blue","red"),lty=1,legend=c("prior","post'r"))

# sd
matplot(
  res$parameters$sd$posterior[, 'x'],
  res$parameters$sd$posterior[,c('y','prior')],
  xlim = c(0, 4),
  type='l', col=c('red','blue'),xlab='sd',lwd=3, ylab='dens')
legend("topright", col=c("blue","red"),lty=1,legend=c("prior","post'r"))

# range
matplot(
  res$parameters$range$posterior[, 'x'],
  res$parameters$range$posterior[,c('y','prior')],
  xlim = c(0, 1.5),
  type='l', col=c('red','blue'),xlab='range',lwd=3, ylab='dens')
legend("topright", col=c("blue","red"),lty=1,legend=c("prior","post'r"))

  matplot(
    res$parameters$scale$posterior[, 'x'],
    res$parameters$scale$posterior[,c('y','prior')],
    xlim = c(0, 2/res$parameters$summary['range','0.025quant']),
#    ylim = c(0, 10^(-3)), xlim = c(0,1000),
    type='l', col=c('red','blue'),xlab='scale',lwd=3, ylab='dens')
  legend("topright", col=c("red","blue"),lty=1,legend=c("post'r","prior"))
}

```

```

resQuantile = res = geostatsp::glgm(
  data=data2,
  grid=25,
  formula=y~1 + x+offset(offset),
  prior = list(
    sd=c(lower=0.2, upper=2),
    range=c(lower=0.02, upper=0.5)),
  family="poisson", buffer=1,
  control.fixed=list(
    mean.intercept=0, prec.intercept=1,
    mean=0,prec=4),
  control.inla = list(strategy='gaussian')
)

if(length(res$parameters)) {
# beta
plot(res$inla$marginals.fixed[['x']], col='blue', type='l',
  xlab='beta',lwd=3)
xseq = res$inla$marginals.fixed[['x']][,'x']
lines(xseq, dnorm(xseq, 0, 1/2),col='red',lty=2,lwd=3)
legend("topright", col=c("blue","red"),lty=1,legend=c("prior","post'r"))

# sd
matplot(
  res$parameters$sd$posterior[, 'x'],
  res$parameters$sd$posterior[,c('y','prior')],
  xlim = c(0, 4),
  type='l', col=c('red','blue'),xlab='sd',lwd=3, ylab='dens')
legend("topright", col=c("blue","red"),lty=1,legend=c("prior","post'r"))

# range
matplot(
  res$parameters$range$posterior[, 'x'],
  res$parameters$range$posterior[,c('y','prior')],
  xlim = c(0, 1.2*res$parameters$summary['range','0.975quant']),
#   xlim = c(0, 1), ylim = c(0,5),
  type='l', col=c('red','blue'),xlab='range',lwd=3, ylab='dens')
legend("topright", col=c("red","blue"),lty=1,legend=c("post'r","prior"))

# scale
matplot(
  res$parameters$scale$posterior[, 'x'],
  res$parameters$scale$posterior[,c('y','prior')],
  xlim = c(0, 2/res$parameters$summary['range','0.025quant']),

```

```
#      ylim = c(0, 10^(-3)), xlim = c(0,1000),
      type='l', col=c('red','blue'),xlab='scale',lwd=3, ylab='dens')
      legend("topright", col=c("red","blue"),lty=1,legend=c("post'r","prior"))
}
```

No data, legacy priors

```
resLegacy = res = geostatsp::glgm(data=data2,
  grid=20,
  formula=y~1 + x+offset(offset),
  priorCI = list(
    sd=c(lower=0.3,upper=0.5),
    range=c(lower=0.25, upper=0.4)),
  family="poisson",
  buffer=0.5,
  control.fixed=list(
    mean.intercept=0,
    prec.intercept=1,
    mean=0, prec=4),
  control.inla = list(strategy='gaussian'),
  control.mode=list(theta=c(2, 2),restart=TRUE)
)

if(length(res$parameters)) {
# intercept
plot(res$inla$marginals.fixed[['(Intercept)']], col='blue', type='l',
  xlab='intercept',lwd=3)
xseq = res$inla$marginals.fixed[['(Intercept)']][,'x']
lines(xseq, dnorm(xseq, 0, 1),col='red',lty=2,lwd=3)
legend("topright", col=c("blue","red"),lty=1,legend=c("prior","post'r"))

# beta
plot(res$inla$marginals.fixed[['x']], col='blue', type='l',
  xlab='beta',lwd=3)
xseq = res$inla$marginals.fixed[['x']][,'x']
lines(xseq, dnorm(xseq, 0, 1/2),col='red',lty=2,lwd=3)
legend("topright", col=c("blue","red"),lty=1,legend=c("prior","post'r"))

# sd
matplot(
  res$parameters$sd$posterior[, 'x'],
  res$parameters$sd$posterior[, c('y','prior')],
  type='l', col=c('red','blue'),xlab='sd',lwd=3, ylab='dens')
legend("topright", col=c("blue","red"),lty=1,legend=c("prior","post'r"))
```

```
# range
  matplot(
    res$parameters$range$posterior[, 'x'],
    res$parameters$range$posterior[, c('y', 'prior')],
    type='l', col=c('red', 'blue'), xlab='range', lwd=3, ylab='dens')
  legend("topright", col=c("blue", "red"), lty=1, legend=c("prior", "post'r"))
}
```

specifying spatial formula

```
swissRain$group = 1+rbinom(length(swissRain), 1, 0.5)
theGrid = geostatsp::squareRaster(swissRain, Ncell, buffer=10*1000)
```

```
swissFit = geostatsp::glgm(
  formula = rain ~ 1,
  data=swissRain,
  grid=theGrid,
  family="gaussian",
  spaceFormula = ~ f(space, model='matern2d',
    nrow = nrow(theGrid), ncol = ncol(theGrid),
    nu = 1, replicate = group),
  control.inla = list(strategy='gaussian'),
)
```

```
if(length(swissFit$parameters)) {
  swissFit$rasterTwo = setValues(
    rast(swissFit$raster, nlyrs=2),
    as.matrix(swissFit$inla$summary.random$space[
      ncell(theGrid)+values(swissFit$raster[['space']]),
      c('mean', '0.5quant')]))
  plot(swissFit$raster[['random.mean']])

  plot(swissFit$rasterTwo[['mean']])
}
```