Q2: Does climate drive lake-landscape coherence?

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This document organizes for openness and reproducibility analyses of the influence of climate .

Data import

In the Q1 manuscript, we output time series from coherent lake-landscape pairs. These are loaded here. We also load time series of three major climate indices (ENSO, PDO, NAO) and local temperature and precipitation.

```
#load coherent lakes data
load("~/Box Sync/NSF EAGER Synchrony/Data/RData files/q2_coherent_lakes.RData")
#load climate index time series
mei.raw<-read.csv("/Users/jonathanwalter/Documents/Research/DATA/ClimateIndices/mei_monthly_1979_2019.cs
pdo.raw<-read.csv("/Users/jonathanwalter/Documents/Research/DATA/ClimateIndices/pdo_monthly_1950_2019.cs
nao.raw<-read.csv("/Users/jonathanwalter/Documents/Research/DATA/ClimateIndices/nao_monthly_1950_2019.cs

mei.gs<-mei.raw[mei.raw$mm >=5 & mei.raw$mm <=9,]
pdo.gs<-pdo.raw[pdo.raw$mm >=5 & pdo.raw$mm <=9,]
nao.gs<-nao.raw[nao.raw$mm >=5 & nao.raw$mm <=9,]

mei.gs<-aggregate(mei.gs$mei,list(mei.gs$yyyy),FUN="mean")
names(mei.gs)<-c("year","mei")
pdo.gs<-aggregate(pdo.gs$PDO,list(pdo.gs$yyyy),FUN="mean")
names(pdo.gs)<-c("year","pdo")
nao.gs<-aggregate(nao.gs$NAO,list(nao.gs$yyyy),FUN="mean")
names(nao.gs)<-c("year","nao")

for(ii in 1:length(coherentlakes.st$lakedata)){
  coherentlakes.st$lakedata[[ii]]<-rbind(coherentlakes.st$lakedata[[ii]],
                                         mei.gs$mei[mei.gs$year %in% colnames(coherentlakes.st$lakedata
                                         pdo.gs$pdo[pdo.gs$year %in% colnames(coherentlakes.st$lakedata
                                         nao.gs$nao[nao.gs$year %in% colnames(coherentlakes.st$lakedata
  rownames(coherentlakes.st$lakedata[[ii]])<-c("chla","ndvi","mei","pdo","nao")
}

for(ii in 1:length(coherentlakes.lt$lakedata)){
  coherentlakes.lt$lakedata[[ii]]<-rbind(coherentlakes.lt$lakedata[[ii]],
                                         mei.gs$mei[mei.gs$year %in% colnames(coherentlakes.lt$lakedata
                                         pdo.gs$pdo[pdo.gs$year %in% colnames(coherentlakes.lt$lakedata
                                         nao.gs$nao[nao.gs$year %in% colnames(coherentlakes.lt$lakedata
  rownames(coherentlakes.lt$lakedata[[ii]])<-c("chla","ndvi","mei","pdo","nao")
}

#add local weather
ppt.files<-paste0("/Users/jonathanwalter/Documents/Research/DATA/PRISM_4km2_gridded/ppt/PRISM_ppt_stabl
                  rep(1989:2018,each=5),
                  rep(c("05","06","07","08","09"),times=30),
```

```
                  "_bil.bil")
ppt<-stack(ppt.files)


tavg.files<-c(paste0("/Users/jonathanwalter/Documents/Research/DATA/PRISM_4km2_gridded/tmean/PRISM_tmean
                  rep(1989:2016,each=5),
                  rep(c("05","06","07","08","09"),times=28),
                  "_bil.bil"),
              paste0("/Users/jonathanwalter/Documents/Research/DATA/PRISM_4km2_gridded/tmean/PRISM_tmean
                  rep(2017:2018,each=5),
                  rep(c("05","06","07","08","09"),times=2),
                  "_bil.bil"))
tavg<-stack(tavg.files)

coherentlakes.st<-addPRISMts(coherentlakes.st, ppt, var="ppt")
coherentlakes.st<-addPRISMts(coherentlakes.st, tavg, var="tmean")
coherentlakes.lt<-addPRISMts(coherentlakes.lt, ppt, var="ppt")
coherentlakes.lt<-addPRISMts(coherentlakes.lt, tavg, var="tmean")
```

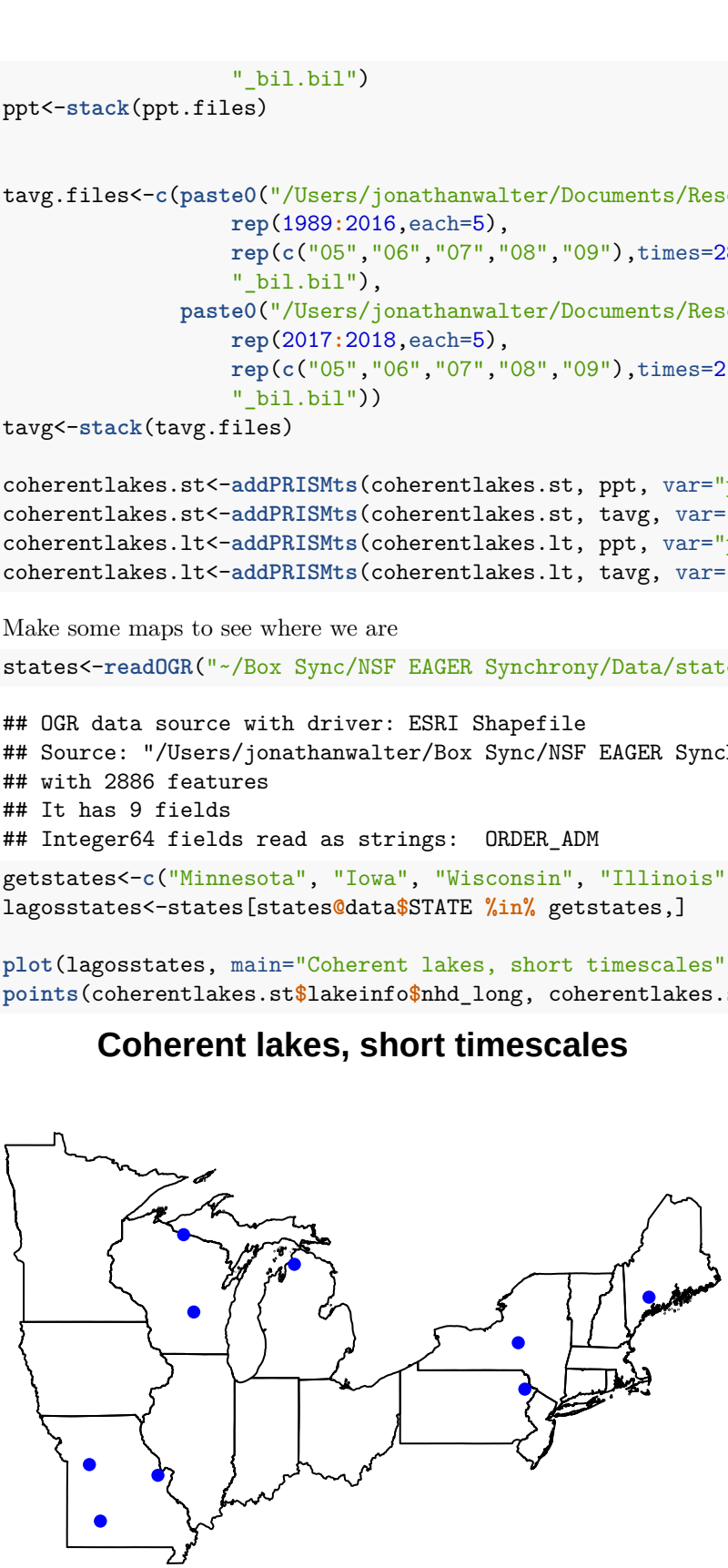
Make some maps to see where we are

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

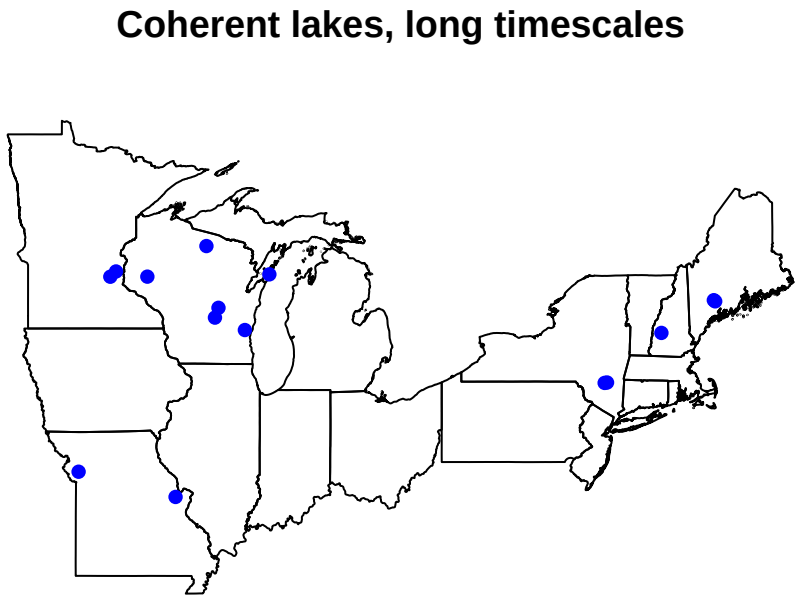
```
## OGR data source with driver: ESRI Shapefile
## Source: "/Users/jonathanwalter/Box Sync/NSF EAGER Synchrony/Data/statesp020_nolakes.shp", layer: "sta
## with 2886 features
## It has 9 fields
## Integer64 fields read as strings:  ORDER_ADM
```

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

plot(lagosstates, main="Coherent lakes, short timescales")
points(coherentlakes.st$lakeinfo$nhd_long, coherentlakes.st$lakeinfo$nhd_lat, pch=16, col="blue")
```



```
plot(lagosstates, main="Coherent lakes, long timescales")
points(coherentlakes.lt$lakeinfo$nhd_long, coherentlakes.lt$lakeinfo$nhd_lat, pch=16, col="blue")
```



Analyses

a) Are lakes and landscapes coherent with the same climate variables? b) Do climate variables explain a similar amount of variability in coherent lakes as the landscape does? c) does this differ by timescale?

First, do coherences with climate variables

```
lakeXclim.st<-data.frame(lagoslakeid=names(coherentlakes.st$lakedata),
                         mei.coh=rep(NA, length(coherentlakes.st$lakedata)),
                         mei.p=rep(NA, length(coherentlakes.st$lakedata)),
                         mei.phi=rep(NA, length(coherentlakes.st$lakedata)),
                         nao.coh=rep(NA, length(coherentlakes.st$lakedata)),
                         nao.p=rep(NA, length(coherentlakes.st$lakedata)),
                         nao.phi=rep(NA, length(coherentlakes.st$lakedata)),
                         pdo.coh=rep(NA, length(coherentlakes.st$lakedata)),
                         pdo.p=rep(NA, length(coherentlakes.st$lakedata)),
                         pdo.phi=rep(NA, length(coherentlakes.st$lakedata)),
                         ppt.coh=rep(NA, length(coherentlakes.st$lakedata)),
                         ppt.p=rep(NA, length(coherentlakes.st$lakedata)),
                         ppt.phi=rep(NA, length(coherentlakes.st$lakedata)),
                         tavg.coh=rep(NA, length(coherentlakes.st$lakedata)),
                         tavg.p=rep(NA, length(coherentlakes.st$lakedata)),
                         tavg.phi=rep(NA, length(coherentlakes.st$lakedata)))
landXclim.st<-lakeXclim.st

lakeXclim.lt<-data.frame(lagoslakeid=names(coherentlakes.lt$lakedata),
                         mei.coh=rep(NA, length(coherentlakes.lt$lakedata)),
                         mei.p=rep(NA, length(coherentlakes.lt$lakedata)),
                         mei.phi=rep(NA, length(coherentlakes.lt$lakedata)),
                         nao.coh=rep(NA, length(coherentlakes.lt$lakedata)),
                         nao.p=rep(NA, length(coherentlakes.lt$lakedata)),
```

```
                          nao.phi=rep(NA, length(coherentlakes.lt$lakedata)),
                          pdo.coh=rep(NA, length(coherentlakes.lt$lakedata)),
                          pdo.p=rep(NA, length(coherentlakes.lt$lakedata)),
                          pdo.phi=rep(NA, length(coherentlakes.lt$lakedata)),
                          ppt.coh=rep(NA, length(coherentlakes.lt$lakedata)),
                          ppt.p=rep(NA, length(coherentlakes.lt$lakedata)),
                          ppt.phi=rep(NA, length(coherentlakes.lt$lakedata)),
                          tavg.coh=rep(NA, length(coherentlakes.lt$lakedata)),
                          tavg.p=rep(NA, length(coherentlakes.lt$lakedata)),
                          tavg.phi=rep(NA, length(coherentlakes.lt$lakedata)))
landXclim.lt<-lakeXclim.lt

# lakes, short timescales
NN=length(coherentlakes.st$lakedata)
ts=c(2,4)
for(ii in 1:NN){
  vars<-rownames(coherentlakes.st$lakedata[[ii]])
  yy<-as.numeric(colnames(coherentlakes.st$lakedata[[ii]]))
  clnd<-cleandat(coherentlakes.st$lakedata[[ii]],yy,clev=5)$cdat

  cohXmei<-coh(clnd[vars=="chla",], clnd[vars=="mei"], yy, norm="powall", sigmethod="fast")
  cohXnao<-coh(clnd[vars=="chla",], clnd[vars=="nao"], yy, norm="powall", sigmethod="fast")
  cohXpdo<-coh(clnd[vars=="chla",], clnd[vars=="pdo"], yy, norm="powall", sigmethod="fast")
  cohXppt<-coh(clnd[vars=="chla",], clnd[vars=="ppt"], yy, norm="powall", sigmethod="fast")
  cohXtavg<-coh(clnd[vars=="chla",], clnd[vars=="tavg"], yy, norm="powall", sigmethod="fast")

  cohXmei<-bandtest.coh(cohXmei,ts)
  cohXnao<-bandtest.coh(cohXnao,ts)
  cohXpdo<-bandtest.coh(cohXpdo,ts)
  cohXppt<-bandtest.coh(cohXppt,ts)
  cohXtavg<-bandtest.coh(cohXtavg,ts)

  lakeXclim.st$mei.coh[ii]<-cohXmei$bandp$mn_coh
  lakeXclim.st$mei.p[ii]<-cohXmei$bandp$p_val
  lakeXclim.st$mei.phi[ii]<-cohXmei$bandp$mn_phs
  lakeXclim.st$nao.coh[ii]<-cohXnao$bandp$mn_coh
  lakeXclim.st$nao.p[ii]<-cohXnao$bandp$p_val
  lakeXclim.st$nao.phi[ii]<-cohXnao$bandp$mn_phs
  lakeXclim.st$pdo.coh[ii]<-cohXpdo$bandp$mn_coh
  lakeXclim.st$pdo.p[ii]<-cohXpdo$bandp$p_val
  lakeXclim.st$pdo.phi[ii]<-cohXpdo$bandp$mn_phs
  lakeXclim.st$ppt.coh[ii]<-cohXppt$bandp$mn_coh
  lakeXclim.st$ppt.p[ii]<-cohXppt$bandp$p_val
  lakeXclim.st$ppt.phi[ii]<-cohXppt$bandp$mn_phs
  lakeXclim.st$tavg.coh[ii]<-cohXtavg$bandp$mn_coh
  lakeXclim.st$tavg.p[ii]<-cohXtavg$bandp$p_val
  lakeXclim.st$tavg.phi[ii]<-cohXtavg$bandp$mn_phs
}

#land, short timescales
NN=length(coherentlakes.st$lakedata)
ts=c(2,4)
for(ii in 1:NN){
```

```
  vars<-rownames(coherentlakes.st$lakedata[[ii]])
  yy<-as.numeric(colnames(coherentlakes.st$lakedata[[ii]]))
  clnd<-cleandat(coherentlakes.st$lakedata[[ii]],yy,clev=5)$cdat

  cohXmei<-coh(clnd[vars=="ndvi",], clnd[vars=="mei"], yy, norm="powall", sigmethod="fast")
  cohXnao<-coh(clnd[vars=="ndvi",], clnd[vars=="nao"], yy, norm="powall", sigmethod="fast")
  cohXpdo<-coh(clnd[vars=="ndvi",], clnd[vars=="pdo"], yy, norm="powall", sigmethod="fast")
  cohXppt<-coh(clnd[vars=="ndvi",], clnd[vars=="ppt"], yy, norm="powall", sigmethod="fast")
  cohXtavg<-coh(clnd[vars=="ndvi",], clnd[vars=="tavg"], yy, norm="powall", sigmethod="fast")

  cohXmei<-bandtest.coh(cohXmei,ts)
  cohXnao<-bandtest.coh(cohXnao,ts)
  cohXpdo<-bandtest.coh(cohXpdo,ts)
  cohXppt<-bandtest.coh(cohXppt,ts)
  cohXtavg<-bandtest.coh(cohXtavg,ts)

  landXclim.st$mei.coh[ii]<-cohXmei$bandp$mn_coh
  landXclim.st$mei.p[ii]<-cohXmei$bandp$p_val
  landXclim.st$mei.phi[ii]<-cohXmei$bandp$mn_phs
  landXclim.st$nao.coh[ii]<-cohXnao$bandp$mn_coh
  landXclim.st$nao.p[ii]<-cohXnao$bandp$p_val
  landXclim.st$nao.phi[ii]<-cohXnao$bandp$mn_phs
  landXclim.st$pdo.coh[ii]<-cohXpdo$bandp$mn_coh
  landXclim.st$pdo.p[ii]<-cohXpdo$bandp$p_val
  landXclim.st$pdo.phi[ii]<-cohXpdo$bandp$mn_phs
  landXclim.st$ppt.coh[ii]<-cohXppt$bandp$mn_coh
  landXclim.st$ppt.p[ii]<-cohXppt$bandp$p_val
  landXclim.st$ppt.phi[ii]<-cohXppt$bandp$mn_phs
  landXclim.st$tavg.coh[ii]<-cohXtavg$bandp$mn_coh
  landXclim.st$tavg.p[ii]<-cohXtavg$bandp$p_val
  landXclim.st$tavg.phi[ii]<-cohXtavg$bandp$mn_phs
}

#lakes, long timescales
NN=length(coherentlakes.lt$lakedata)
ts=c(4,Inf)
for(ii in 1:NN){
  vars<-rownames(coherentlakes.lt$lakedata[[ii]])
  yy<-as.numeric(colnames(coherentlakes.lt$lakedata[[ii]]))
  clnd<-cleandat(coherentlakes.lt$lakedata[[ii]],yy,clev=5)$cdat

  cohXmei<-coh(clnd[vars=="chla",], clnd[vars=="mei"], yy, norm="powall", sigmethod="fast")
  cohXnao<-coh(clnd[vars=="chla",], clnd[vars=="nao"], yy, norm="powall", sigmethod="fast")
  cohXpdo<-coh(clnd[vars=="chla",], clnd[vars=="pdo"], yy, norm="powall", sigmethod="fast")
  cohXppt<-coh(clnd[vars=="chla",], clnd[vars=="ppt"], yy, norm="powall", sigmethod="fast")
  cohXtavg<-coh(clnd[vars=="chla",], clnd[vars=="tavg"], yy, norm="powall", sigmethod="fast")

  cohXmei<-bandtest.coh(cohXmei,ts)
  cohXnao<-bandtest.coh(cohXnao,ts)
  cohXpdo<-bandtest.coh(cohXpdo,ts)
  cohXppt<-bandtest.coh(cohXppt,ts)
  cohXtavg<-bandtest.coh(cohXtavg,ts)
```

```
  lakeXclim.lt$mei.coh[ii]<-cohXmei$bandp$mn_coh
  lakeXclim.lt$mei.p[ii]<-cohXmei$bandp$p_val
  lakeXclim.lt$mei.phi[ii]<-cohXmei$bandp$mn_phs
  lakeXclim.lt$nao.coh[ii]<-cohXnao$bandp$mn_coh
  lakeXclim.lt$nao.p[ii]<-cohXnao$bandp$p_val
  lakeXclim.lt$nao.phi[ii]<-cohXnao$bandp$mn_phs
  lakeXclim.lt$pdo.coh[ii]<-cohXpdo$bandp$mn_coh
  lakeXclim.lt$pdo.p[ii]<-cohXpdo$bandp$p_val
  lakeXclim.lt$pdo.phi[ii]<-cohXpdo$bandp$mn_phs
  lakeXclim.lt$ppt.coh[ii]<-cohXppt$bandp$mn_coh
  lakeXclim.lt$ppt.p[ii]<-cohXppt$bandp$p_val
  lakeXclim.lt$ppt.phi[ii]<-cohXppt$bandp$mn_phs
  lakeXclim.lt$tavg.coh[ii]<-cohXtavg$bandp$mn_coh
  lakeXclim.lt$tavg.p[ii]<-cohXtavg$bandp$p_val
  lakeXclim.lt$tavg.phi[ii]<-cohXtavg$bandp$mn_phs
}

#land, long timescales
NN=length(coherentlakes.lt$lakedata)
ts=c(4,Inf)
for(ii in 1:NN){
  vars<-rownames(coherentlakes.lt$lakedata[[ii]])
  yy<-as.numeric(colnames(coherentlakes.lt$lakedata[[ii]]))
  clnd<-cleandat(coherentlakes.lt$lakedata[[ii]],yy,clev=5)$cdat

  cohXmei<-coh(clnd[vars=="ndvi",], clnd[vars=="mei"], yy, norm="powall", sigmethod="fast")
  cohXnao<-coh(clnd[vars=="ndvi",], clnd[vars=="nao"], yy, norm="powall", sigmethod="fast")
  cohXpdo<-coh(clnd[vars=="ndvi",], clnd[vars=="pdo"], yy, norm="powall", sigmethod="fast")
  cohXppt<-coh(clnd[vars=="ndvi",], clnd[vars=="ppt"], yy, norm="powall", sigmethod="fast")
  cohXtavg<-coh(clnd[vars=="ndvi",], clnd[vars=="tavg"], yy, norm="powall", sigmethod="fast")

  cohXmei<-bandtest.coh(cohXmei,ts)
  cohXnao<-bandtest.coh(cohXnao,ts)
  cohXpdo<-bandtest.coh(cohXpdo,ts)
  cohXppt<-bandtest.coh(cohXppt,ts)
  cohXtavg<-bandtest.coh(cohXtavg,ts)

  landXclim.lt$mei.coh[ii]<-cohXmei$bandp$mn_coh
  landXclim.lt$mei.p[ii]<-cohXmei$bandp$p_val
  landXclim.lt$mei.phi[ii]<-cohXmei$bandp$mn_phs
  landXclim.lt$nao.coh[ii]<-cohXnao$bandp$mn_coh
  landXclim.lt$nao.p[ii]<-cohXnao$bandp$p_val
  landXclim.lt$nao.phi[ii]<-cohXnao$bandp$mn_phs
  landXclim.lt$pdo.coh[ii]<-cohXpdo$bandp$mn_coh
  landXclim.lt$pdo.p[ii]<-cohXpdo$bandp$p_val
  landXclim.lt$pdo.phi[ii]<-cohXpdo$bandp$mn_phs
  landXclim.lt$ppt.coh[ii]<-cohXppt$bandp$mn_coh
  landXclim.lt$ppt.p[ii]<-cohXppt$bandp$p_val
  landXclim.lt$ppt.phi[ii]<-cohXppt$bandp$mn_phs
  landXclim.lt$tavg.coh[ii]<-cohXtavg$bandp$mn_coh
  landXclim.lt$tavg.p[ii]<-cohXtavg$bandp$p_val
  landXclim.lt$tavg.phi[ii]<-cohXtavg$bandp$mn_phs
}
```

```r
# test correlation between coherence of lakes and coherence of land
cor.test(lakeXclim.st$mei.coh,landXclim.st$mei.coh)
```

```
##
##  Pearson's product-moment correlation
##
## data:  lakeXclim.st$mei.coh and landXclim.st$mei.coh
## t = 1.3414, df = 7, p-value = 0.2217
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.3028733  0.8585029
## sample estimates:
##       cor
## 0.4522076
```

```r
cor.test(lakeXclim.st$nao.coh,landXclim.st$nao.coh)
```

```
##
##  Pearson's product-moment correlation
##
## data:  lakeXclim.st$nao.coh and landXclim.st$nao.coh
## t = 0.68977, df = 7, p-value = 0.5125
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.4947335  0.7848954
## sample estimates:
##       cor
## 0.2522773
```

```r
cor.test(lakeXclim.st$pdo.coh,landXclim.st$pdo.coh)
```

```
##
##  Pearson's product-moment correlation
##
## data:  lakeXclim.st$pdo.coh and landXclim.st$pdo.coh
## t = -0.57848, df = 7, p-value = 0.5811
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.7686794  0.5249961
## sample estimates:
##        cor
## -0.2135995
```

```r
cor.test(lakeXclim.st$ppt.coh,landXclim.st$ppt.coh)
```

```
##
##  Pearson's product-moment correlation
##
## data:  lakeXclim.st$ppt.coh and landXclim.st$ppt.coh
## t = 1.3166, df = 7, p-value = 0.2294
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.3104692  0.8562821
## sample estimates:
##       cor
## 0.4455124
```

```r
cor.test(lakeXclim.st$tavg.coh,landXclim.st$tavg.coh)
```

```
##
##  Pearson's product-moment correlation
##
## data:  lakeXclim.st$tavg.coh and landXclim.st$tavg.coh
## t = 0.25192, df = 7, p-value = 0.8083
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.6075812  0.7139652
## sample estimates:
##        cor
## 0.09478832
```

```r
# no significant correlations at short timescales

cor.test(lakeXclim.lt$mei.coh,landXclim.lt$mei.coh)
```

```
##
##  Pearson's product-moment correlation
##
## data:  lakeXclim.lt$mei.coh and landXclim.lt$mei.coh
## t = 3.5536, df = 13, p-value = 0.003532
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.2962014 0.8930793
## sample estimates:
##       cor
## 0.7019546
```

```r
cor.test(lakeXclim.lt$nao.coh,landXclim.lt$nao.coh)
```

```
##
##  Pearson's product-moment correlation
##
## data:  lakeXclim.lt$nao.coh and landXclim.lt$nao.coh
## t = 1.2218, df = 13, p-value = 0.2435
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  -0.2289608  0.7155634
## sample estimates:
##       cor
## 0.3209451
```

```r
cor.test(lakeXclim.lt$pdo.coh,landXclim.lt$pdo.coh)
```

```
##
##  Pearson's product-moment correlation
##
## data:  lakeXclim.lt$pdo.coh and landXclim.lt$pdo.coh
## t = 2.496, df = 13, p-value = 0.02679
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.08035359 0.83731218
## sample estimates:
##       cor
```

```
## 0.5691874
```

```
cor.test(lakeXclim.lt$ppt.coh,landXclim.lt$ppt.coh)
```

```
##
##  Pearson's product-moment correlation
##
## data:  lakeXclim.lt$ppt.coh and landXclim.lt$ppt.coh
## t = 2.5375, df = 13, p-value = 0.02477
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.08972716 0.84011223
## sample estimates:
##       cor
## 0.5755361
```

```
cor.test(lakeXclim.lt$tavg.coh,landXclim.lt$tavg.coh)
```

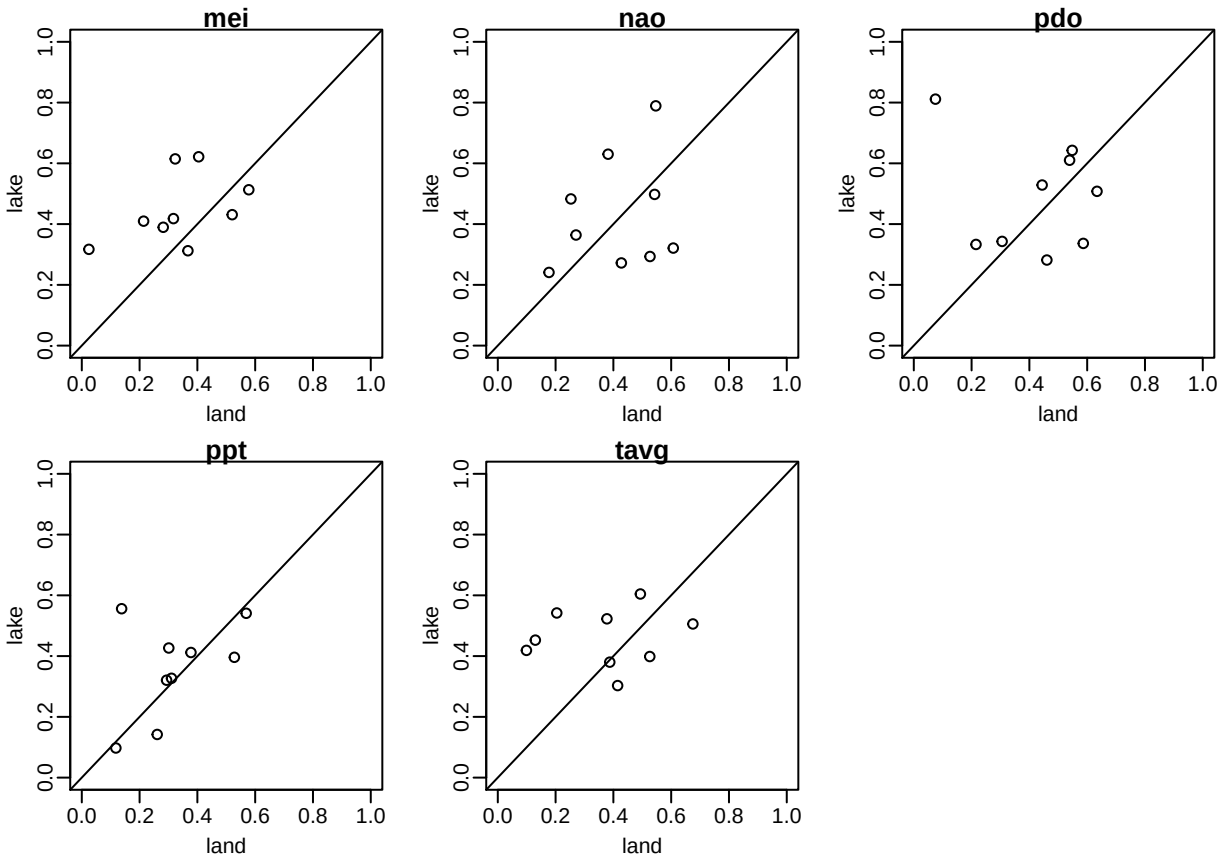
```
##
##  Pearson's product-moment correlation
##
## data:  lakeXclim.lt$tavg.coh and landXclim.lt$tavg.coh
## t = 2.6555, df = 13, p-value = 0.0198
## alternative hypothesis: true correlation is not equal to 0
## 95 percent confidence interval:
##  0.1160012 0.8477532
## sample estimates:
##       cor
## 0.5930247
```

```
# mostly significant correlations at long timescales
```

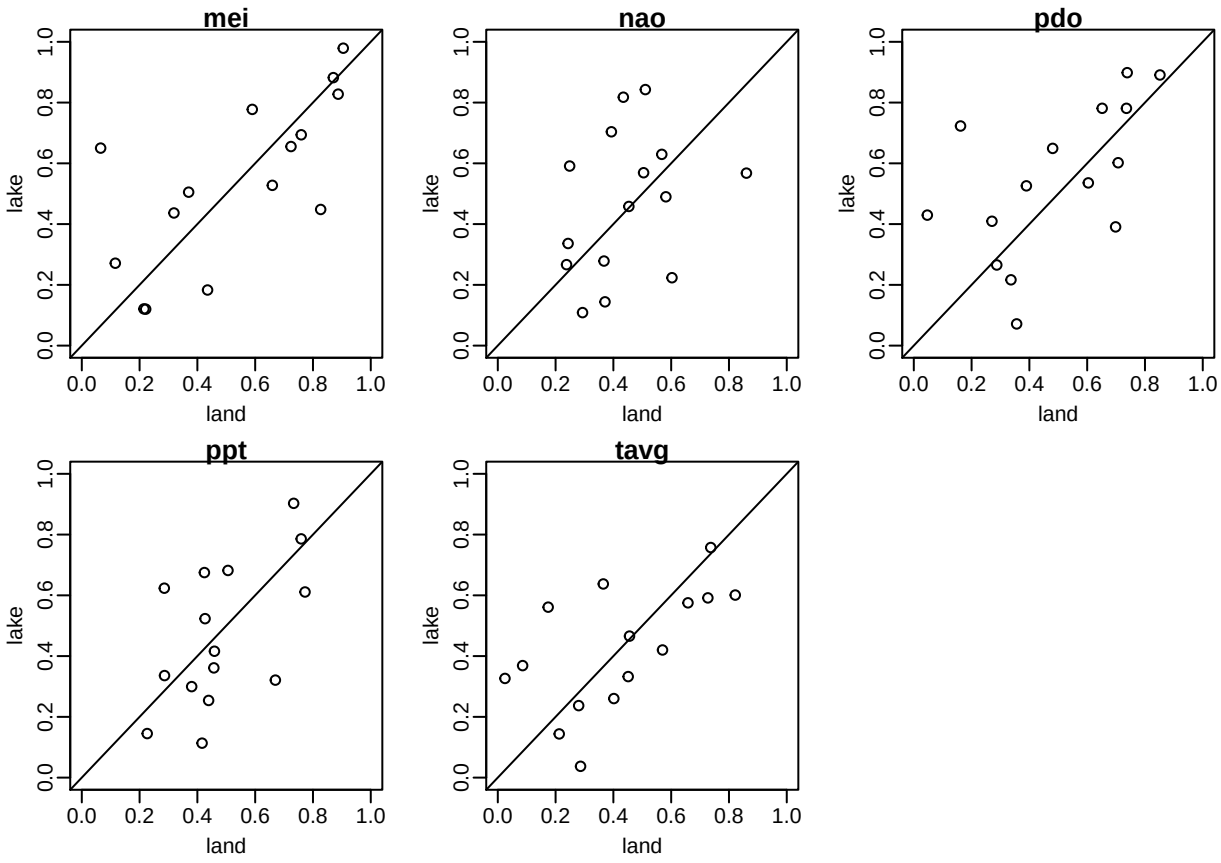
Coherence with climate variables was essentially uncorrelated between lakes and the landscape at short timescales, albeit with a small (n=9) number of lakes. However, at long timescales coherence with climate variables tended to be significantly and positively correlated between lakes and the landscape.

```
par(mfrow=c(2,3),mar=c(3.1,3.1,1,1),mgp=c(1.7,0.5,0))
plot(landXclim.st$mei.coh, lakeXclim.st$mei.coh, xlim=c(0,1), ylim=c(0,1), xlab="land", ylab="lake",mai
abline(a=0,b=1)
plot(landXclim.st$nao.coh, lakeXclim.st$nao.coh, xlim=c(0,1), ylim=c(0,1), xlab="land", ylab="lake",mai
abline(a=0,b=1)
plot(landXclim.st$pdo.coh, lakeXclim.st$pdo.coh, xlim=c(0,1), ylim=c(0,1), xlab="land", ylab="lake",mai
abline(a=0,b=1)
plot(landXclim.st$ppt.coh, lakeXclim.st$ppt.coh, xlim=c(0,1), ylim=c(0,1), xlab="land", ylab="lake",mai
abline(a=0,b=1)
plot(landXclim.st$tavg.coh, lakeXclim.st$tavg.coh, xlim=c(0,1), ylim=c(0,1), xlab="land", ylab="lake",ma
abline(a=0,b=1)

par(mfrow=c(2,3),mar=c(3.1,3.1,1,1),mgp=c(1.7,0.5,0))
```




```
plot(landXclim.lt$mei.coh, lakeXclim.lt$mei.coh, xlim=c(0,1), ylim=c(0,1), xlab="land", ylab="lake",mai
abline(a=0,b=1)
plot(landXclim.lt$nao.coh, lakeXclim.lt$nao.coh, xlim=c(0,1), ylim=c(0,1), xlab="land", ylab="lake",mai
abline(a=0,b=1)
plot(landXclim.lt$pdo.coh, lakeXclim.lt$pdo.coh, xlim=c(0,1), ylim=c(0,1), xlab="land", ylab="lake",mai
abline(a=0,b=1)
plot(landXclim.lt$ppt.coh, lakeXclim.lt$ppt.coh, xlim=c(0,1), ylim=c(0,1), xlab="land", ylab="lake",mai
abline(a=0,b=1)
plot(landXclim.lt$tavg.coh, lakeXclim.lt$tavg.coh, xlim=c(0,1), ylim=c(0,1), xlab="land", ylab="lake",ma
abline(a=0,b=1)
```



Second, find out how much variability in lakes is explained by coherence with the landscape

```
## Short timescales----------------------------------------------------------
varexpl.land_v_clim.st<-data.frame(lagoslakeid=names(coherentlakes.st$lakedata),
                                   varexpl.land=rep(NA, length(names(coherentlakes.st$lakedata))),
                                   varexpl.clim=rep(NA, length(names(coherentlakes.st$lakedata))))

#2851 - Walloon Lake
yy<-as.numeric(colnames(coherentlakes.st$lakedata$`2851`))
dat<-list(cleandat(coherentlakes.st$lakedata$`2851`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.st$lakedata$`2851`[2,],yy,clev=5)$cdat)
wlm.lakeland.2851<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.st$varexpl.land[1]<-mean(syncexpl(wlm.lakeland.2851)$syncexpl[syncexpl(wlm.lakeland

#3370 - White Lake
yy<-as.numeric(colnames(coherentlakes.st$lakedata$`3370`))
dat<-list(cleandat(coherentlakes.st$lakedata$`3370`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.st$lakedata$`3370`[2,],yy,clev=5)$cdat)
wlm.lakeland.3370<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.st$varexpl.land[2]<-mean(syncexpl(wlm.lakeland.3370)$syncexpl[syncexpl(wlm.lakeland

#6075 - Fellows Lake
yy<-as.numeric(colnames(coherentlakes.st$lakedata$`6075`))
dat<-list(cleandat(coherentlakes.st$lakedata$`6075`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.st$lakedata$`6075`[2,],yy,clev=5)$cdat)
wlm.lakeland.6075<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.st$varexpl.land[3]<-mean(syncexpl(wlm.lakeland.6075)$syncexpl[syncexpl(wlm.lakeland
```

```
#6547 - Lake Moraine
yy<-as.numeric(colnames(coherentlakes.st$lakedata$`6547`))
dat<-list(cleandat(coherentlakes.st$lakedata$`6547`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.st$lakedata$`6547`[2,],yy,clev=5)$cdat)
wlm.lakeland.6547<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.st$varexpl.land[4]<-mean(syncexpl(wlm.lakeland.6547)$syncexpl[syncexpl(wlm.lakeland

#7523 - Annabessacook Lake
yy<-as.numeric(colnames(coherentlakes.st$lakedata$`7523`))
dat<-list(cleandat(coherentlakes.st$lakedata$`7523`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.st$lakedata$`7523`[2,],yy,clev=5)$cdat)
wlm.lakeland.7523<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.st$varexpl.land[5]<-mean(syncexpl(wlm.lakeland.7523)$syncexpl[syncexpl(wlm.lakeland

#28836 - Higginsville Old City Lake
yy<-as.numeric(colnames(coherentlakes.st$lakedata$`28836`))
dat<-list(cleandat(coherentlakes.st$lakedata$`28836`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.st$lakedata$`28836`[2,],yy,clev=5)$cdat)
wlm.lakeland.28836<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.st$varexpl.land[6]<-mean(syncexpl(wlm.lakeland.28836)$syncexpl[syncexpl(wlm.lakelan

#72641 - Lake Wallenpaupack
yy<-as.numeric(colnames(coherentlakes.st$lakedata$`72641`))
dat<-list(cleandat(coherentlakes.st$lakedata$`72641`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.st$lakedata$`72641`[2,],yy,clev=5)$cdat)
wlm.lakeland.72641<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.st$varexpl.land[7]<-mean(syncexpl(wlm.lakeland.72641)$syncexpl[syncexpl(wlm.lakelan

#133500 - Kraut run lake
yy<-as.numeric(colnames(coherentlakes.st$lakedata$`133500`))
dat<-list(cleandat(coherentlakes.st$lakedata$`133500`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.st$lakedata$`133500`[2,],yy,clev=5)$cdat)
wlm.lakeland.133500<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.st$varexpl.land[8]<-mean(syncexpl(wlm.lakeland.133500)$syncexpl[syncexpl(wlm.lakela

#4909 - Annabelle lake
yy<-as.numeric(colnames(coherentlakes.st$lakedata$`4909`))
dat<-list(cleandat(coherentlakes.st$lakedata$`4909`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.st$lakedata$`4909`[2,],yy,clev=5)$cdat)
wlm.lakeland.4909<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.st$varexpl.land[9]<-mean(syncexpl(wlm.lakeland.4909)$syncexpl[syncexpl(wlm.lakeland

## Long timescales ------------------------------------------------------------
varexpl.land_v_clim.lt<-data.frame(lagoslakeid=names(coherentlakes.lt$lakedata),
                                   varexpl.land=rep(NA, length(names(coherentlakes.lt$lakedata))),
                                   varexpl.clim=rep(NA, length(names(coherentlakes.lt$lakedata))))
# 3370 - White Lake
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`3370`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`3370`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`3370`[2,],yy,clev=5)$cdat)
wlm.lakeland.3370<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[1]<-mean(syncexpl(wlm.lakeland.3370)$syncexpl[syncexpl(wlm.lakeland
```

```
# 3834 - Hasbrook Lake
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`3834`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`3834`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`3834`[2,],yy,clev=5)$cdat)
wlm.lakeland.3834<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[2]<-mean(syncexpl(wlm.lakeland.3834)$syncexpl[syncexpl(wlm.lakeland

# 4243 - unnamed
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`4243`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`4243`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`4243`[2,],yy,clev=5)$cdat)
wlm.lakeland.4243<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[3]<-mean(syncexpl(wlm.lakeland.4243)$syncexpl[syncexpl(wlm.lakeland

# 4416 - Green Lake
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`4416`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`4416`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`4416`[2,],yy,clev=5)$cdat)
wlm.lakeland.4416<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[4]<-mean(syncexpl(wlm.lakeland.4416)$syncexpl[syncexpl(wlm.lakeland

# 4434 - Kangaroo Lake
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`4434`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`4434`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`4434`[2,],yy,clev=5)$cdat)
wlm.lakeland.4434<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[5]<-mean(syncexpl(wlm.lakeland.4434)$syncexpl[syncexpl(wlm.lakeland

# 5895 - Lake Sunapee
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`5895`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`5895`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`5895`[2,],yy,clev=5)$cdat)
wlm.lakeland.5895<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[6]<-mean(syncexpl(wlm.lakeland.5895)$syncexpl[syncexpl(wlm.lakeland

# 6199 - unnamed
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`6199`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`6199`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`6199`[2,],yy,clev=5)$cdat)
wlm.lakeland.6199<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[7]<-mean(syncexpl(wlm.lakeland.6199)$syncexpl[syncexpl(wlm.lakeland

# 7523 - Annabessacook Lake
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`7523`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`7523`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`7523`[2,],yy,clev=5)$cdat)
wlm.lakeland.7523<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[8]<-mean(syncexpl(wlm.lakeland.7523)$syncexpl[syncexpl(wlm.lakeland

# 8369 - unnamed
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`8369`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`8369`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`8369`[2,],yy,clev=5)$cdat)
```

```
wlm.lakeland.8369<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[9]<-mean(syncexpl(wlm.lakeland.8369)$syncexpl[syncexpl(wlm.lakeland

# 39489 - Ashokan Reservoir West Basin
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`39489`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`39489`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`39489`[2,],yy,clev=5)$cdat)
wlm.lakeland.39489<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[10]<-mean(syncexpl(wlm.lakeland.39489)$syncexpl[syncexpl(wlm.lakelan

# 115040 - Ashokan Reservoir East Basin
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`115040`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`115040`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`115040`[2,],yy,clev=5)$cdat)
wlm.lakeland.115040<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[11]<-mean(syncexpl(wlm.lakeland.115040)$syncexpl[syncexpl(wlm.lakela

# 133500 - Kraut Run Lake
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`133500`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`133500`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`133500`[2,],yy,clev=5)$cdat)
wlm.lakeland.133500<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[12]<-mean(syncexpl(wlm.lakeland.133500)$syncexpl[syncexpl(wlm.lakela

# 14815 - unnamed
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`14815`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`14815`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`14815`[2,],yy,clev=5)$cdat)
wlm.lakeland.14815<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[13]<-mean(syncexpl(wlm.lakeland.14815)$syncexpl[syncexpl(wlm.lakelan

# 102115 - Wilkinson Lake
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`102115`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`102115`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`102115`[2,],yy,clev=5)$cdat)
wlm.lakeland.102115<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[14]<-mean(syncexpl(wlm.lakeland.102115)$syncexpl[syncexpl(wlm.lakela

# 5463 - Pearl Lake
yy<-as.numeric(colnames(coherentlakes.lt$lakedata$`5463`))
dat<-list(cleandat(coherentlakes.lt$lakedata$`5463`[1,],yy,clev=5)$cdat,
          cleandat(coherentlakes.lt$lakedata$`5463`[2,],yy,clev=5)$cdat)
wlm.lakeland.5463<-wlm(dat,yy,1,2,norm="powall")
varexpl.land_v_clim.lt$varexpl.land[15]<-mean(syncexpl(wlm.lakeland.5463)$syncexpl[syncexpl(wlm.lakelan
```

Third, find out how much variability in lakes is explained by coherence with variables the landscape is coherent with

```
is.coh_land.lt<-landXclim.lt[colnames(landXclim.lt) %in%
                               c("lagoslakeid","mei.p","nao.p","pdo.p","ppt.p","tavg.p")]
is.coh_land.lt$mei.p<-ifelse(is.coh_land.lt$mei.p<0.1,1,0)
is.coh_land.lt$nao.p<-ifelse(is.coh_land.lt$nao.p<0.1,1,0)
is.coh_land.lt$pdo.p<-ifelse(is.coh_land.lt$pdo.p<0.1,1,0)
is.coh_land.lt$ppt.p<-ifelse(is.coh_land.lt$ppt.p<0.1,1,0)
```

```
is.coh_land.lt$tavg.p<-ifelse(is.coh_land.lt$tavg.p<0.1,1,0)
```