Q1: Are lake and terrestrial primary productivity coherent?

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This document organizes for openness and reproducibility analyses of the temporal coherence of interannual variation in lake primary productivity with terrestrial primary productivity in the landscape surrounding the lake.

Data import

Data produced in 'ms1__prep.Rmd' are loaded.

```
load("~/Box Sync/NSF EAGER Synchrony/Data/RData files/ms1_analysis_inprogress1_v10873_2.RData")
```

```
any(sapply(analysislakes$lakedata, function(x){any(is.infinite(x))}))
```

```
## [1] FALSE
```

```
any(sapply(analysislakes$lakedata, function(x){any(is.na(x))}))
```

```
## [1] TRUE
```

```
which(sapply(analysislakes$lakedata, function(x){any(is.na(x))}))
```

```
## 7545 7790 7970 8271
##   70   72   76   77
```

```
analysislakes$lakeinfo[which(sapply(analysislakes$lakedata, function(x){any(is.na(x))})),]
```

```
##      lagoslakeid         gnis_name  nhd_lat  nhd_long lake_area_ha
## 7445        7545        Alton Pond 41.44294 -71.71835    17.843701
## 7689        7790     Watchaug Pond 41.38381 -71.69161   232.391660
## 7867        7970       Yawgoo Pond 41.51113 -71.57300    60.724131
## 8165        8271 Meadow Brook Pond 41.44110 -71.69034     9.808244
##      lake_perim_meters nhd_ftype nhd_fcode hu4_zoneid hu12_zoneid
## 7445          3746.121       390     39004     HU4_10  HU12_16347
## 7689          8397.096       390     39010     HU4_10  HU12_17513
## 7867          3195.857       390     39010     HU4_10  HU12_17512
## 8165          2030.864       390     39004     HU4_10  HU12_17513
##      state_zoneid elevation_m start  end
## 7445      State_8     14.3702  1989 2010
## 7689      State_8     11.1300  1989 2010
## 7867      State_8     36.1000  1989 2010
## 8165      State_8     16.2900  1989 2010
```

```
dbuff[which(sapply(analysislakes$lakedata, function(x){any(is.na(x))}))]
```

```
## [1] 2500.000 4939.589 2500.000 2500.000
```

```
analysislakes$lakeinfo<-analysislakes$lakeinfo[!sapply(analysislakes$lakedata, function(x){any(is.na(x)
analysislakes$lakedata<-analysislakes$lakedata[!sapply(analysislakes$lakedata, function(x){any(is.na(x)
```

```r
analysislakes$lakeinfo$tslength<-analysislakes$lakeinfo$end-analysislakes$lakeinfo$start+1
```

```r
source("~/GitHub/AquaTerrSynch/AnalysisCode/bandtest_coh.R")

tsranges<-rbind(c(2,4),c(4,Inf),c(2,Inf))

coh.chlaXaccndvi<-NULL

for(lind in 1:length(analysislakes$lakedata)){
  lakedat.ii<-cleandat(analysislakes$lakedata[[lind]], as.numeric(colnames(analysislakes$lakedata[[lind
  chlaXaccndvi<-coh(lakedat.ii[1,], lakedat.ii[2,], as.numeric(colnames(analysislakes$lakedata[[lind]])
                    norm="powall", sigmethod="fast", nrand=10000)
  for(rind in 1:nrow(tsranges)){
    chlaXaccndvi<-bandtest.coh(chlaXaccndvi, tsranges[rind,])
  }
  coh.chlaXaccndvi<-rbind(coh.chlaXaccndvi, c(t(as.matrix(chlaXaccndvi$bandp[,3:5]))))
}

coh.chlaXaccndvi<-as.data.frame(coh.chlaXaccndvi)

colnames(coh.chlaXaccndvi)<-paste0("accndvi",c("p.ts1","phi.ts1","coh.ts1","p.ts2","phi.ts2","coh.ts2",

coh.chlaXaccndvi$lagoslakeid<-analysislakes$lakeinfo$lagoslakeid
```

```r
tmax=50
res=0.1
tt=seq(1,tmax,res)

p1<-2
sig1<-sin(seq(0,2*pi*tmax/p1,length.out=length(tt)))
p2<-10
sig2<-sin(seq(0,2*pi*tmax/p2,length.out=length(tt)))

comb1<-sig1+0.7*sig2+3.5
comb2<-sig1+-0.7*sig2


laymat<-matrix(1,nrow=2,ncol=3)
laymat[2,]<-2:4

sig3<-sig2[tt<=20]
sig4<-sig3*0.9
sig5<-sin(seq(-pi/2,2*pi*20/p2-(pi/2),length.out=length(tt[tt<=20])))
sig6<-sig3*-1

tiff("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig1_pedagogical.tif", uni
     res=300, width=6.5, height=4)

layout(laymat)
par(mar=c(1.5,1.5,2,1.5), mgp=c(1,1,0), oma=c(2,2,0,0))

plot(NA,NA,ylim=c(-2,5.2),xlim=range(tt), xlab="", ylab="", xaxt="n",yaxt="n")
lines(tt,comb1,lwd=2)
```

```
lines(tt,comb2,lwd=2,col="red")
axis(1, at=c(0,10,20,30,40,50),labels=NA)
axis(2, at=c(-1,1.5,4), labels=NA)
mtext("Timescale specific relationship",3,line=0.25)
text(0.4,4.9,"a)",cex=1.2)

plot(NA,NA,ylim=c(-1,1),xlim=c(0,20),xaxt="n",yaxt="n",xlab="",ylab="")
axis(1, at=c(0,10,20), labels=NA)
axis(2, at=c(-1,0,1), labels=NA)
lines(tt[tt<=20],sig3,lwd=2)
lines(tt[tt<=20],sig4,lwd=2,col="red")
mtext(expression(paste(phi," = 0")))
text(1,0.9,"b)",cex=1.2)

plot(NA,NA,ylim=c(-1,1),xlim=c(0,20),xaxt="n",yaxt="n",xlab="",ylab="")
axis(1, at=c(0,10,20), labels=NA)
axis(2, at=c(-1,0,1), labels=NA)
lines(tt[tt<=20],sig3,lwd=2)
lines(tt[tt<=20],sig5,lwd=2,col="red")
mtext(expression(paste(phi," = ",pi,"/2")))
text(1,0.9,"c)",cex=1.2)

plot(NA,NA,ylim=c(-1,1),xlim=c(0,20),xaxt="n",yaxt="n",xlab="",ylab="")
axis(1, at=c(0,10,20), labels=NA)
axis(2, at=c(-1,0,1), labels=NA)
lines(tt[tt<=20],sig3,lwd=2)
lines(tt[tt<=20],sig6,lwd=2,col="red")
mtext(expression(paste(phi," = ",pi)))
text(1,0.9,"d)",cex=1.2)

mtext("Time", 1, outer=T)
mtext("Signal", 2, outer=T)

dev.off()
```

```
## pdf
##   2
```

```
#short timescales
quantile(coh.chlaXaccndvi$accndvicoh.ts1)
```

```
##         0%        25%        50%        75%       100%
## 0.06293777 0.26880179 0.36586451 0.49214074 0.92134749
```

```
alpha=0.05
sum(coh.chlaXaccndvi$accndvip.ts1<alpha)/nrow(coh.chlaXaccndvi)
```

```
## [1] 0.06870229
```

```
print(cbind(coh.chlaXaccndvi$lagoslakeid, coh.chlaXaccndvi$accndvip.ts1)[coh.chlaXaccndvi$accndvip.ts1<
```

```
##         [,1]       [,2]
##  [1,]   2851 0.03249675
##  [2,]   3370 0.00009999
##  [3,]   6075 0.04199580
##  [4,]   6547 0.00809919
```

```
## [5,]   7523 0.02039796
## [6,]  28836 0.00679932
## [7,]  72641 0.00629937
## [8,] 133500 0.02809719
## [9,]   4909 0.03279672
```

```r
print(cbind(coh.chlaXaccndvi$lagoslakeid, coh.chlaXaccndvi$accndvip.ts2)[coh.chlaXaccndvi$accndvip.ts2<a
```

```
##         [,1]       [,2]
##  [1,]   3370 0.01429857
##  [2,]   3834 0.00849915
##  [3,]   4243 0.00009999
##  [4,]   4416 0.01069893
##  [5,]   4434 0.02659734
##  [6,]   5895 0.02249775
##  [7,]   6199 0.03799620
##  [8,]   7523 0.02549745
##  [9,]   8369 0.03119688
## [10,]  39489 0.04539546
## [11,] 115040 0.00779922
## [12,] 133500 0.02279772
## [13,]  14815 0.00349965
## [14,] 102115 0.00289971
## [15,]   5463 0.03079692
```

```r
cor(coh.chlaXaccndvi$accndvicoh.ts1,coh.chlaXaccndvi$accndvicoh.ts2)
```

```
## [1] 0.02535991
```

```r
#long timescales
quantile(coh.chlaXaccndvi$accndvicoh.ts2)
```

```
##         0%        25%        50%        75%       100%
## 0.07654579 0.37832224 0.53015425 0.73194394 0.95309993
```

```r
alpha=0.05
sum(coh.chlaXaccndvi$accndvip.ts2<alpha)/nrow(coh.chlaXaccndvi)
```

```
## [1] 0.1145038
```

```r
print(coh.chlaXaccndvi$accndviphi.ts2[coh.chlaXaccndvi$accndvip.ts2<alpha]/pi)
```

```
##  [1]  0.73992662 -0.90124264  0.53888310  0.27521830 -0.95606597
##  [6]  0.52712388 -0.68599147 -0.91773670 -0.29662433 -0.40541240
## [11] -0.22793834 -0.04840174 -0.57269988 -0.52827164  0.88106993
```

```r
#plotting
tiff("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig2_distributions_2019103
     res=300, width=6.5, height=6.5)

par(mar=c(3,3,2,1),mgp=c(1.7,0.5,0),mfrow=c(2,2),cex.main=0.9)

hist(coh.chlaXaccndvi$accndvicoh.ts1, main="Short timescale coherence", xlab="Coherence", ylab="Frequen
text(par()$usr[1]+.05,0.95*par()$usr[4],"a)")
hist(coh.chlaXaccndvi$accndvicoh.ts2, main="Long timescale coherence", xlab="Coherence", ylab="Frequency
text(par()$usr[1]+.05,0.95*par()$usr[4],"b)")

par(mar=c(1,1,2,1))
```

```r
rose(coh.chlaXaccndvi$accndviphi.ts1[coh.chlaXaccndvi$accndvip.ts1<0.3], unit="radian", col="lightgrey"
     breaks=c(0,pi/4,pi/2,3*pi/4,pi,5*pi/4,3*pi/2,7*pi/4,2*pi), main="Short timescale phases",
       at=c(0,pi/4,pi/2,3*pi/4,pi,-3*pi/4,-pi/2,-pi/4))
text(0.9*par()$usr[1],0.95*par()$usr[4],"c)")
rose(coh.chlaXaccndvi$accndviphi.ts2[coh.chlaXaccndvi$accndvip.ts2<0.3], unit="radian", col="lightgrey"
     breaks=c(0,pi/4,pi/2,3*pi/4,pi,5*pi/4,3*pi/2,7*pi/4,2*pi), main="Long timescale phases",
     at=c(0,pi/4,pi/2,3*pi/4,pi,-3*pi/4,-pi/2,-pi/4))
text(0.9*par()$usr[1],0.95*par()$usr[4],"d)")

dev.off()
```

```
## pdf
##   2
```

```r
states<-readOGR("~/Box Sync/NSF EAGER Synchrony/Data/statesp020_nolakes.shp")
```

```
## OGR data source with driver: ESRI Shapefile
## Source: "/Users/jonathanwalter/Box Sync/NSF EAGER Synchrony/Data/statesp020_nolakes.shp", layer: "sta
## with 2886 features
## It has 9 fields
## Integer64 fields read as strings:  ORDER_ADM
```

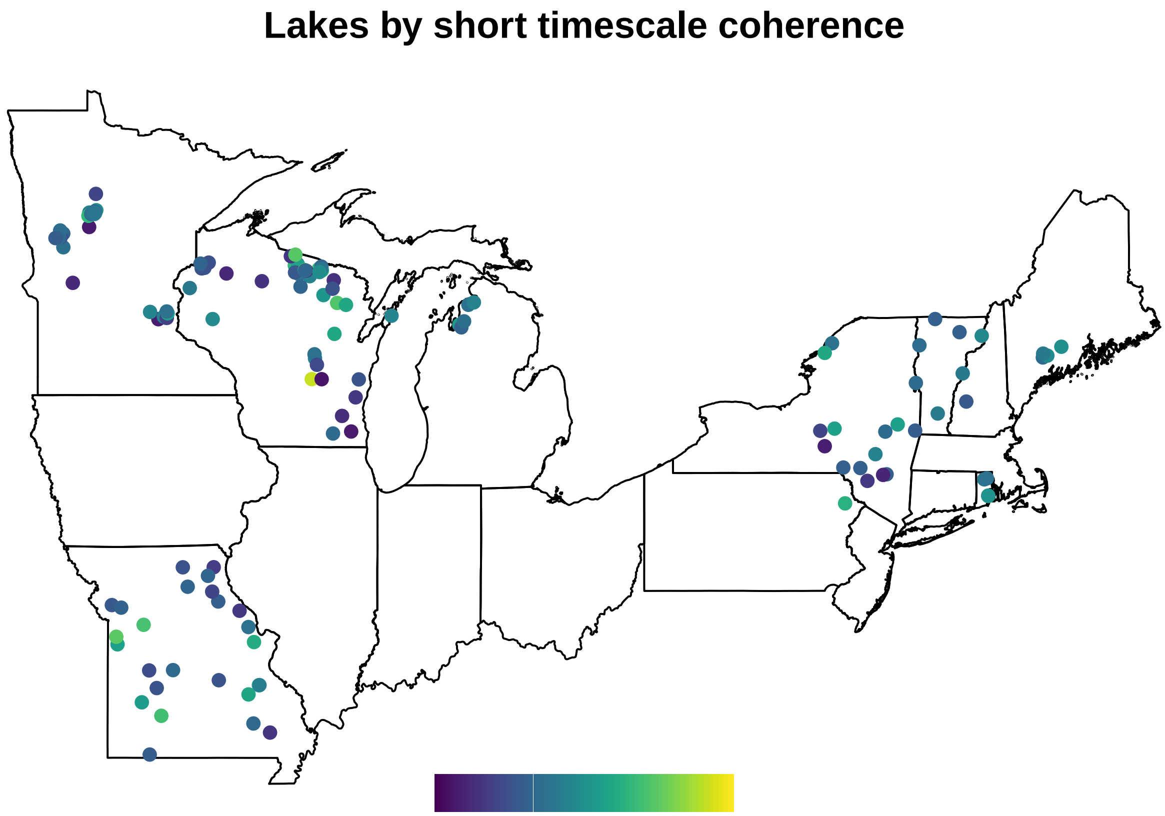
```r
getstates<-c("Minnesota", "Iowa", "Wisconsin", "Illinois", "Missouri", "Michigan", "Indiana", "Ohio", "
lagosstates<-states[states@data$STATE %in% getstates,]

tiff("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig2_map.tif",units="in",
     res=300, width=3.25, height=2.75)
par(mar=rep(0,4))
plot(lagosstates, main="",bty="o")
points(analysislakes$lakeinfo$nhd_long, analysislakes$lakeinfo$nhd_lat, pch=21, cex=0.45, col="black",b
legend("bottomright",pch=c(0,21),col="black",pt.bg="grey",legend=c("States in LAGOS-NE","Selected lakes
dev.off()
```

```
## pdf
##   2
```

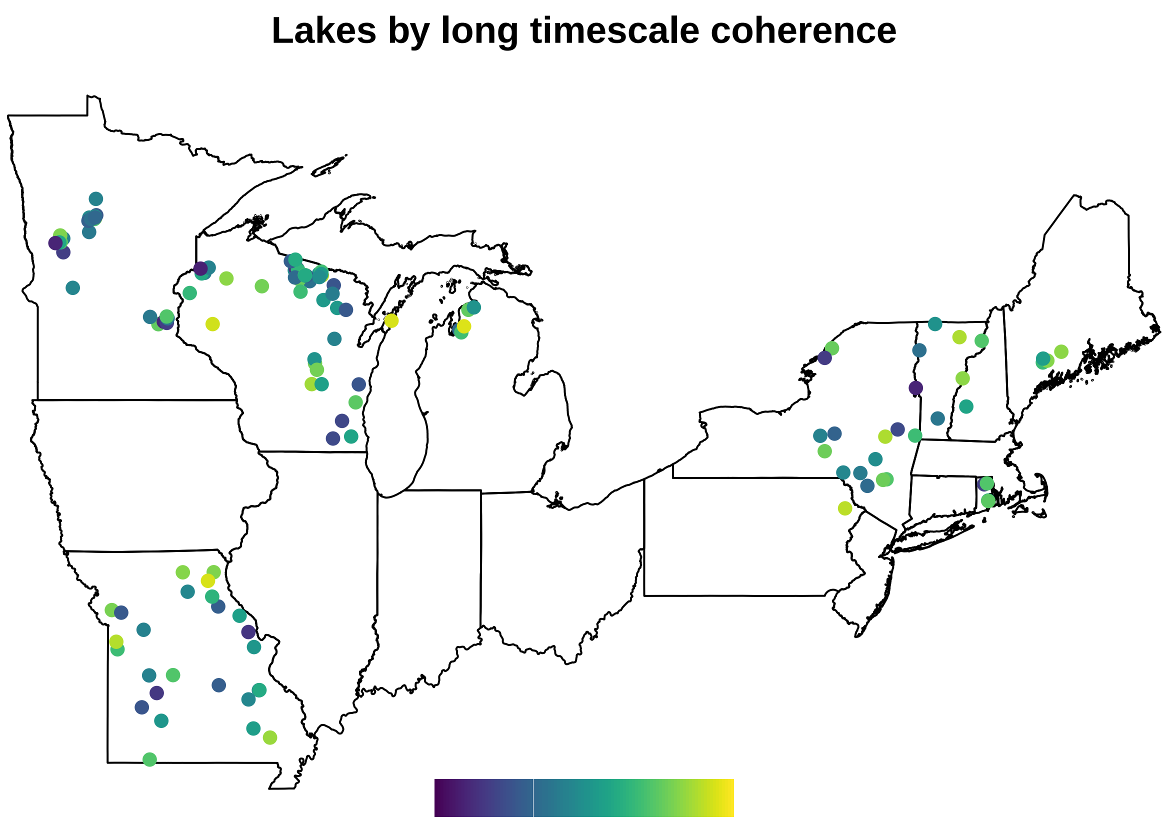
```r
cohplotdata<-left_join(analysislakes$lakeinfo, coh.chlaXaccndvi, by="lagoslakeid")

pal<-viridis(100)

par(mar=c(1,0,2,0))

plot(lagosstates, main="Lakes by short timescale coherence")
par()$usr
```

```
## [1] -98.49241 -65.70056  35.45947  49.92124
```

```r
points(cohplotdata$nhd_long, cohplotdata$nhd_lat, pch=16, cex=1, col=pal[round(cohplotdata$accndvicoh.t
colorbar.plot(x=mean(par("usr")[1:2]),y=par("usr")[3],strip=1:100,col=pal,horizontal = T)
```




```
plot(lagosstates, main="Lakes by long timescale coherence")
points(cohplotdata$nhd_long, cohplotdata$nhd_lat, pch=16, cex=1, col=pal[round(cohplotdata$accndvicoh.ts
colorbar.plot(x=mean(par("usr")[1:2]),y=par("usr")[3],strip=1:100,col=pal,horizontal = T)
```




```
laymat=matrix(1,nrow=2,ncol=13)
laymat[2,]<-2
laymat[,13]<-3

tiff("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/figS1_coherencemap.tif", un
     res=300, width=6.5, height=7.5)

layout(laymat)
par(mar=c(0,0,1.5,0))

plot(lagosstates, main="Short timescale coherence")
points(cohplotdata$nhd_long, cohplotdata$nhd_lat, pch=16, cex=1.5, col=pal[round(cohplotdata$accndvicoh
text(0.99*par()$usr[1],0.99*par()$usr[4],"a)",cex=1.5)

plot(lagosstates, main="Long timescale coherence")
points(cohplotdata$nhd_long, cohplotdata$nhd_lat, pch=16, cex=1.5, col=pal[round(cohplotdata$accndvicoh
text(0.99*par()$usr[1],0.99*par()$usr[4],"b)",cex=1.5)

par(mar=c(5,1,5,1))
image(matrix(1:100,nrow=1),col=pal,xaxt="n",yaxt="n")
axis(2,at=seq(0,1,0.2))

dev.off()
```

```
## pdf
##   2
```

```
dt<-lagosne_load("1.087.3")
```

```
dt.conn<-dt$buffer500m.conn
dt.conn<-dt.conn[,!grepl("sum_lengthm",colnames(dt.conn))]
dt.conn<-dt.conn[,colnames(dt.conn)!="buffer500m_nhdid"]


dt.chag<-dt$hu12.chag
dt.chag<-dt.chag[,!grepl("_min",colnames(dt.chag))]
dt.chag<-dt.chag[,!grepl("_max",colnames(dt.chag))]
dt.chag<-dt.chag[,!grepl("_ha",colnames(dt.chag))]
dt.chag<-dt.chag[,!colnames(dt.chag)=="borderhu12s"]
dt.chag$hu12_dep_no3_tavg_mean<-rowMeans(dt.chag[,grepl("hu12_dep_no3",colnames(dt.chag)) &
                                                   grepl("_mean",colnames(dt.chag))])
dt.chag$hu12_dep_no3_tavg_std<-rowMeans(dt.chag[,grepl("hu12_dep_no3",colnames(dt.chag)) &
                                                   grepl("_std",colnames(dt.chag))])
dt.chag$hu12_dep_so4_tavg_mean<-rowMeans(dt.chag[,grepl("hu12_dep_so4",colnames(dt.chag)) &
                                                    grepl("_mean", colnames(dt.chag))])
dt.chag$hu12_dep_so4_tavg_std<-rowMeans(dt.chag[,grepl("hu12_dep_so4",colnames(dt.chag)) &
                                                    grepl("_std", colnames(dt.chag))])
dt.chag$hu12_dep_totaln_tavg_mean<-rowMeans(dt.chag[,grepl("hu12_dep_totaln",colnames(dt.chag)) &
                                                      grepl("_mean", colnames(dt.chag))])
dt.chag$hu12_dep_totaln_tavg_std<-rowMeans(dt.chag[,grepl("hu12_dep_totaln",colnames(dt.chag)) &
                                                      grepl("_std", colnames(dt.chag))])
dt.chag<-dt.chag[,!(grepl("hu12_dep",colnames(dt.chag)) & grepl("_19",colnames(dt.chag)))]
dt.chag<-dt.chag[,!(grepl("hu12_dep",colnames(dt.chag)) & grepl("_20",colnames(dt.chag)))]
dt.chag<-dt.chag[,!(grepl("_std",colnames(dt.chag)))]
dt.chag<-dt.chag[,!grepl("surficialgeology",colnames(dt.chag))]


dt.geo<-dt$lakes.geo
dt.geo<-dt$lakes.geo[,!colnames(dt.geo) %in% c("state_zoneid","iws_zoneid","edu_zoneid","county_zoneid"
dt.geo<-dt.geo[,!grepl("_count",colnames(dt.geo))]

dt.lulc<-dt$hu12.lulc
dt.lulc<-dt.lulc[,!grepl("_ha_",colnames(dt.lulc))]
dt.lulc<-dt.lulc[,!grepl("_nlcd1992_",colnames(dt.lulc))]
dt.lulc<-dt.lulc[,!grepl("_nlcd2006_",colnames(dt.lulc))]
dt.lulc<-dt.lulc[,!grepl("_nlcd2001_",colnames(dt.lulc))]
dt.lulc<-dt.lulc[,colnames(dt.lulc)!="hu12_damdensity_pointsperha"]
dt.lulc<-dt.lulc[,colnames(dt.lulc)!="hu12_damdensity_pointcount"]
dt.lulc<-dt.lulc[,colnames(dt.lulc)!="hu12_roaddensity_sum_lengthm"]
dt.lulc<-dt.lulc[,!grepl("_min",colnames(dt.lulc))]
dt.lulc<-dt.lulc[,!grepl("_max",colnames(dt.lulc))]
dt.lulc<-dt.lulc[,!grepl("_std",colnames(dt.lulc))]

#depth
depth<-lagosne_select(table="lakes_limno", vars=c("lagoslakeid","maxdepth"))
depth<-depth[depth$lagoslakeid %in% analysislakes$lakeinfo$lagoslakeid,] #use max depth because it's mo

#growing season Chlorophyll-a
chla<-lagosne_select(table="epi_nutr", vars=c("lagoslakeid","samplemonth","chla"))
chla<-chla[chla$lagoslakeid %in% analysislakes$lakeinfo$lagoslakeid,]
gs.chla<-chla[chla$samplemonth %in% 5:9,]
avg.chla<-aggregate(chla ~ lagoslakeid, data=gs.chla, FUN=mean, na.rm=T)
```

```r
#Chlorophyll-a TSI class
#TSI(CHL) = 9.81 ln(CHL) + 30.6
tsi.chl<-data.frame(lagoslakeid=avg.chla$lagoslakeid, tsi=9.81 * log(avg.chla$chla) + 30.6)
tsi.chl$tsi.cat<-rep("lake",nrow(tsi.chl))

tsi.chl$tsi.cat[tsi.chl$tsi < 40]<-"oligotrophic"
tsi.chl$tsi.cat[tsi.chl$tsi >=40 & tsi.chl$tsi < 50]<-"mesotrophic"
tsi.chl$tsi.cat[tsi.chl$tsi >=50 & tsi.chl$tsi < 70]<-"eutrophic"
tsi.chl$tsi.cat[tsi.chl$tsi >= 70] <-"hypereutrophic"

#CV of terrestrial NDVI
cv.accndvi<-NULL
for(lake in 1:length(analysislakes$lakedata)){
  tmp<-analysislakes$lakedata[[lake]][rownames(analysislakes$lakedata[[lake]])=="avhrrdata",]

  cv.accndvi<-c(cv.accndvi, sd(tmp)/mean(tmp))
 # rm(tmp)
}
cv.accndvi<-data.frame(lagoslakeid=as.numeric(names(analysislakes$lakedata)), cv.accndvi=cv.accndvi)

#shoreline development ratio
sdev<-analysislakes$lakeinfo$lake_perim_meters/(2*sqrt(pi*analysislakes$lakeinfo$lake_area_ha*10000))
shoredev<-data.frame(lagoslakeid=analysislakes$lakeinfo$lagoslakeid,shoredev=sdev)

preds<-analysislakes$lakeinfo[,colnames(analysislakes$lakeinfo) %in% c("lagoslakeid","end","start")]
preds$tslength<-preds$end-preds$start + 1
preds<-left_join(preds, dt.geo, by="lagoslakeid")
preds<-left_join(preds, dt.conn, by="lagoslakeid")
preds<-left_join(preds, dt.chag, by="hu12_zoneid")
preds<-left_join(preds, dt.lulc, by="hu12_zoneid")
preds<-left_join(preds, avg.chla, by="lagoslakeid")
preds<-left_join(preds, cv.accndvi, by="lagoslakeid")
preds<-left_join(preds, depth, by="lagoslakeid")
preds<-left_join(preds, shoredev, by="lagoslakeid")


conpreds<-preds[,sapply(preds, is.numeric)]
cor.conpreds<-cor(conpreds,use="pairwise.complete.obs")
```

```
## Warning in cor(conpreds, use = "pairwise.complete.obs"): the standard
## deviation is zero
```

```r
preds<-preds[,!colnames(preds) %in% c("hu12_surficialgeology_beach_pct",
                                      "hu12_surficialgeology_colluv_pct",
                                      "hu12_surficialgeology_grus_pct",
                                      "hu12_surficialgeology_other_pct",
                                      "hu12_surficialgeology_solif_pct",
                                      "hu12_surficialgeology_till_oth_pct",
                                      "hu12_nlcd2011_pct_0")]

#huc2 and huc4 watershed codes
huc_codes<-read.csv("~/GitHub/AquaTerrSynch/AnalysisCode/match_huc_codes.csv", colClasses = 'character')
```

```r
#state info
states<-lagosne_select(table="state", vars=c("state_zoneid","state_name"))

for(nn in 1:ncol(preds)){
  if(is.factor(preds[,nn])){
    preds[,nn]<-factor(preds[,nn])
  }
}

#write.csv(colnames(preds),file="~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/
```

```r
rfdat.cohst<-left_join(coh.chlaXaccndvi[,c(10,3)], preds)
```

```
## Joining, by = "lagoslakeid"
```

```r
rfdat.cohst<-rfdat.cohst[,!colnames(rfdat.cohst) %in% c("lagoslakeid","start","end","lakes_nhdid","hu12_
rfdat.cohst<-rfdat.cohst[,!grepl("borderhu12s",colnames(rfdat.cohst))]

for(nn in 1:ncol(rfdat.cohst)){
  if(is.character(rfdat.cohst[,nn])){
    rfdat.cohst[,nn]<-as.factor(rfdat.cohst[,nn])
  }
}

cf.cohst<-party::cforest(accndvicoh.ts1 ~ ., data=rfdat.cohst, controls=cforest_control(ntree=50000,minc

varimp.coh.st<-varimp(cf.cohst)
print(varimp.coh.st[order(varimp.coh.st, decreasing=T)][1:10])
```

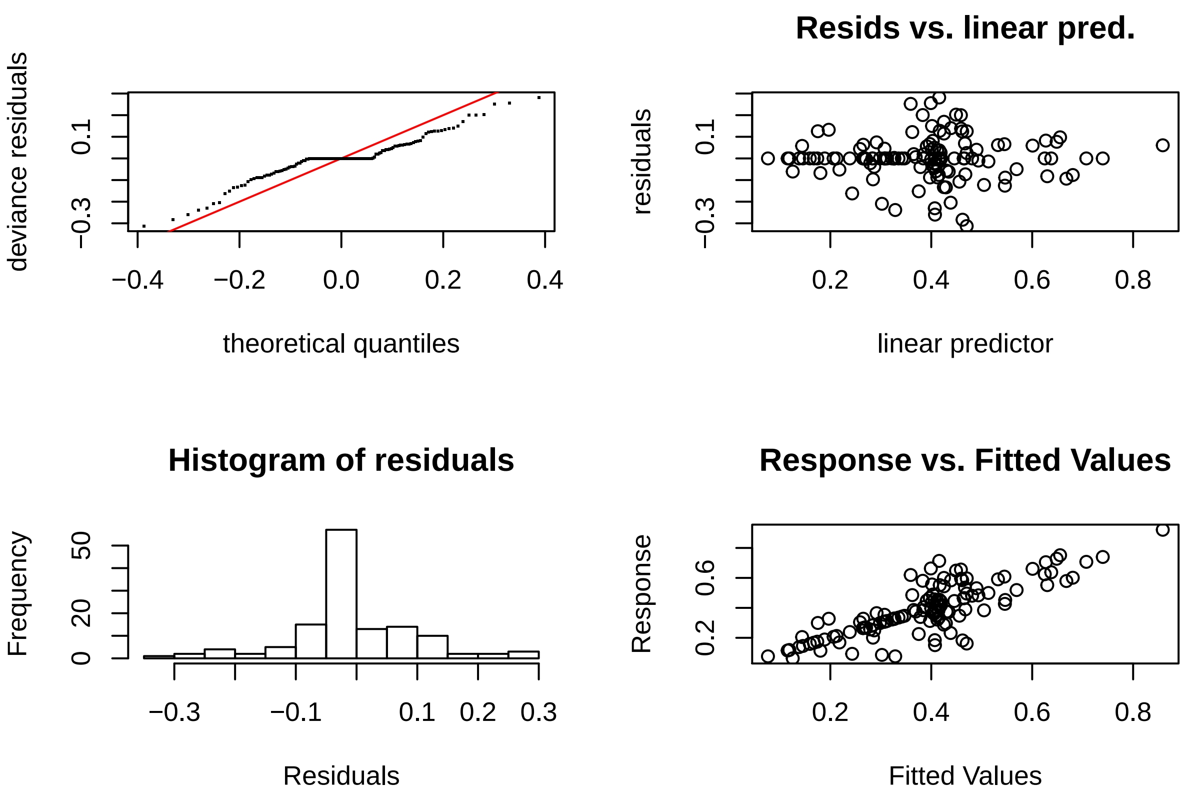
```
##                                     cv.accndvi
##                                   0.0005710355
##                                     hu8_zoneid
##                                   0.0005568739
##                      hu12_dep_totaln_tavg_mean
##                                   0.0004949402
##                           hu12_nlcd2011_pct_90
##                                   0.0001939783
##                           hu12_nlcd2011_pct_95
##                                   0.0001609831
## wlconnections_scrubshrubwetlands_shoreline_km
##                                   0.0001473959
##        wlconnections_allwetlands_shoreline_km
##                                   0.0001400305
##                                hu12_slope_mean
##                                   0.0001274735
##                                  hu12_tri_mean
##                                   0.0001274102
##   wlconnections_forestedwetlands_shoreline_km
##                                   0.0000901705
```

```r
predcoh.st<-predict(cf.cohst, newdata=rfdat.cohst,type="response")
cor.test(predcoh.st,rfdat.cohst$accndvicoh.ts1)
```

```
##
##  Pearson's product-moment correlation
```

```
##
## data:  predcoh.st and rfdat.cohst$accndvicoh.ts1
## t = 17.438, df = 129, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.7782621 0.8826028
## sample estimates:
##       cor
## 0.8379308
```

```
lwgt<-preds$tslength/mean(preds$tslength)

gam.cohst<-gam(accndvicoh.ts1 ~ s(cv.accndvi) + hu8_zoneid + s(hu12_dep_totaln_tavg_mean) +
               s(hu12_nlcd2011_pct_90) + s(hu12_nlcd2011_pct_95), data=rfdat.cohst, gamma=1, weights=lw
gam.check(gam.cohst)
```




```
##
## Method: GCV   Optimizer: magic
## Smoothing parameter selection converged after 12 iterations.
## The RMS GCV score gradient at convergence was 5.16565e-08 .
## The Hessian was positive definite.
## Model rank =  101 / 101
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##                                k'  edf k-index p-value
## s(cv.accndvi)                9.00 1.00    0.88   0.055 .
## s(hu12_dep_totaln_tavg_mean) 9.00 1.00    1.05   0.615
## s(hu12_nlcd2011_pct_90)      9.00 1.00    1.23   0.990
```

```
## s(hu12_nlcd2011_pct_95)      9.00 1.48    1.22   0.995
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
concurvity(gam.cohst,full=F)$estimate
```

```
##                                      para s(cv.accndvi)
## para                         1.000000e+00  6.059830e-29
## s(cv.accndvi)                5.021612e-26  1.000000e+00
## s(hu12_dep_totaln_tavg_mean) 8.759603e-24  1.086538e-01
## s(hu12_nlcd2011_pct_90)      7.915962e-25  8.910736e-02
## s(hu12_nlcd2011_pct_95)      5.473439e-25  7.304589e-02
##                              s(hu12_dep_totaln_tavg_mean)
## para                                         4.287652e-26
## s(cv.accndvi)                                7.547220e-02
## s(hu12_dep_totaln_tavg_mean)                 1.000000e+00
## s(hu12_nlcd2011_pct_90)                      1.067223e-01
## s(hu12_nlcd2011_pct_95)                      2.211129e-01
##                              s(hu12_nlcd2011_pct_90)
## para                                    4.859488e-28
## s(cv.accndvi)                           1.066378e-01
## s(hu12_dep_totaln_tavg_mean)            2.134301e-01
## s(hu12_nlcd2011_pct_90)                 1.000000e+00
## s(hu12_nlcd2011_pct_95)                 1.626272e-01
##                              s(hu12_nlcd2011_pct_95)
## para                                    1.559485e-27
## s(cv.accndvi)                           7.299190e-02
## s(hu12_dep_totaln_tavg_mean)            9.052390e-02
## s(hu12_nlcd2011_pct_90)                 6.931528e-02
## s(hu12_nlcd2011_pct_95)                 1.000000e+00
```

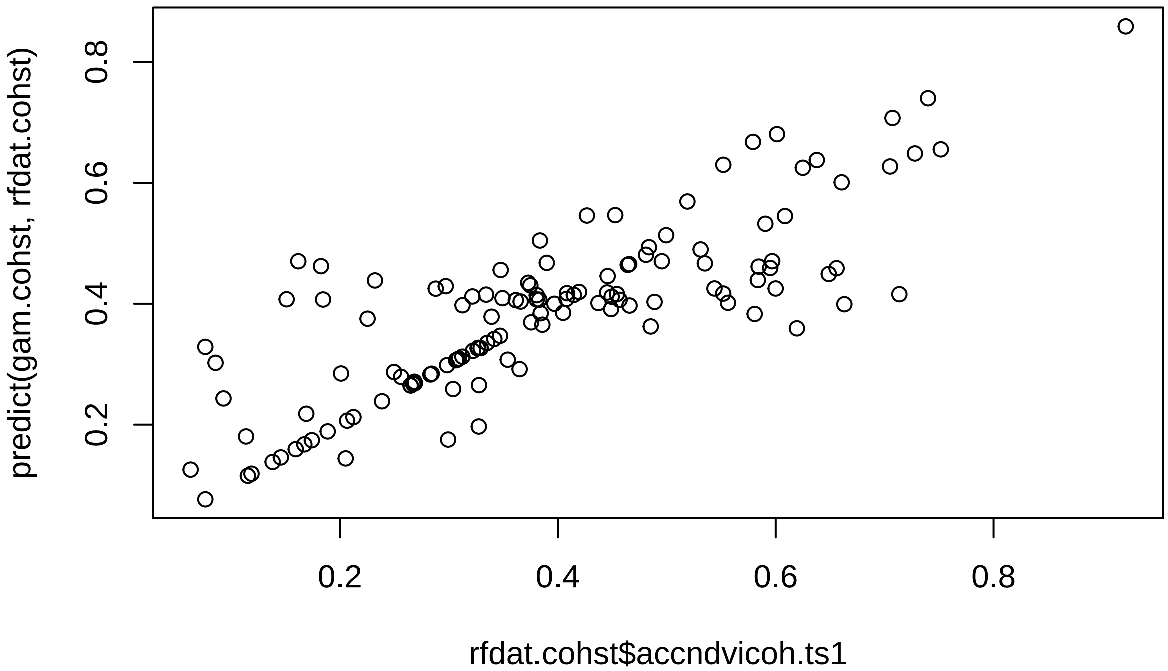
```r
summary(gam.cohst)
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## accndvicoh.ts1 ~ s(cv.accndvi) + hu8_zoneid + s(hu12_dep_totaln_tavg_mean) +
##     s(hu12_nlcd2011_pct_90) + s(hu12_nlcd2011_pct_95)
##
## Parametric coefficients:
##                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)         0.66607    0.16815   3.961 0.000199 ***
## hu8_zoneidHU8_13   -0.46394    0.20628  -2.249 0.028156 *
## hu8_zoneidHU8_141 -0.35966    0.18774  -1.916 0.060122 .
## hu8_zoneidHU8_142 -0.32575    0.25377  -1.284 0.204159
## hu8_zoneidHU8_143 -0.30654    0.16304  -1.880 0.064907 .
## hu8_zoneidHU8_160 -0.41906    0.21050  -1.991 0.051029 .
## hu8_zoneidHU8_161 -0.33585    0.15666  -2.144 0.036078 *
## hu8_zoneidHU8_163 -0.38638    0.17314  -2.232 0.029357 *
## hu8_zoneidHU8_164 -0.24380    0.24363  -1.001 0.320968
## hu8_zoneidHU8_165 -0.22857    0.21579  -1.059 0.293725
## hu8_zoneidHU8_167  0.09318    0.20545   0.454 0.651800
## hu8_zoneidHU8_168 -0.38464    0.21313  -1.805 0.076097 .
```

```
## hu8_zoneidHU8_169 -0.43064    0.24210  -1.779 0.080305 .
## hu8_zoneidHU8_170 -0.10694    0.19211  -0.557 0.579829
## hu8_zoneidHU8_173 -0.35952    0.23783  -1.512 0.135825
## hu8_zoneidHU8_177 -0.36422    0.26648  -1.367 0.176750
## hu8_zoneidHU8_181 -0.49226    0.25888  -1.901 0.062000 .
## hu8_zoneidHU8_186 -0.25460    0.26503  -0.961 0.340553
## hu8_zoneidHU8_204 -0.18662    0.18704  -0.998 0.322372
## hu8_zoneidHU8_23  -0.25930    0.21928  -1.183 0.241617
## hu8_zoneidHU8_24  -0.39770    0.23049  -1.725 0.089546 .
## hu8_zoneidHU8_256 -0.13672    0.19874  -0.688 0.494138
## hu8_zoneidHU8_325 -0.55321    0.20123  -2.749 0.007866 **
## hu8_zoneidHU8_331 -0.67101    0.24964  -2.688 0.009272 **
## hu8_zoneidHU8_335 -0.41596    0.19304  -2.155 0.035172 *
## hu8_zoneidHU8_343 -0.25784    0.21306  -1.210 0.230914
## hu8_zoneidHU8_346 -0.59853    0.23267  -2.572 0.012570 *
## hu8_zoneidHU8_350 -0.19939    0.24091  -0.828 0.411118
## hu8_zoneidHU8_370 -0.13870    0.23707  -0.585 0.560677
## hu8_zoneidHU8_382 -0.49275    0.23041  -2.139 0.036515 *
## hu8_zoneidHU8_39  -0.41626    0.24259  -1.716 0.091296 .
## hu8_zoneidHU8_40  -0.38443    0.22590  -1.702 0.093939 .
## hu8_zoneidHU8_428 -0.32358    0.22284  -1.452 0.151643
## hu8_zoneidHU8_429  0.08399    0.23477   0.358 0.721779
## hu8_zoneidHU8_431 -0.15119    0.25480  -0.593 0.555153
## hu8_zoneidHU8_434 -0.22451    0.24506  -0.916 0.363242
## hu8_zoneidHU8_435 -0.15210    0.23628  -0.644 0.522179
## hu8_zoneidHU8_436 -0.17288    0.26281  -0.658 0.513156
## hu8_zoneidHU8_437 -0.16545    0.25617  -0.646 0.520818
## hu8_zoneidHU8_440 -0.25435    0.25972  -0.979 0.331307
## hu8_zoneidHU8_449 -0.34913    0.22649  -1.541 0.128414
## hu8_zoneidHU8_452 -0.24126    0.24067  -1.002 0.320106
## hu8_zoneidHU8_453 -0.06632    0.19838  -0.334 0.739287
## hu8_zoneidHU8_456 -0.55425    0.22728  -2.439 0.017693 *
## hu8_zoneidHU8_481 -0.14888    0.24776  -0.601 0.550136
## hu8_zoneidHU8_484 -0.18386    0.25027  -0.735 0.465386
## hu8_zoneidHU8_49  -0.22461    0.19239  -1.168 0.247585
## hu8_zoneidHU8_491 -0.36769    0.23348  -1.575 0.120513
## hu8_zoneidHU8_492  0.06696    0.20996   0.319 0.750894
## hu8_zoneidHU8_493 -0.29583    0.23167  -1.277 0.206497
## hu8_zoneidHU8_494  0.13104    0.21678   0.604 0.547784
## hu8_zoneidHU8_495 -0.18891    0.24275  -0.778 0.439494
## hu8_zoneidHU8_501  0.21839    0.25218   0.866 0.389892
## hu8_zoneidHU8_507 -0.33116    0.22758  -1.455 0.150787
## hu8_zoneidHU8_51  -0.05103    0.25899  -0.197 0.844448
## hu8_zoneidHU8_59  -0.31527    0.19029  -1.657 0.102738
## hu8_zoneidHU8_61  -0.24905    0.21948  -1.135 0.260971
## hu8_zoneidHU8_73  -0.23908    0.22671  -1.055 0.295815
## hu8_zoneidHU8_74  -0.27462    0.23530  -1.167 0.247755
## hu8_zoneidHU8_75  -0.10783    0.24346  -0.443 0.659420
## hu8_zoneidHU8_76  -0.13279    0.29684  -0.447 0.656234
## hu8_zoneidHU8_81  -0.43415    0.20523  -2.115 0.038517 *
## hu8_zoneidHU8_83  -0.32212    0.25942  -1.242 0.219148
## hu8_zoneidHU8_84  -0.23217    0.24338  -0.954 0.343923
## hu8_zoneidHU8_96   0.01637    0.23228   0.070 0.944063
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                                 edf Ref.df      F  p-value
## s(cv.accndvi)                 1.000  1.000  0.997 0.322058
## s(hu12_dep_totaln_tavg_mean) 1.000  1.000  3.010 0.087775 .
## s(hu12_nlcd2011_pct_90)      1.000  1.000  0.004 0.948613
## s(hu12_nlcd2011_pct_95)      1.478  1.791 13.352 0.000823 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.287   Deviance explained = 66.5%
## GCV = 0.04542  Scale est. = 0.021145  n = 130
```

```
plot(rfdat.cohst$accndvicoh.ts1, predict(gam.cohst, rfdat.cohst))
```




```
rfdat.cohlt<-left_join(coh.chlaXaccndvi[,c(10,6)], preds)
```

```
## Joining, by = "lagoslakeid"
```

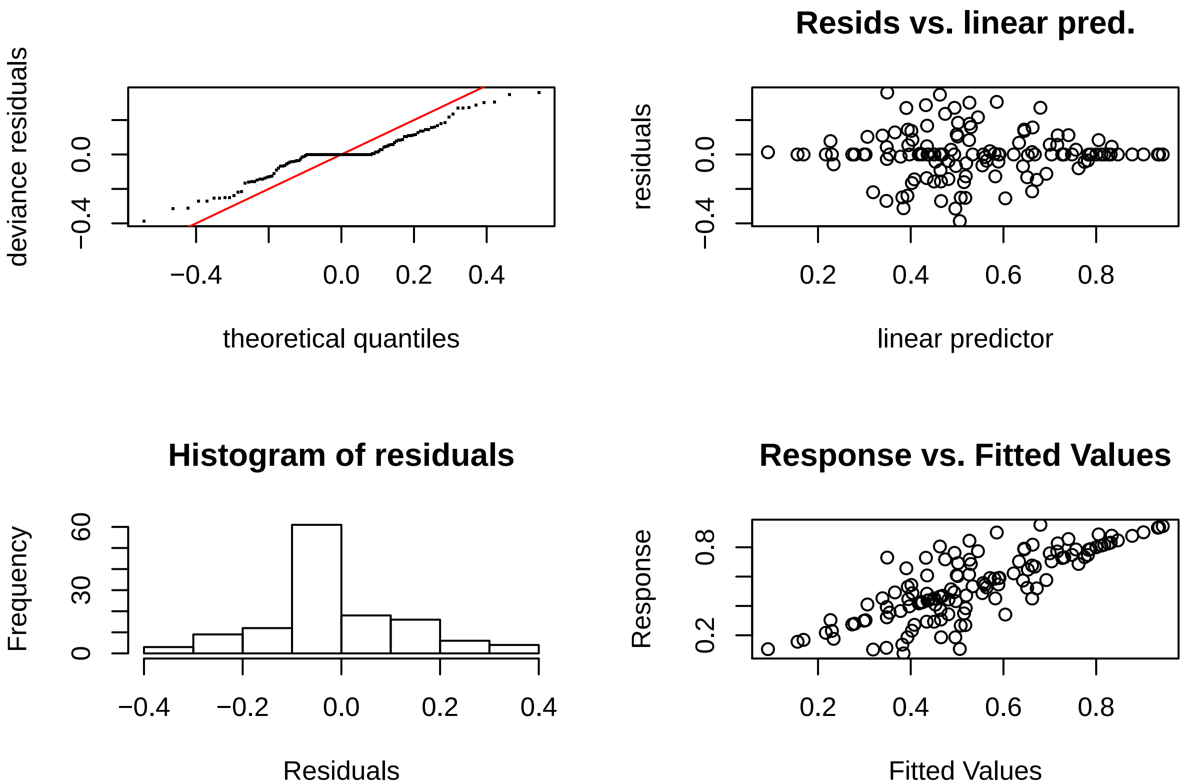
```
rfdat.cohlt<-rfdat.cohlt[,!colnames(rfdat.cohlt) %in% c("lagoslakeid","start","end","lakes_nhdid","hu12_
rfdat.cohlt<-rfdat.cohlt[,!grepl("borderhu12s",colnames(rfdat.cohlt))]

for(nn in 1:ncol(rfdat.cohlt)){
  if(is.character(rfdat.cohlt[,nn])){
    rfdat.cohlt[,nn]<-as.factor(rfdat.cohlt[,nn])
  }
}

cf.cohlt<-party::cforest(accndvicoh.ts2 ~ ., data=rfdat.cohlt, controls=cforest_control(ntree=50000,mine

varimp.coh.lt<-varimp(cf.cohlt)
print(varimp.coh.lt[order(varimp.coh.lt, decreasing=T)][1:10])
```

```
##                                        hu8_zoneid
##                                      1.224867e-03
##                              hu12_nlcd2011_pct_52
##                                      9.141534e-04
##                                        cv.accndvi
##                                      4.451874e-04
##  hu12_prism_ppt_30yr_normal_800mm2_annual_mean
##                                      1.450424e-04
## wlconnections_allwetlands_contributing_area_ha
##                                      1.447590e-04
##    wlconnections_forestedwetlands_shoreline_km
##                                      1.362169e-04
##                              hu12_nlcd2011_pct_95
##                                      1.257159e-04
##         wlconnections_allwetlands_shoreline_km
##                                      9.856973e-05
##                            hu12_dep_so4_tavg_mean
##                                      8.810665e-05
##                     hu12_groundwaterrecharge_mean
##                                      7.183743e-05
```

```
predcoh.lt<-predict(cf.cohlt, newdata=rfdat.cohlt,type="response")
cor.test(predcoh.lt,rfdat.cohlt$accndvicoh.ts2)
```

```
##
##  Pearson's product-moment correlation
##
## data:  predcoh.lt and rfdat.cohlt$accndvicoh.ts2
## t = 16.474, df = 129, p-value < 2.2e-16
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.7589455 0.8717201
## sample estimates:
##       cor
## 0.8232956
```

```
lwgt<-preds$tslength/mean(preds$tslength)

gam.cohlt<-gam(accndvicoh.ts2 ~ hu8_zoneid + s(hu12_nlcd2011_pct_52) + s(cv.accndvi) +
                 s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean) +
                 s(wlconnections_allwetlands_contributing_area_ha), data=rfdat.cohlt, gamma=1, weights=l
gam.check(gam.cohlt)
```




```
##
## Method: GCV   Optimizer: magic
## Smoothing parameter selection converged after 11 iterations.
## The RMS GCV score gradient at convergence was 3.51053e-08 .
## The Hessian was positive definite.
## Model rank =  101 / 101
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##                                                 k'  edf k-index
## s(hu12_nlcd2011_pct_52)                       9.00 1.65    0.96
## s(cv.accndvi)                                 9.00 1.00    0.96
## s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean) 9.00 1.52    0.96
## s(wlconnections_allwetlands_contributing_area_ha) 9.00 2.56    0.91
##                                               p-value
## s(hu12_nlcd2011_pct_52)                          0.23
## s(cv.accndvi)                                    0.28
## s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean)    0.29
## s(wlconnections_allwetlands_contributing_area_ha)    0.11
```

```
concurvity(gam.cohlt,full=F)$estimate
```

```
##                                                       para
## para                                          1.000000e+00
## s(hu12_nlcd2011_pct_52)                       2.639051e-25
## s(cv.accndvi)                                 9.137579e-26
## s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean) 6.743208e-24
## s(wlconnections_allwetlands_contributing_area_ha) 2.093031e-22
##                                               s(hu12_nlcd2011_pct_52)
```

```
## para                                                       5.584223e-28
## s(hu12_nlcd2011_pct_52)                                    1.000000e+00
## s(cv.accndvi)                                              3.658879e-02
## s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean)           1.193729e-01
## s(wlconnections_allwetlands_contributing_area_ha)          2.844090e-02
##                                                   s(cv.accndvi)
## para                                               1.933866e-28
## s(hu12_nlcd2011_pct_52)                            5.282735e-02
## s(cv.accndvi)                                      1.000000e+00
## s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean)   1.841519e-01
## s(wlconnections_allwetlands_contributing_area_ha)  1.829351e-02
##                                                   s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean)
## para                                                                                  1.731286e-26
## s(hu12_nlcd2011_pct_52)                                                               1.295185e-01
## s(cv.accndvi)                                                                         1.750324e-01
## s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean)                                      1.000000e+00
## s(wlconnections_allwetlands_contributing_area_ha)                                     6.266707e-02
##                                                   s(wlconnections_allwetlands_contributing_area_ha)
## para                                                                                   2.606193e-27
## s(hu12_nlcd2011_pct_52)                                                                2.741690e-02
## s(cv.accndvi)                                                                          5.964451e-02
## s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean)                                       1.904579e-01
## s(wlconnections_allwetlands_contributing_area_ha)                                      1.000000e+00
```

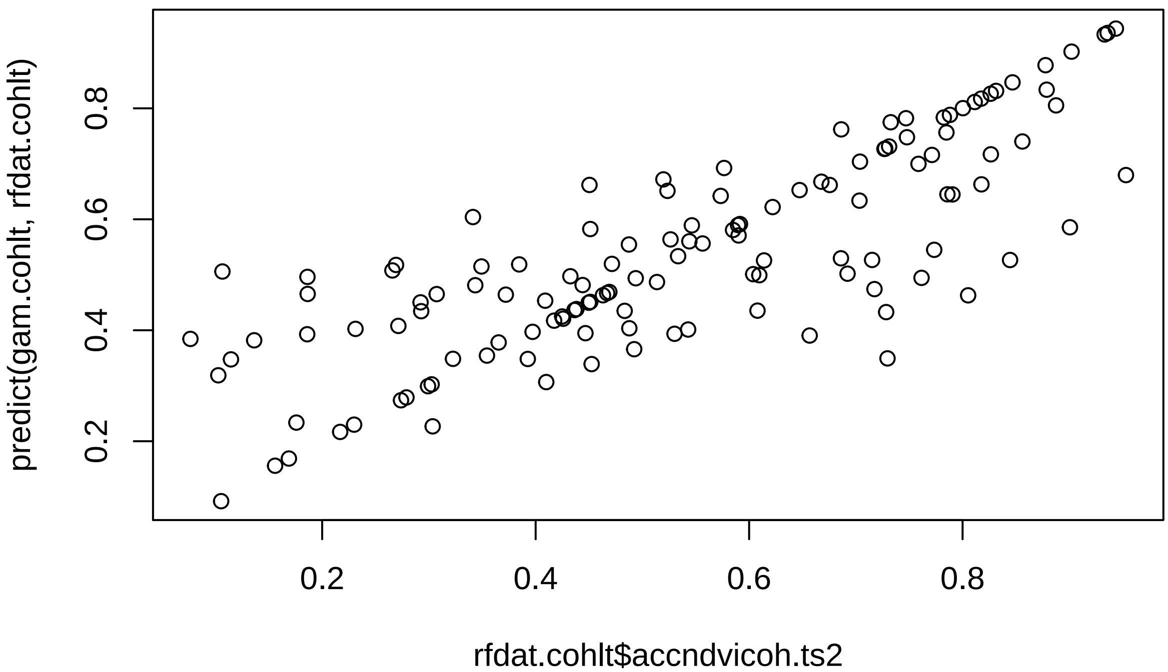
```r
summary(gam.cohlt)
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## accndvicoh.ts2 ~ hu8_zoneid + s(hu12_nlcd2011_pct_52) + s(cv.accndvi) +
##     s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean) + s(wlconnections_allwetlands_contributing_area_
##
## Parametric coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)        0.75889    0.28821   2.633   0.0109 *
## hu8_zoneidHU8_13  -0.41434    0.58974  -0.703   0.4852
## hu8_zoneidHU8_141 -0.12373    0.24014  -0.515   0.6084
## hu8_zoneidHU8_142  0.09404    0.37317   0.252   0.8019
## hu8_zoneidHU8_143 -0.21479    0.24318  -0.883   0.3808
## hu8_zoneidHU8_160  0.09694    0.29600   0.328   0.7445
## hu8_zoneidHU8_161 -0.07240    0.21834  -0.332   0.7414
## hu8_zoneidHU8_163 -0.02368    0.24539  -0.097   0.9235
## hu8_zoneidHU8_164 -0.40819    0.32336  -1.262   0.2119
## hu8_zoneidHU8_165  0.31112    0.30887   1.007   0.3180
## hu8_zoneidHU8_167 -0.13308    0.26109  -0.510   0.6122
## hu8_zoneidHU8_168 -0.13017    0.29557  -0.440   0.6613
## hu8_zoneidHU8_169  0.04436    0.27899   0.159   0.8742
## hu8_zoneidHU8_170  0.01939    0.22945   0.084   0.9330
## hu8_zoneidHU8_173  0.05803    0.31537   0.184   0.8546
## hu8_zoneidHU8_177 -0.54188    0.37206  -1.456   0.1507
## hu8_zoneidHU8_181 -0.16975    0.36886  -0.460   0.6471
## hu8_zoneidHU8_186 -0.56225    0.35602  -1.579   0.1198
## hu8_zoneidHU8_204 -0.03407    0.26828  -0.127   0.8994
```

```
## hu8_zoneidHU8_23  -0.35935    0.64457  -0.557   0.5794
## hu8_zoneidHU8_24  -0.22661    0.62488  -0.363   0.7182
## hu8_zoneidHU8_256 -0.74020    0.49793  -1.487   0.1426
## hu8_zoneidHU8_325  0.21175    0.44703   0.474   0.6375
## hu8_zoneidHU8_331  0.24622    0.49654   0.496   0.6219
## hu8_zoneidHU8_335  0.15394    0.41083   0.375   0.7093
## hu8_zoneidHU8_343 -0.32168    0.23180  -1.388   0.1706
## hu8_zoneidHU8_346  0.19840    0.47132   0.421   0.6754
## hu8_zoneidHU8_350  0.04084    0.29586   0.138   0.8907
## hu8_zoneidHU8_370  0.07754    0.39777   0.195   0.8461
## hu8_zoneidHU8_382  0.22620    0.30015   0.754   0.4542
## hu8_zoneidHU8_39  -0.14051    0.49483  -0.284   0.7775
## hu8_zoneidHU8_40  -0.47570    0.63494  -0.749   0.4568
## hu8_zoneidHU8_428 -0.32976    0.46624  -0.707   0.4823
## hu8_zoneidHU8_429 -0.45029    0.57492  -0.783   0.4367
## hu8_zoneidHU8_431  0.05843    0.46905   0.125   0.9013
## hu8_zoneidHU8_434 -0.67415    0.52419  -1.286   0.2036
## hu8_zoneidHU8_435 -0.79011    0.52619  -1.502   0.1387
## hu8_zoneidHU8_436 -0.14853    0.52906  -0.281   0.7799
## hu8_zoneidHU8_437 -0.51404    0.55209  -0.931   0.3557
## hu8_zoneidHU8_440 -0.06096    0.47189  -0.129   0.8977
## hu8_zoneidHU8_449 -0.50624    0.66210  -0.765   0.4476
## hu8_zoneidHU8_452 -0.69661    0.62973  -1.106   0.2733
## hu8_zoneidHU8_453 -0.50435    0.59240  -0.851   0.3981
## hu8_zoneidHU8_456 -0.27104    0.68837  -0.394   0.6952
## hu8_zoneidHU8_481 -0.63306    0.51366  -1.232   0.2228
## hu8_zoneidHU8_484 -0.07017    0.47309  -0.148   0.8826
## hu8_zoneidHU8_49  -0.57253    0.55954  -1.023   0.3105
## hu8_zoneidHU8_491 -1.10149    0.71445  -1.542   0.1286
## hu8_zoneidHU8_492 -0.60067    0.60326  -0.996   0.3236
## hu8_zoneidHU8_493 -0.81884    0.59296  -1.381   0.1727
## hu8_zoneidHU8_494 -0.20877    0.57390  -0.364   0.7174
## hu8_zoneidHU8_495 -0.29560    0.66121  -0.447   0.6565
## hu8_zoneidHU8_501 -0.57169    0.56034  -1.020   0.3119
## hu8_zoneidHU8_507 -0.25710    0.63610  -0.404   0.6876
## hu8_zoneidHU8_51  -0.60603    0.64522  -0.939   0.3515
## hu8_zoneidHU8_59  -0.57307    0.61762  -0.928   0.3574
## hu8_zoneidHU8_61  -0.18705    0.58375  -0.320   0.7498
## hu8_zoneidHU8_73  -0.54316    0.57005  -0.953   0.3447
## hu8_zoneidHU8_74  -0.62987    0.63392  -0.994   0.3246
## hu8_zoneidHU8_75  -0.28072    0.58793  -0.477   0.6348
## hu8_zoneidHU8_76  -0.30280    0.61228  -0.495   0.6228
## hu8_zoneidHU8_81  -0.79225    0.52637  -1.505   0.1378
## hu8_zoneidHU8_83  -0.69823    0.64291  -1.086   0.2820
## hu8_zoneidHU8_84  -0.59714    0.63175  -0.945   0.3485
## hu8_zoneidHU8_96  -0.19036    0.60584  -0.314   0.7545
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                                                  edf Ref.df     F
## s(hu12_nlcd2011_pct_52)                        1.654  2.086 1.337
## s(cv.accndvi)                                  1.000  1.000 2.072
## s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean)  1.522  1.893 0.343
```

```
## s(wlconnections_allwetlands_contributing_area_ha) 2.562  3.022 1.446
##                                                  p-value
## s(hu12_nlcd2011_pct_52)                            0.272
## s(cv.accndvi)                                      0.155
## s(hu12_prism_ppt_30yr_normal_800mm2_annual_mean)   0.661
## s(wlconnections_allwetlands_contributing_area_ha)  0.253
##
## R-sq.(adj) =  0.207   Deviance explained = 64.5%
## GCV = 0.093851  Scale est. = 0.041659  n = 129
```

```r
plot(rfdat.cohlt$accndvicoh.ts2, predict(gam.cohlt, rfdat.cohlt))
```




```r
rfdat.phist<-left_join(coh.chlaXaccndvi[,c(10,2)], preds)
```

```
## Joining, by = "lagoslakeid"
```

```r
rfdat.phist<-rfdat.phist[,!colnames(rfdat.phist) %in%
                          c("lagoslakeid","start","end","lakes_nhdid","hu12_zoneid","tslength","county_
rfdat.phist<-rfdat.phist[,!grepl("borderhu12s",colnames(rfdat.phist))]

rfdat.phist<-rfdat.phist[coh.chlaXaccndvi$accndvip.ts1<0.3,]

for(nn in 1:ncol(rfdat.phist)){
  if(is.character(rfdat.phist[,nn])){
    rfdat.phist[,nn]<-as.factor(rfdat.phist[,nn])
  }
}

#cosine
cf.cosphist<-party::cforest(cos(accndviphi.ts1) ~ ., data=rfdat.phist,
                         controls=cforest_control(ntree=50000,mincriterion = 0.9,mtry=3))
varimp.cosphi.st<-varimp(cf.cosphist)
print(varimp.cosphi.st[order(varimp.cosphi.st, decreasing=T)][1:10])
```

```
##       wlconnections_openwaterwetlands_shoreline_km
##                                       0.0036115389
## buffer500m_streamdensity_headwaters_density_mperha
##                                       0.0029414252
##                                               chla
##                                       0.0021518812
##    buffer500m_streamdensity_streams_density_mperha
##                                       0.0017242667
## wlconnections_openwaterwetlands_contributing_area_
##                                       0.0017159523
##                               hu12_nlcd2011_pct_21
##                                       0.0016690333
##                             hu12_dep_no3_tavg_mean
##                                       0.0006145133
##                      hu12_roaddensity_density_mperha
##                                       0.0003925408
##                               hu12_nlcd2011_pct_43
##                                       0.0002946801
##     wlconnections_allwetlands_contributing_area_ha
##                                       0.0002103607
```

```
pred.cosphi.st<-predict(cf.cosphist, newdata=rfdat.phist,type="response")
cor.test(pred.cosphi.st,cos(rfdat.phist$accndviphi.ts1))
```

```
##
##  Pearson's product-moment correlation
##
## data:  pred.cosphi.st and cos(rfdat.phist$accndviphi.ts1)
## t = 10.23, df = 37, p-value = 2.463e-12
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.7464346 0.9243592
## sample estimates:
##      cor
## 0.859523
```

```
#sine
cf.sinphist<-party::cforest(sin(accndviphi.ts1) ~ ., data=rfdat.phist,
                         controls=cforest_control(ntree=50000,mincriterion = 0.9,mtry=3))
varimp.sinphi.st<-varimp(cf.sinphist)
print(varimp.sinphi.st[order(varimp.sinphi.st, decreasing=T)][1:10])
```

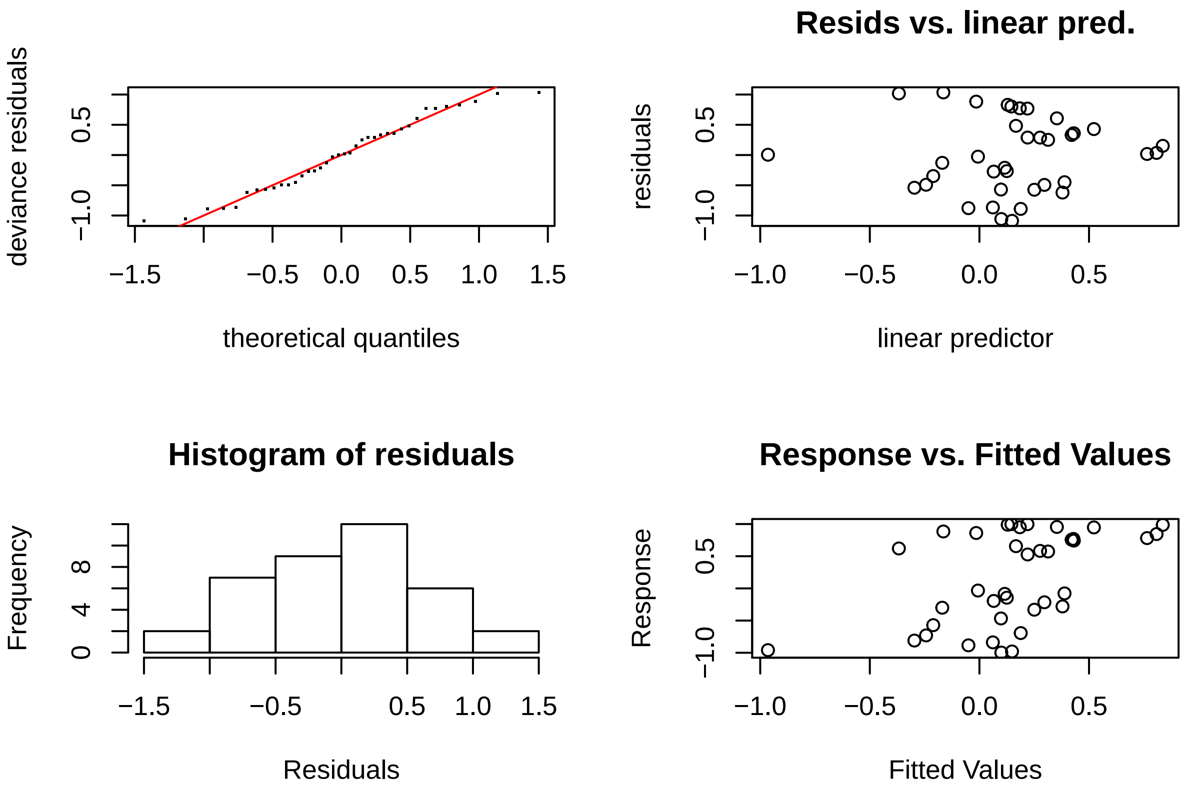
```
## buffer500m_streamdensity_headwaters_density_mperha
##                                        0.010017274
##                             hu12_dep_so4_tavg_mean
##                                        0.007667561
##    buffer500m_streamdensity_streams_density_mperha
##                                        0.006856405
##                             hu12_dep_no3_tavg_mean
##                                        0.005219028
##                       hu12_damdensity_pointspersqkm
##                                        0.004444435
##      hu12_prism_ppt_30yr_normal_800mm2_annual_mean
##                                        0.003206801
##                                    hu12_runoff_mean
```

```
##                                      0.003003752
##                                       hu4_zoneid
##                                      0.002132984
##                      hu12_groundwaterrecharge_mean
##                                      0.001955628
##                               hu12_nlcd2011_pct_21
##                                      0.001909523
```

```
pred.sinphi.st<-predict(cf.sinphist, newdata=rfdat.phist,type="response")
cor.test(pred.sinphi.st,sin(rfdat.phist$accndviphi.ts1))
```

```
##
##  Pearson's product-moment correlation
##
## data:  pred.sinphi.st and sin(rfdat.phist$accndviphi.ts1)
## t = 8.4605, df = 37, p-value = 3.55e-10
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.6673868 0.8975239
## sample estimates:
##       cor
## 0.8119335
```

```
lwgt<-preds$tslength[coh.chlaXaccndvi$accndvip.ts1<0.3]/mean(preds$tslength[coh.chlaXaccndvi$accndvip.ts

#cosine
gam.cosphist<-gam(cos(accndviphi.ts1) ~ s(wlconnections_openwaterwetlands_shoreline_km) +
                 s(buffer500m_streamdensity_headwaters_density_mperha) +
                 s(chla),
               data=rfdat.phist, gamma=1, weights=lwgt)
gam.check(gam.cosphist)
```




```
##
## Method: GCV   Optimizer: magic
## Smoothing parameter selection converged after 18 iterations.
## The RMS GCV score gradient at convergence was 6.535151e-08 .
## The Hessian was positive definite.
## Model rank =  28 / 28
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##                                                        k'  edf k-index
## s(wlconnections_openwaterwetlands_shoreline_km)      9.00 1.00    1.16
## s(buffer500m_streamdensity_headwaters_density_mperha) 9.00 1.00    1.07
## s(chla)                                              9.00 1.93    1.00
##                                                      p-value
## s(wlconnections_openwaterwetlands_shoreline_km)         0.78
## s(buffer500m_streamdensity_headwaters_density_mperha)   0.53
## s(chla)                                                 0.41
```

```
concurvity(gam.cosphist, full=F)$estimate
```

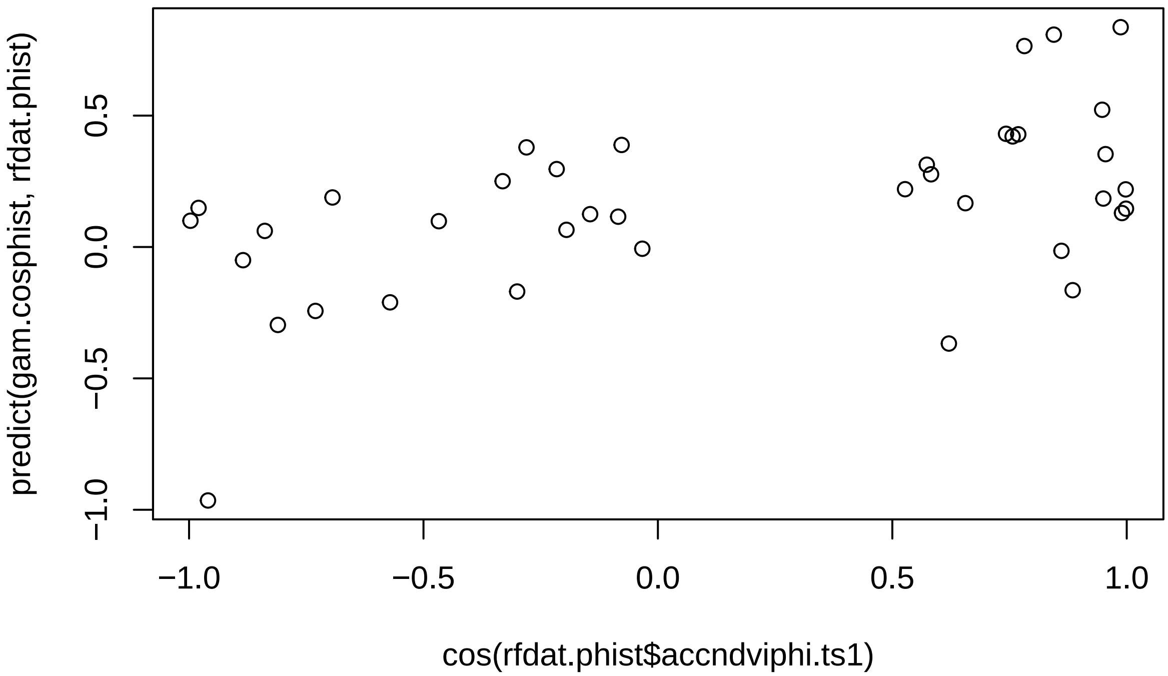
```
##                                                               para
## para                                                  1.000000e+00
## s(wlconnections_openwaterwetlands_shoreline_km)       2.086622e-16
## s(buffer500m_streamdensity_headwaters_density_mperha) 1.103013e-21
## s(chla)                                               1.274873e-23
##                                                       s(wlconnections_openwaterwetlands_shoreline_km
## para                                                                                          1.287237e-2
## s(wlconnections_openwaterwetlands_shoreline_km)                                               1.000000e+0
## s(buffer500m_streamdensity_headwaters_density_mperha)                                         2.090337e-0
```

```
## s(chla)                                                                         8.865244e-0
##                                                   s(buffer500m_streamdensity_headwaters_density_
## para                                                                                   3.790
## s(wlconnections_openwaterwetlands_shoreline_km)                                        9.092
## s(buffer500m_streamdensity_headwaters_density_mperha)                                  1.000
## s(chla)                                                                                4.930
##                                                           s(chla)
## para                                                  2.003688e-27
## s(wlconnections_openwaterwetlands_shoreline_km)       9.679937e-02
## s(buffer500m_streamdensity_headwaters_density_mperha) 3.007850e-01
## s(chla)                                               1.000000e+00
```

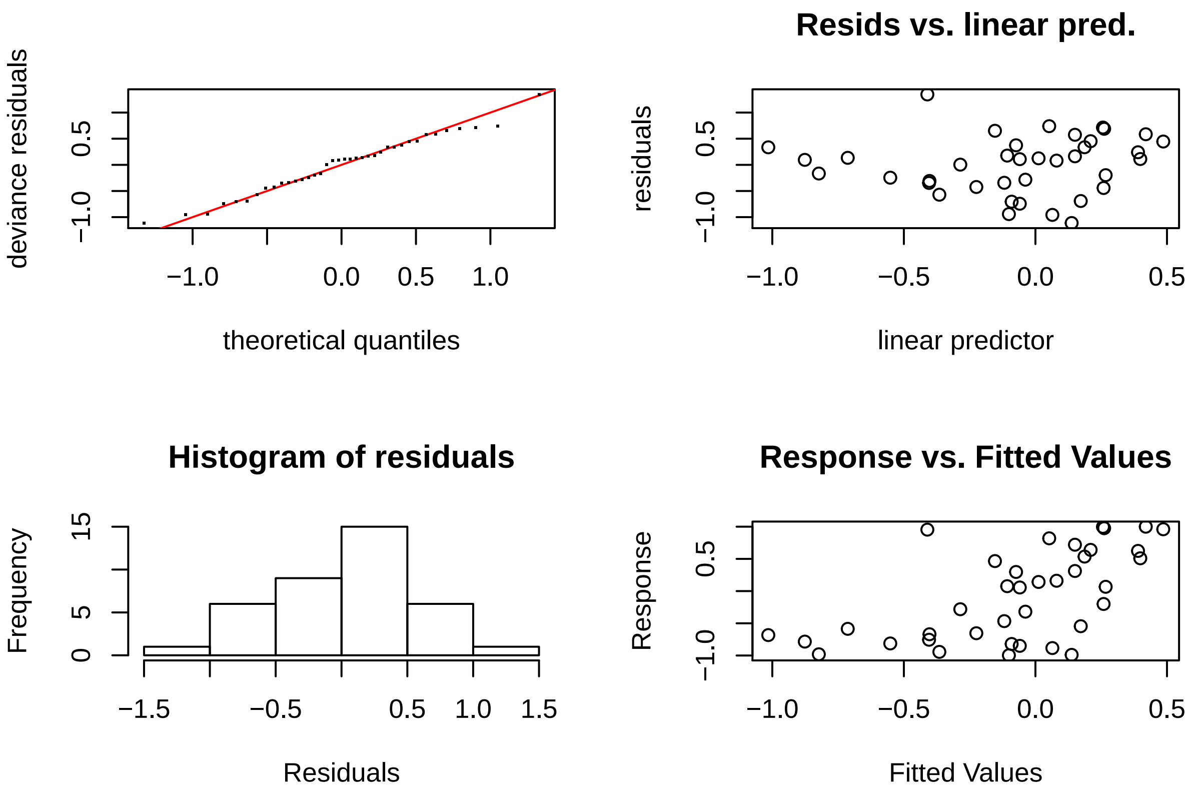
```r
summary(gam.cosphist)
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## cos(accndviphi.ts1) ~ s(wlconnections_openwaterwetlands_shoreline_km) +
##     s(buffer500m_streamdensity_headwaters_density_mperha) + s(chla)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   0.1566     0.1050   1.491    0.145
##
## Approximate significance of smooth terms:
##                                                         edf Ref.df     F
## s(wlconnections_openwaterwetlands_shoreline_km)       1.000  1.000 2.722
## s(buffer500m_streamdensity_headwaters_density_mperha) 1.000  1.000 4.536
## s(chla)                                               1.927  2.316 2.172
##                                                       p-value
## s(wlconnections_openwaterwetlands_shoreline_km)        0.1083
## s(buffer500m_streamdensity_headwaters_density_mperha)  0.0406 *
## s(chla)                                                0.1043
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.186   Deviance explained = 27.3%
## GCV = 0.47882  Scale est. = 0.41674   n = 38
```

```r
plot(cos(rfdat.phist$accndviphi.ts1), predict(gam.cosphist, rfdat.phist))
```




```
#sine -- ignored in main text
gam.sinphist<-gam(sin(accndviphi.ts1) ~ s(buffer500m_streamdensity_headwaters_density_mperha) +
                  s(hu12_dep_so4_tavg_mean) +
                  s(hu12_damdensity_pointspersqkm),
                data=rfdat.phist, gamma=1, weights=lwgt)
gam.check(gam.sinphist)
```




```
##
```

```
## Method: GCV   Optimizer: magic
## Smoothing parameter selection converged after 17 iterations.
## The RMS GCV score gradient at convergence was 4.469946e-08 .
## The Hessian was positive definite.
## Model rank =  28 / 28
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##                                                           k'  edf k-index
## s(buffer500m_streamdensity_headwaters_density_mperha) 9.00 3.55    1.01
## s(hu12_dep_so4_tavg_mean)                             9.00 1.00    0.81
## s(hu12_damdensity_pointspersqkm)                      9.00 1.00    1.07
##                                                       p-value
## s(buffer500m_streamdensity_headwaters_density_mperha)    0.50
## s(hu12_dep_so4_tavg_mean)                                0.08 .
## s(hu12_damdensity_pointspersqkm)                         0.66
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
concurvity(gam.sinphist,full=F)$estimate
```

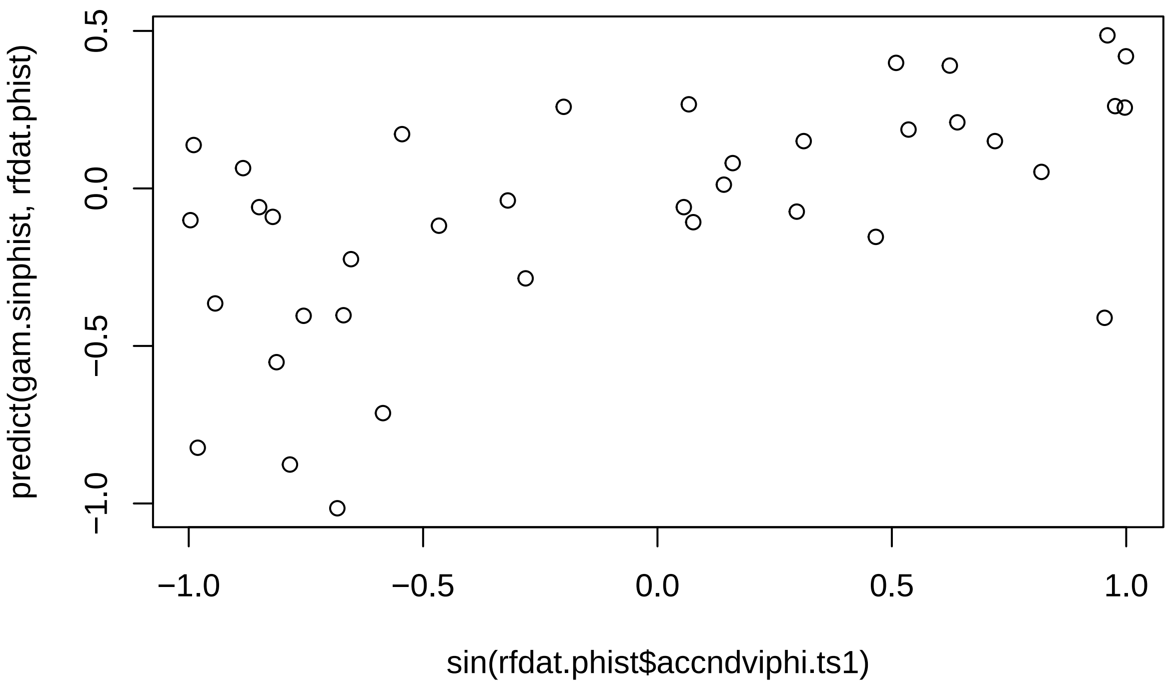
```
##                                                               para
## para                                                  1.000000e+00
## s(buffer500m_streamdensity_headwaters_density_mperha) 1.103094e-21
## s(hu12_dep_so4_tavg_mean)                             1.670584e-26
## s(hu12_damdensity_pointspersqkm)                      4.263181e-23
##                                                       s(buffer500m_streamdensity_headwaters_density_
## para                                                                                           3.790
## s(buffer500m_streamdensity_headwaters_density_mperha)                                          1.000
## s(hu12_dep_so4_tavg_mean)                                                                      5.309
## s(hu12_damdensity_pointspersqkm)                                                               1.854
##                                                       s(hu12_dep_so4_tavg_mean)
## para                                                               2.708298e-29
## s(buffer500m_streamdensity_headwaters_density_mperha)              4.495375e-01
## s(hu12_dep_so4_tavg_mean)                                          1.000000e+00
## s(hu12_damdensity_pointspersqkm)                                   4.367652e-01
##                                                       s(hu12_damdensity_pointspersqkm)
## para                                                                      1.894220e-25
## s(buffer500m_streamdensity_headwaters_density_mperha)                     1.926165e-01
## s(hu12_dep_so4_tavg_mean)                                                 3.954777e-01
## s(hu12_damdensity_pointspersqkm)                                          1.000000e+00
```

```r
summary(gam.sinphist)
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## sin(accndviphi.ts1) ~ s(buffer500m_streamdensity_headwaters_density_mperha) +
##     s(hu12_dep_so4_tavg_mean) + s(hu12_damdensity_pointspersqkm)
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept) -0.07683    0.09714  -0.791    0.435
##
## Approximate significance of smooth terms:
##                                                   edf  Ref.df     F
## s(buffer500m_streamdensity_headwaters_density_mperha) 3.552  4.272 1.746
## s(hu12_dep_so4_tavg_mean)                         1.000  1.000 1.280
## s(hu12_damdensity_pointspersqkm)                  1.000  1.000 0.461
##                                                   p-value
## s(buffer500m_streamdensity_headwaters_density_mperha)   0.152
## s(hu12_dep_so4_tavg_mean)                           0.266
## s(hu12_damdensity_pointspersqkm)                    0.502
##
## R-sq.(adj) =  0.254   Deviance explained = 36.6%
## GCV = 0.43076  Scale est. = 0.35649   n = 38
```

```r
plot(sin(rfdat.phist$accndviphi.ts1), predict(gam.sinphist, rfdat.phist))
```




```r
rfdat.philt<-left_join(coh.chlaXaccndvi[,c(10,5)], preds)
```

```
## Joining, by = "lagoslakeid"
```

```r
rfdat.philt<-rfdat.philt[,!colnames(rfdat.philt) %in%
                          c("lagoslakeid","start","end","lakes_nhdid","hu12_zoneid","tslength","county_
rfdat.philt<-rfdat.philt[,!grepl("borderhu12s",colnames(rfdat.philt))]

rfdat.philt<-rfdat.philt[coh.chlaXaccndvi$accndvip.ts2<0.3,]

for(nn in 1:ncol(rfdat.philt)){
  if(is.character(rfdat.philt[,nn])){
    rfdat.philt[,nn]<-as.factor(rfdat.philt[,nn])
  }
}

#cosine
```

```r
cf.cosphilt<-party::cforest(cos(accndviphi.ts2) ~ ., data=rfdat.philt,
                         controls=cforest_control(ntree=50000,mincriterion = 0.9,mtry=3))

varimp.cosphi.lt<-varimp(cf.cosphilt)
print(varimp.cosphi.lt[order(varimp.cosphi.lt, decreasing=T)][1:10])
```

```
##                                          hu4_zoneid
##                                         0.011242853
##                                          hu6_zoneid
##                                         0.009603132
##                                     hu12_slope_mean
##                                         0.007261197
##                                       hu12_tri_mean
##                                         0.006826300
##                                 hu12_nlcd2011_pct_90
##                                         0.004997338
##                                 hu12_nlcd2011_pct_41
##                                         0.004453411
## buffer500m_streamdensity_headwaters_density_mperha
##                                         0.004395259
##                            hu12_dep_totaln_tavg_mean
##                                         0.004302371
##                                          hu8_zoneid
##                                         0.003799415
## buffer500m_streamdensity_midreaches_density_mperha
##                                         0.002683593
```

```r
pred.cosphi.lt<-predict(cf.cosphilt, newdata=rfdat.philt,type="response")
cor.test(pred.cosphi.lt,cos(rfdat.philt$accndviphi.ts2))
```

```
##
##  Pearson's product-moment correlation
##
## data:  pred.cosphi.lt and cos(rfdat.philt$accndviphi.ts2)
## t = 10.436, df = 43, p-value = 2.327e-13
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.7361460 0.9132678
## sample estimates:
##       cor
## 0.8467179
```

```r
#sine
cf.sinphilt<-party::cforest(sin(accndviphi.ts2) ~ ., data=rfdat.philt,
                         controls=cforest_control(ntree=50000,mincriterion = 0.9,mtry=3))

varimp.sinphi.lt<-varimp(cf.sinphilt)
print(varimp.sinphi.lt[order(varimp.sinphi.lt, decreasing=T)][1:10])
```

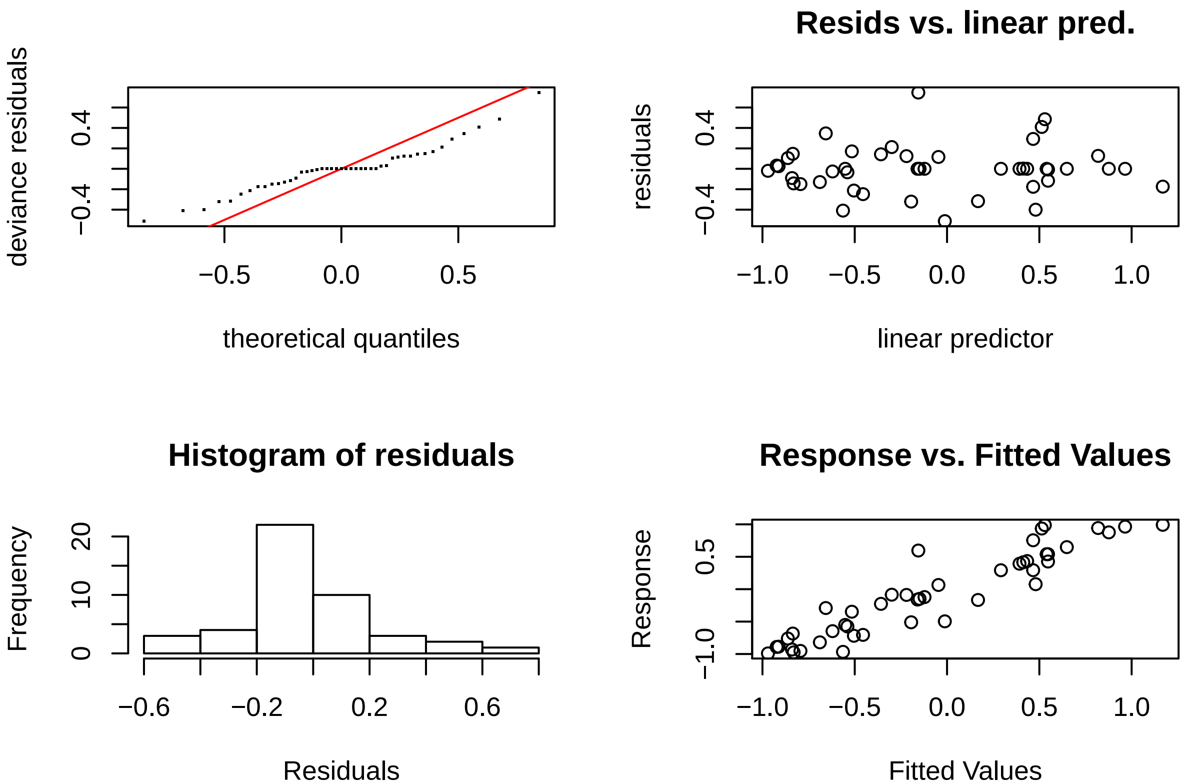
```
##                                          hu4_zoneid
##                                         0.015237229
##                                          hu6_zoneid
##                                         0.010382363
##                                 hu12_nlcd2011_pct_82
##                                         0.008137326
```

```
##                                            hu8_zoneid
##                                           0.007785586
##                                  hu12_nlcd2011_pct_21
##                                           0.005314177
## wlconnections_openwaterwetlands_contributing_area_
##                                           0.003765287
##       wlconnections_openwaterwetlands_shoreline_km
##                                           0.003187586
##             wlconnections_allwetlands_shoreline_km
##                                           0.002555512
##                                  hu12_nlcd2011_pct_11
##                                           0.002021439
##        wlconnections_forestedwetlands_shoreline_km
##                                           0.001808104
```

```
pred.sinphi.lt<-predict(cf.sinphilt, newdata=rfdat.philt,type="response")
cor.test(pred.sinphi.lt,sin(rfdat.philt$accndviphi.ts2))
```

```
##
##  Pearson's product-moment correlation
##
## data:  pred.sinphi.lt and sin(rfdat.philt$accndviphi.ts2)
## t = 10.353, df = 43, p-value = 2.984e-13
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.7330286 0.9121372
## sample estimates:
##       cor
## 0.8447901
```

```
lwgt<-preds$tslength[coh.chlaXaccndvi$accndvip.ts2<0.3]/mean(preds$tslength[coh.chlaXaccndvi$accndvip.ts

#cosine
gam.cosphilt<-gam(cos(accndviphi.ts2) ~ hu4_zoneid + s(hu12_slope_mean) +
                 s(hu12_nlcd2011_pct_90),
               data=rfdat.philt, gamma=1, weights=lwgt)
gam.check(gam.cosphilt)
```




```
##
## Method: GCV   Optimizer: magic
## Smoothing parameter selection converged after 12 iterations.
## The RMS GCV score gradient at convergence was 8.687603e-08 .
## The Hessian was positive definite.
## Model rank =  40 / 40
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##                            k'  edf k-index p-value
## s(hu12_slope_mean)       9.00 1.00    1.31    0.94
## s(hu12_nlcd2011_pct_90) 9.00 4.49    0.94    0.31
```

```
concurvity(gam.cosphilt,full=F)$estimate
```

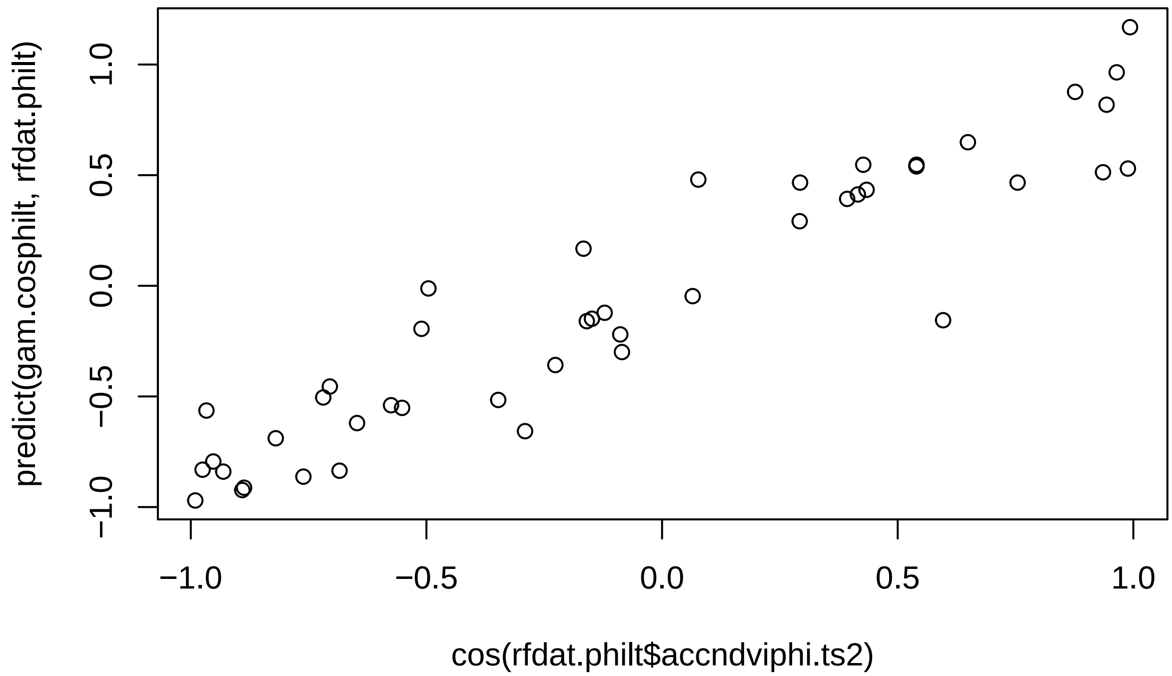
```
##                                 para s(hu12_slope_mean)
## para                    1.000000e+00       5.626002e-29
## s(hu12_slope_mean)      4.786705e-26       1.000000e+00
## s(hu12_nlcd2011_pct_90) 3.163661e-25       1.223702e-01
##                         s(hu12_nlcd2011_pct_90)
## para                               1.774799e-27
## s(hu12_slope_mean)                 2.439443e-01
## s(hu12_nlcd2011_pct_90)            1.000000e+00
```

```
summary(gam.cosphilt)
```

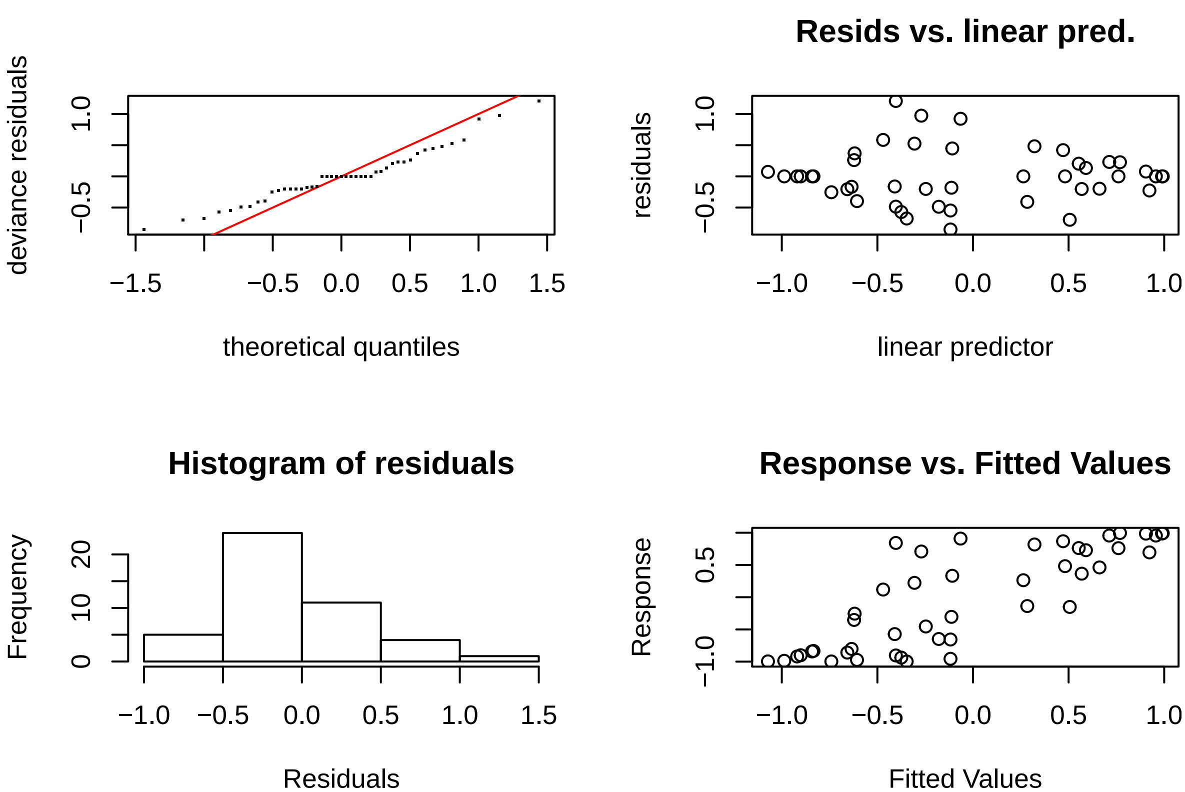
```
##
## Family: gaussian
## Link function: identity
```

```
##
## Formula:
## cos(accndviphi.ts2) ~ hu4_zoneid + s(hu12_slope_mean) + s(hu12_nlcd2011_pct_90)
##
## Parametric coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)      -0.18714    0.30536  -0.613  0.54786
## hu4_zoneidHU4_12 -0.33067    0.47342  -0.698  0.49406
## hu4_zoneidHU4_16  0.72647    0.48301   1.504  0.15039
## hu4_zoneidHU4_18  0.52995    0.49544   1.070  0.29930
## hu4_zoneidHU4_25 -0.64913    0.40954  -1.585  0.13085
## hu4_zoneidHU4_27  0.14844    0.49095   0.302  0.76594
## hu4_zoneidHU4_29  1.00467    0.36172   2.778  0.01265 *
## hu4_zoneidHU4_30  1.25402    0.38694   3.241  0.00466 **
## hu4_zoneidHU4_32  0.26735    0.37751   0.708  0.48815
## hu4_zoneidHU4_33  0.08305    0.52170   0.159  0.87535
## hu4_zoneidHU4_35  1.78804    0.50304   3.554  0.00235 **
## hu4_zoneidHU4_36  1.23219    0.47379   2.601  0.01835 *
## hu4_zoneidHU4_4   0.27415    0.34390   0.797  0.43602
## hu4_zoneidHU4_5   0.36503    0.46342   0.788  0.44141
## hu4_zoneidHU4_51 -0.53839    0.55972  -0.962  0.34920
## hu4_zoneidHU4_54  0.34948    0.54579   0.640  0.53025
## hu4_zoneidHU4_60  0.09461    0.35678   0.265  0.79398
## hu4_zoneidHU4_63 -1.04778    0.52845  -1.983  0.06331 .
## hu4_zoneidHU4_64 -0.87465    0.54104  -1.617  0.12384
## hu4_zoneidHU4_65 -0.55797    0.52403  -1.065  0.30145
## hu4_zoneidHU4_67 -0.87794    0.69085  -1.271  0.22042
## hu4_zoneidHU4_7  -0.45327    0.45150  -1.004  0.32909
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                          edf Ref.df      F p-value
## s(hu12_slope_mean)      1.000  1.000 10.093 0.00520 **
## s(hu12_nlcd2011_pct_90) 4.492  5.327  5.264 0.00307 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.682   Deviance explained = 87.3%
## GCV = 0.35027  Scale est. = 0.13628   n = 45
```

```r
plot(cos(rfdat.philt$accndviphi.ts2), predict(gam.cosphilt, rfdat.philt))
```




```
#sine
gam.sinphilt<-gam(sin(accndviphi.ts2) ~ hu4_zoneid + s(hu12_nlcd2011_pct_82) +
                  s(hu12_nlcd2011_pct_21),
                  data=rfdat.philt, gamma=1, weights=lwgt)
gam.check(gam.sinphilt)
```




```
##
## Method: GCV   Optimizer: magic
```

```
## Smoothing parameter selection converged after 16 iterations.
## The RMS GCV score gradient at convergence was 9.021055e-08 .
## The Hessian was positive definite.
## Model rank =  40 / 40
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##                          k' edf k-index p-value
## s(hu12_nlcd2011_pct_82)  9   1    1.19    0.87
## s(hu12_nlcd2011_pct_21)  9   1    1.04    0.57
```

```r
concurvity(gam.sinphilt,full=F)$estimate
```

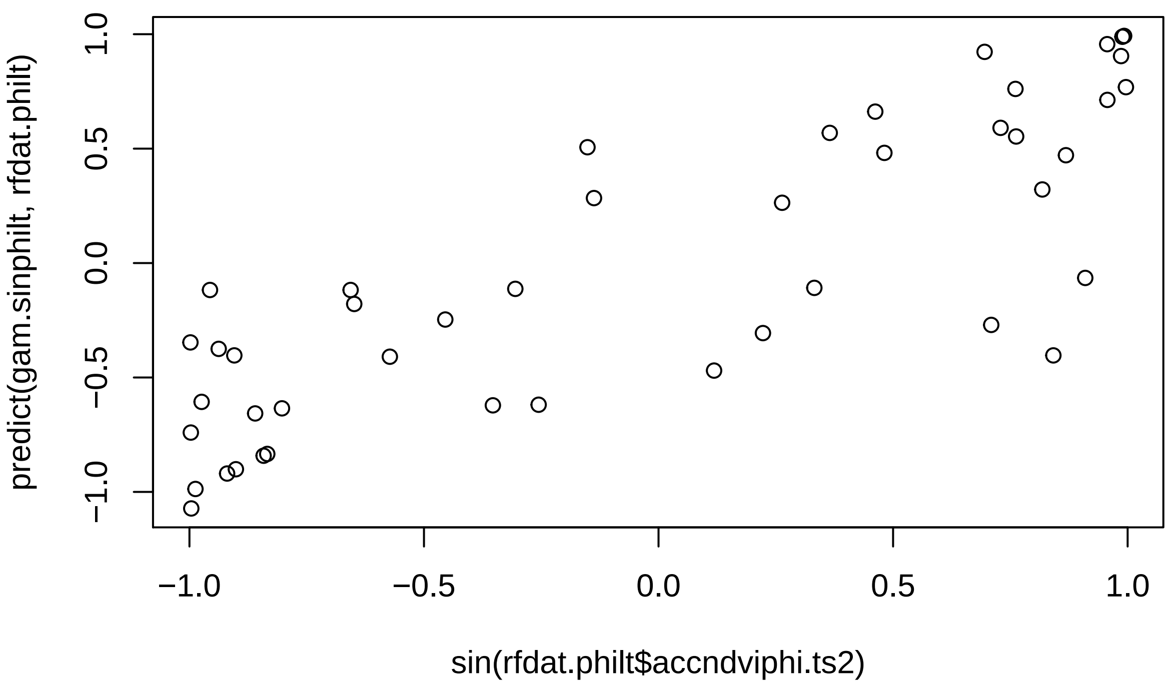
```
##                                 para s(hu12_nlcd2011_pct_82)
## para                    1.000000e+00            9.241976e-26
## s(hu12_nlcd2011_pct_82) 7.966017e-24            1.000000e+00
## s(hu12_nlcd2011_pct_21) 3.596625e-25            1.469472e-01
##                         s(hu12_nlcd2011_pct_21)
## para                               3.569289e-28
## s(hu12_nlcd2011_pct_82)            2.085543e-01
## s(hu12_nlcd2011_pct_21)            1.000000e+00
```

```r
summary(gam.sinphilt)
```

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## sin(accndviphi.ts2) ~ hu4_zoneid + s(hu12_nlcd2011_pct_82) +
##     s(hu12_nlcd2011_pct_21)
##
## Parametric coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)       0.71856    0.46879   1.533   0.1403
## hu4_zoneidHU4_12 -0.86381    0.55846  -1.547   0.1369
## hu4_zoneidHU4_16 -1.31844    0.79102  -1.667   0.1104
## hu4_zoneidHU4_18 -1.67325    0.80817  -2.070   0.0509 .
## hu4_zoneidHU4_25 -1.05635    0.57354  -1.842   0.0797 .
## hu4_zoneidHU4_27 -0.04563    1.00959  -0.045   0.9644
## hu4_zoneidHU4_29 -1.01752    0.58301  -1.745   0.0956 .
## hu4_zoneidHU4_30 -1.41049    0.65170  -2.164   0.0421 *
## hu4_zoneidHU4_32 -0.42915    0.62146  -0.691   0.4974
## hu4_zoneidHU4_33 -0.82743    0.55940  -1.479   0.1540
## hu4_zoneidHU4_35 -0.23449    0.95633  -0.245   0.8087
## hu4_zoneidHU4_36  0.08427    0.95827   0.088   0.9308
## hu4_zoneidHU4_4  -1.32548    0.58349  -2.272   0.0337 *
## hu4_zoneidHU4_5  -1.20527    0.65070  -1.852   0.0781 .
## hu4_zoneidHU4_51 -1.50451    0.74801  -2.011   0.0573 .
## hu4_zoneidHU4_54 -0.28087    0.77874  -0.361   0.7220
## hu4_zoneidHU4_60 -0.27171    0.64760  -0.420   0.6791
## hu4_zoneidHU4_63 -1.45096    0.77839  -1.864   0.0764 .
## hu4_zoneidHU4_64 -1.55263    0.77223  -2.011   0.0574 .
## hu4_zoneidHU4_65  0.29763    0.75187   0.396   0.6962
```

```
## hu4_zoneidHU4_67 -0.42789    0.75233  -0.569   0.5756
## hu4_zoneidHU4_7   0.08444    0.65527   0.129   0.8987
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##                          edf Ref.df     F p-value
## s(hu12_nlcd2011_pct_82)   1      1 0.381   0.544
## s(hu12_nlcd2011_pct_21)   1      1 1.023   0.323
##
## R-sq.(adj) =  0.325   Deviance explained = 67.8%
## GCV = 0.84873  Scale est. = 0.39608   n = 45
```

```r
plot(sin(rfdat.philt$accndviphi.ts2), predict(gam.sinphilt, rfdat.philt))
```




```r
# save.image(file="~/Box Sync/NSF EAGER Synchrony/Data/results_20191106.RData")
```

```r
print(varimp.coh.st[order(varimp.coh.st, decreasing=T)][1:10])
```

```
##                                     cv.accndvi
##                                   0.0005710355
##                                    hu8_zoneid
##                                   0.0005568739
##                      hu12_dep_totaln_tavg_mean
##                                   0.0004949402
##                           hu12_nlcd2011_pct_90
##                                   0.0001939783
##                           hu12_nlcd2011_pct_95
##                                   0.0001609831
## wlconnections_scrubshrubwetlands_shoreline_km
##                                   0.0001473959
##        wlconnections_allwetlands_shoreline_km
##                                   0.0001400305
```

```
##                                hu12_slope_mean
##                                   0.0001274735
##                                 hu12_tri_mean
##                                   0.0001274102
##   wlconnections_forestedwetlands_shoreline_km
##                                   0.0000901705
```

```r
ltxt.st<-c("cv(NDVI)","HUC-8 sub-basin","total N deposition","% woody wetlands","% herbaceous wetlands"
           "shrub wetlands shoreline","all wetlands shoreline","slope","topographic roughness","foreste

print(varimp.coh.lt[order(varimp.coh.lt, decreasing=T)][1:10])
```

```
##                                     hu8_zoneid
##                                   1.224867e-03
##                           hu12_nlcd2011_pct_52
##                                   9.141534e-04
##                                      cv.accndvi
##                                   4.451874e-04
##  hu12_prism_ppt_30yr_normal_800mm2_annual_mean
##                                   1.450424e-04
## wlconnections_allwetlands_contributing_area_ha
##                                   1.447590e-04
##    wlconnections_forestedwetlands_shoreline_km
##                                   1.362169e-04
##                           hu12_nlcd2011_pct_95
##                                   1.257159e-04
##        wlconnections_allwetlands_shoreline_km
##                                   9.856973e-05
##                         hu12_dep_so4_tavg_mean
##                                   8.810665e-05
##                hu12_groundwaterrecharge_mean
##                                   7.183743e-05
```

```r
ltxt.lt<-c("HUC-8 sub-basin","% shrub/scrub","cv(NDVI)","annual precipitation","all wetlands contrib. a
           "forested wetlands shoreline","% woody wetlands","all wetlands shoreline","sulfate depositio
           "groundwater recharge")

print(varimp.cosphi.st[order(varimp.cosphi.st, decreasing = T)][1:10])
```

```
##       wlconnections_openwaterwetlands_shoreline_km
##                                       0.0036115389
## buffer500m_streamdensity_headwaters_density_mperha
##                                       0.0029414252
##                                               chla
##                                       0.0021518812
##    buffer500m_streamdensity_streams_density_mperha
##                                       0.0017242667
## wlconnections_openwaterwetlands_contributing_area_
##                                       0.0017159523
##                               hu12_nlcd2011_pct_21
##                                       0.0016690333
##                             hu12_dep_no3_tavg_mean
##                                       0.0006145133
##                      hu12_roaddensity_density_mperha
##                                       0.0003925408
```

```
##                               hu12_nlcd2011_pct_43
##                                       0.0002946801
##     wlconnections_allwetlands_contributing_area_ha
##                                       0.0002103607
```

```r
ltxt.cosphist<-c("open wetlands shoreline","headwaters density","stream density","mean chlorophyll-a",
              "% developed open space","open wetlands contrib. area","all wetlands contrib. area", "roac
              "% pasture/hay")

print(varimp.sinphi.lt[order(varimp.sinphi.lt, decreasing = T)][1:10])
```

```
##                                         hu4_zoneid
##                                        0.015237229
##                                         hu6_zoneid
##                                        0.010382363
##                               hu12_nlcd2011_pct_82
##                                        0.008137326
##                                         hu8_zoneid
##                                        0.007785586
##                               hu12_nlcd2011_pct_21
##                                        0.005314177
## wlconnections_openwaterwetlands_contributing_area_
##                                        0.003765287
##       wlconnections_openwaterwetlands_shoreline_km
##                                        0.003187586
##             wlconnections_allwetlands_shoreline_km
##                                        0.002555512
##                               hu12_nlcd2011_pct_11
##                                        0.002021439
##        wlconnections_forestedwetlands_shoreline_km
##                                        0.001808104
```

```r
ltxt.sinphilt<-c("HUC-4 subregion","HUC-6 basin","% cultivated crops","HUC-8 sub-basin","% developed ope
                "open wetlands contrib. area","all wetlands contrib. area","% open water","all wetlands


tiff("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig4_varimp_top10.tif",unit

par(mfrow=c(2,2), mar=c(4,11,1,1), cex.main=0.9, cex.axis=0.9)

barplot(rev(varimp.coh.st[order(varimp.coh.st, decreasing=T)][1:10]),names.arg=rev(ltxt.st),las=2,main=

barplot(rev(varimp.coh.lt[order(varimp.coh.lt, decreasing=T)][1:10]),names.arg=rev(ltxt.lt),las=2,main=

barplot(rev(varimp.cosphi.st[order(varimp.cosphi.st, decreasing=T)][1:10]),names.arg=rev(ltxt.cosphist)
        main=expression(paste("b) Short timescale cosine(",phi,")",sep="")), horiz=T)

barplot(rev(varimp.sinphi.lt[order(varimp.sinphi.lt, decreasing=T)][1:10]),names.arg=rev(ltxt.sinphilt)
        main=expression(paste("d) Long timescale sine(",phi,")",sep="")), horiz=T)

dev.off()
```

```
## pdf
##   2
```

```r
## Make geographic variation images
huc4_bdys<-readOGR("~/Box Sync/NSF EAGER Synchrony/Data/HU4.shp")
```

```
## OGR data source with driver: ESRI Shapefile
## Source: "/Users/jonathanwalter/Box Sync/NSF EAGER Synchrony/Data/HU4.shp", layer: "HU4"
## with 65 features
## It has 13 fields
## Integer64 fields read as strings:  GNIS_ID
```

```r
huc8_bdys<-readOGR("~/Box Sync/NSF EAGER Synchrony/Data/HU8.shp")
```

```
## OGR data source with driver: ESRI Shapefile
## Source: "/Users/jonathanwalter/Box Sync/NSF EAGER Synchrony/Data/HU8.shp", layer: "HU8"
## with 511 features
## It has 13 fields
## Integer64 fields read as strings:  GNIS_ID
```

```r
cohst_huc8<-data.frame(ZoneID=names(gam.cohst$coefficients)[grepl("hu8_zoneid",names(gam.cohst$coeffici
                       coeff=gam.cohst$coefficients[grepl("hu8_zoneid",names(gam.cohst$coefficients))])
rownames(cohst_huc8)<-c()
cohst_huc8$ZoneID<-substring(cohst_huc8$ZoneID,11)

cohlt_huc8<-data.frame(ZoneID=names(gam.cohlt$coefficients)[grepl("hu8_zoneid",names(gam.cohlt$coeffici
                       coeff=gam.cohlt$coefficients[grepl("hu8_zoneid",names(gam.cohlt$coefficients))])
rownames(cohlt_huc8)<-c()
cohlt_huc8$ZoneID<-substring(cohlt_huc8$ZoneID,11)

sinphilt_huc4<-data.frame(ZoneID=names(gam.sinphilt$coefficients)[grepl("hu4_zoneid",names(gam.sinphilt$
                       coeff=gam.sinphilt$coefficients[grepl("hu4_zoneid",names(gam.sinphilt$coefficients
rownames(sinphilt_huc4)<-c()
sinphilt_huc4$ZoneID<-substring(sinphilt_huc4$ZoneID,11)

# lagosstates_outline<-lagosstates
# lagosstates_outline@data$dissolve<-rep(1,length(lagosstates_outline))
# lagosstates_outline<-gUnaryUnion(lagosstates_outline,id=lagosstates_outline@data$dissolve)
# huc4_bdys<-raster::intersect(huc4_bdys,lagosstates_outline)
# huc8_bdys<-raster::intersect(huc8_bdys,lagosstates_outline)

# huc_codes<-read.csv("/Users/jonathanwalter/GitHub/AquaTerrSynch/AnalysisCode/match_huc_codes.csv", co
# huc_codes<-huc_codes[huc_codes$hu4_zoneid %in% analysislakes$lakeinfo$hu4_zoneid,]

huc_bdys_cohst<-huc8_bdys[huc8_bdys$ZoneID %in% cohst_huc8$ZoneID,]
huc_bdys_cohst@data<-left_join(huc_bdys_cohst@data, cohst_huc8)
```

```
## Joining, by = "ZoneID"
## Warning: Column `ZoneID` joining factor and character vector, coercing into
## character vector
```

```r
huc_bdys_cohlt<-huc8_bdys[huc8_bdys$ZoneID %in% cohlt_huc8$ZoneID,]
huc_bdys_cohlt@data<-left_join(huc_bdys_cohlt@data, cohlt_huc8)
```

```
## Joining, by = "ZoneID"
## Warning: Column `ZoneID` joining factor and character vector, coercing into
## character vector
```

```r
huc_bdys_sinphilt<-huc4_bdys[huc4_bdys$ZoneID %in% sinphilt_huc4$ZoneID,]
huc_bdys_sinphilt@data<-left_join(huc_bdys_sinphilt@data, sinphilt_huc4)
```

```
## Joining, by = "ZoneID"

## Warning: Column `ZoneID` joining factor and character vector, coercing into
## character vector
```

```r
scale1_100<-function(x){
  x1<-x-min(x)+1/100
  x1<-round(x1/max(x1)*100)
  return(x1)
}
#make smaller images that we can insert into the main figure

bight=6.5
bigwd=6.5

lagosstates_prj<-spTransform(lagosstates, proj4string(huc8_bdys))

# png("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5b_hu8_cohst.png", uni
#      res=300, width=bigwd/5, height=bight/4)
# par(mar=c(0,0,2,0))
# plot(huc_bdys_cohst,bty="o",xlab="HU8 watershed", col=pal[scale1_100(huc_bdys_cohst$coeff)],xlim=c(-9
# lines(lagosstates_prj,lwd=0.5)
# par(fig=c(0.2,0.8,0.875,1), new=T,mar=c(.5,0,0.2,0), tcl=-0.15, mgp=c(1,0.2,0))
# image(matrix(1:100,ncol=1),col=pal[1:100], xaxt="n", yaxt="n")
# axis(1,at=c(0,0.25,0.5,0.75,1),labels=round(seq(min(huc_bdys_cohst$coeff), max(huc_bdys_cohst$coeff),
# dev.off()
#
# png("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5i_hu8_cohlt.png", uni
#      res=300, width=bigwd/5, height=bight/4)
# par(mar=c(0,0,2,0))
# plot(huc_bdys_cohlt,bty="o",xlab="HU8 watershed", col=pal[scale1_100(huc_bdys_cohlt$coeff)],xlim=c(-9
# lines(lagosstates_prj,lwd=0.5)
# par(fig=c(0.2,0.8,0.875,1), new=T,mar=c(.5,0,0.2,0), tcl=-0.15, mgp=c(1,0.2,0))
# image(matrix(1:100,ncol=1),col=pal[1:100], xaxt="n", yaxt="n")
# axis(1,at=c(0,0.25,0.5,0.75,1),labels=round(seq(min(huc_bdys_cohlt$coeff), max(huc_bdys_cohlt$coeff),
# dev.off()
#
# png("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5n_hu4_sinphilt.png",
#      res=300, width=bigwd/5, height=bight/4)
# par(mar=c(0,0,2,0))
# plot(huc_bdys_sinphilt,bty="o",xlab="HU4 watershed", col=pal[scale1_100(huc_bdys_sinphilt$coeff)],xli
# lines(lagosstates_prj,lwd=0.5)
# par(fig=c(0.2,0.8,0.875,1), new=T,mar=c(.5,0,0.2,0), tcl=-0.15, mgp=c(1,0.2,0))
# image(matrix(1:100,ncol=1),col=pal[1:100], xaxt="n", yaxt="n")
# axis(1,at=c(0,0.25,0.5,0.75,1),labels=round(seq(min(huc_bdys_sinphilt$coeff), max(huc_bdys_sinphilt$c
# dev.off()
#
#
# panel5b<-readPNG("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5b_hu8_co
# panel5i<-readPNG("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5i_hu8_co
# panel5n<-readPNG("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5n_hu4_si
#
```

```
# mar1<-c(3,1.5,0.5,1)
# fudge=1/40
#
# tiff("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5_gamfits.tif",units=
#
# par(mfrow=c(4,5),mgp=c(1.5,0.5,0),oma=c(0,2.5,0,0),mar=mar1)
#
# plot(gam.cohst,select=1,residuals=T,rug=FALSE,shade=T,cex=2,xlab="cv(NDVI)",ylab="short coherence")
# plot(NA,NA,xlim=c(0,1),ylim=c(0,1),xaxs="i",yaxs="i",ylab="",xlab="HUC-8 sub-basin",xaxt="n",yaxt="n"
# rasterImage(image=panel5b,xleft=1e-2,ybottom=1e-2,xright=1-1e-2,ytop=1-1e-2)
# plot(gam.cohst,select=2,residuals=T,rug=FALSE,shade=T,cex=2,xlab="total N deposition",ylab="")
# plot(gam.cohst,select=3,residuals=T,rug=FALSE,shade=T,cex=2,xlab="% woody wetlands",ylab="")
# plot(gam.cohst,select=4,residuals=T,rug=FALSE,shade=T,cex=2,xlab="% herbaceous wetld.",ylab="")
#
# plot(gam.cosphist,select=1,residuals=T,rug=FALSE,shade=T,cex=2,xlab="open wetlands shoreline",ylab="s
# plot(gam.cosphist,select=2,residuals=T,rug=FALSE,shade=T,cex=2,xlab="headwaters density",ylab="")
# plot(gam.cosphist,select=3,residuals=T,rug=FALSE,shade=T,cex=2,xlab="mean chlorophyll-a",ylab="")
# plot.new()
# plot.new()
#
# plot(NA,NA,xlim=c(0,1),ylim=c(0,1),xaxs="i",yaxs="i",ylab="",xlab="HUC-8 sub-basin",xaxt="n",yaxt="n"
# rasterImage(image=panel5i,xleft=1e-2,ybottom=1e-2,xright=1-1e-2,ytop=1-1e-2)
# plot(gam.cohlt,select=1,residuals=T,rug=FALSE,shade=T,cex=2,xlab="% shrub/scrub",ylab="long coherence
# plot(gam.cohlt,select=2,residuals=T,rug=FALSE,shade=T,cex=2,xlab="cv(NDVI)",ylab="",ylim=c(-1,1))
# plot(gam.cohlt,select=3,residuals=T,rug=FALSE,shade=T,cex=2,xlab="annual precipitation",ylab="")
# plot(gam.cohlt,select=4,residuals=T,rug=FALSE,shade=T,cex=2,xlab="all wetld. contrib. area",ylab="",y
#
# plot(NA,NA,xlim=c(0,1),ylim=c(0,1),xaxs="i",yaxs="i",ylab="",xlab="HUC-4 sub-region",xaxt="n",yaxt="n
# rasterImage(image=panel5n,xleft=1e-2,ybottom=1e-2,xright=1-1e-2,ytop=1-1e-2)
# plot(gam.sinphilt,select=1,residuals=T,rug=FALSE,shade=T,cex=2,xlab="% pasture",ylab="")
# plot(gam.sinphilt,select=2,residuals=T,rug=FALSE,shade=T,cex=2,xlab="% developed-open space",ylab="")
#
# mtext("Partial residuals",2,outer=T,line=1.2,cex=0.8)
# mtext("sin(long phase)",2,at=1/8+fudge,outer=T,line=0,cex=0.7)
# mtext("long coherence",2,at=1/8+1/4+fudge,outer=T,line=0,cex=0.7)
# mtext("cos(short phase)",2,at=1/8+2/4+fudge,outer=T,line=0,cex=0.7)
# mtext("short coherence",2,at=1/8+3/4+fudge,outer=T,line=0,cex=0.7)
#
# dev.off()


## try out landscape orientation

bight=5.5
bigwd=9

lagosstates_prj<-spTransform(lagosstates, proj4string(huc8_bdys))

png("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5b_hu8_cohst_lscp.png", u
    res=300, width=bigwd/5, height=bight/4)
par(mar=c(0,0,1,0))
plot(huc_bdys_cohst,bty="o",xlab="HU8 watershed", col=pal[scale1_100(huc_bdys_cohst$coeff)],xlim=c(-918
    ylim=c(1454000,3012981),lwd=0.5)
```

```
lines(lagosstates_prj,lwd=0.5)
par(fig=c(0.25,0.75,0.855,1), new=T,mar=c(.5,0,0.2,0), tcl=-0.15, mgp=c(1,0.05,0))
image(matrix(1:100,ncol=1),col=pal[1:100], xaxt="n", yaxt="n")
axis(1,at=c(0,0.25,0.5,0.75,1),labels=round(seq(min(huc_bdys_cohst$coeff), max(huc_bdys_cohst$coeff), le
dev.off()
```

```
## pdf
##   2
```

```
png("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5i_hu8_cohlt_lscp.png", u
     res=300, width=bigwd/5, height=bight/4)
par(mar=c(0,0,1,0))
plot(huc_bdys_cohlt,bty="o",xlab="HU8 watershed", col=pal[scale1_100(huc_bdys_cohlt$coeff)],xlim=c(-9183
     ylim=c(1454000,3012981),lwd=0.5)
lines(lagosstates_prj,lwd=0.5)
par(fig=c(0.25,0.75,0.855,1), new=T,mar=c(.5,0,0.2,0), tcl=-0.15, mgp=c(1,0.05,0))
image(matrix(1:100,ncol=1),col=pal[1:100], xaxt="n", yaxt="n")
axis(1,at=c(0,0.25,0.5,0.75,1),labels=round(seq(min(huc_bdys_cohlt$coeff), max(huc_bdys_cohlt$coeff), le
dev.off()
```

```
## pdf
##   2
```

```
png("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5n_hu4_sinphilt_lscp.png
     res=300, width=bigwd/5, height=bight/4)
par(mar=c(0,0,1,0))
plot(huc_bdys_sinphilt,bty="o",xlab="HU4 watershed", col=pal[scale1_100(huc_bdys_sinphilt$coeff)],xlim=c
     ylim=c(1454000,3012981),lwd=0.5)
lines(lagosstates_prj,lwd=0.5)
par(fig=c(0.25,0.75,0.855,1), new=T,mar=c(.5,0,0.2,0), tcl=-0.15, mgp=c(1,0.2,0))
image(matrix(1:100,ncol=1),col=pal[1:100], xaxt="n", yaxt="n")
axis(1,at=c(0,0.25,0.5,0.75,1),labels=round(seq(min(huc_bdys_sinphilt$coeff), max(huc_bdys_sinphilt$coef
dev.off()
```

```
## pdf
##   2
```

```
panel5b<-readPNG("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5b_hu8_cohs
panel5i<-readPNG("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5i_hu8_cohl
panel5n<-readPNG("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5n_hu4_sinp

mar1<-c(3,1.5,0.5,0.2)
fudge=1/34

tiff("~/Box Sync/NSF EAGER Synchrony/Manuscripts/1_CoherenceSpatialVariation/fig5_gamfits_landscape.tif

par(mfrow=c(4,5),mgp=c(1.5,0.5,0), oma=c(0,2.5,0,0.5),mar=mar1,tcl=-0.3)

plot(gam.cohst,select=1,residuals=T,rug=FALSE,shade=T,cex=2,xlab="cv(NDVI)",ylab="short coherence")
plot(NA,NA,xlim=c(0,1),ylim=c(0,1),xaxs="i",yaxs="i",ylab="",xlab="HUC-8 sub-basin",xaxt="n",yaxt="n",mg
rasterImage(image=panel5b,xleft=1e-2,ybottom=1e-2,xright=1-1e-2,ytop=1-1e-2)
plot(gam.cohst,select=2,residuals=T,rug=FALSE,shade=T,cex=2,xlab="total N deposition",ylab="")
plot(gam.cohst,select=3,residuals=T,rug=FALSE,shade=T,cex=2,xlab="% woody wetlands",ylab="")
plot(gam.cohst,select=4,residuals=T,rug=FALSE,shade=T,cex=2,xlab="% herbaceous wetld.",ylab="")

plot(gam.cosphist,select=1,residuals=T,rug=FALSE,shade=T,cex=2,xlab="open wetlands shoreline",ylab="sho
```

```
plot(gam.cosphist,select=2,residuals=T,rug=FALSE,shade=T,cex=2,xlab="headwaters density",ylab="")
plot(gam.cosphist,select=3,residuals=T,rug=FALSE,shade=T,cex=2,xlab="mean chlorophyll-a",ylab="")
plot.new()
plot.new()

plot(NA,NA,xlim=c(0,1),ylim=c(0,1),xaxs="i",yaxs="i",ylab="",xlab="HUC-8 sub-basin",xaxt="n",yaxt="n",mg
rasterImage(image=panel5i,xleft=1e-2,ybottom=1e-2,xright=1-1e-2,ytop=1-1e-2)
plot(gam.cohlt,select=1,residuals=T,rug=FALSE,shade=T,cex=2,xlab="% shrub/scrub",ylab="long coherence",y
plot(gam.cohlt,select=2,residuals=T,rug=FALSE,shade=T,cex=2,xlab="cv(NDVI)",ylab="",ylim=c(-1,1))
plot(gam.cohlt,select=3,residuals=T,rug=FALSE,shade=T,cex=2,xlab="annual precipitation",ylab="")
plot(gam.cohlt,select=4,residuals=T,rug=FALSE,shade=T,cex=2,xlab="all wetld. contrib. area",ylab="",ylin

plot(NA,NA,xlim=c(0,1),ylim=c(0,1),xaxs="i",yaxs="i",ylab="",xlab="HUC-4 sub-region",xaxt="n",yaxt="n",m
rasterImage(image=panel5n,xleft=1e-2,ybottom=1e-2,xright=1-1e-2,ytop=1-1e-2)
plot(gam.sinphilt,select=1,residuals=T,rug=FALSE,shade=T,cex=2,xlab="% pasture",ylab="")
plot(gam.sinphilt,select=2,residuals=T,rug=FALSE,shade=T,cex=2,xlab="% developed-open space",ylab="")

mtext("Partial residuals",2,outer=T,line=1.2,cex=0.8)
mtext(expression(paste("long sin(",phi,")",sep="")),2,at=1/8+fudge,outer=T,line=0,cex=0.7)
mtext("long coherence",2,at=1/8+1/4+fudge,outer=T,line=0,cex=0.7)
mtext(expression(paste("short cos(",phi,")",sep="")),2,at=1/8+2/4+fudge,outer=T,line=0,cex=0.7)
mtext("short coherence",2,at=1/8+3/4+fudge,outer=T,line=0,cex=0.7)

dev.off()
```

```
## pdf
##   2
```