Case 4

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Bangladesh: tropical cyclones and stormsurges, heavy precipitation.

Bangladesh is highly vulnerable to climate induced hazards and disasters and its coastal part are mostly threatened for the impacts of climate change in case of cyclone, storm surges, flood, salinity and tsunami disaster. Even last twenty years the coastal peoples have suffered due to super cyclone SIDR (2007-11-15) and AILA (YYYY-MM-DD) devastations. Last two deacdes a lots of disaster coping interventions have been provided to the community to achieve resiliency in this areas. So really it will be a field laboratory for the research of Disaster Resilience and Climate Change: Science and innovation for adaptation to climate change: from assessing costs, risks and opportunities to demonstration of options and practices.

R Markdown

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

```
library(esd)
```

```
## Loading required package: ncdf4

## Loading required package: zoo

##
## Attaching package: 'zoo'

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

##
## Attaching package: 'esd'

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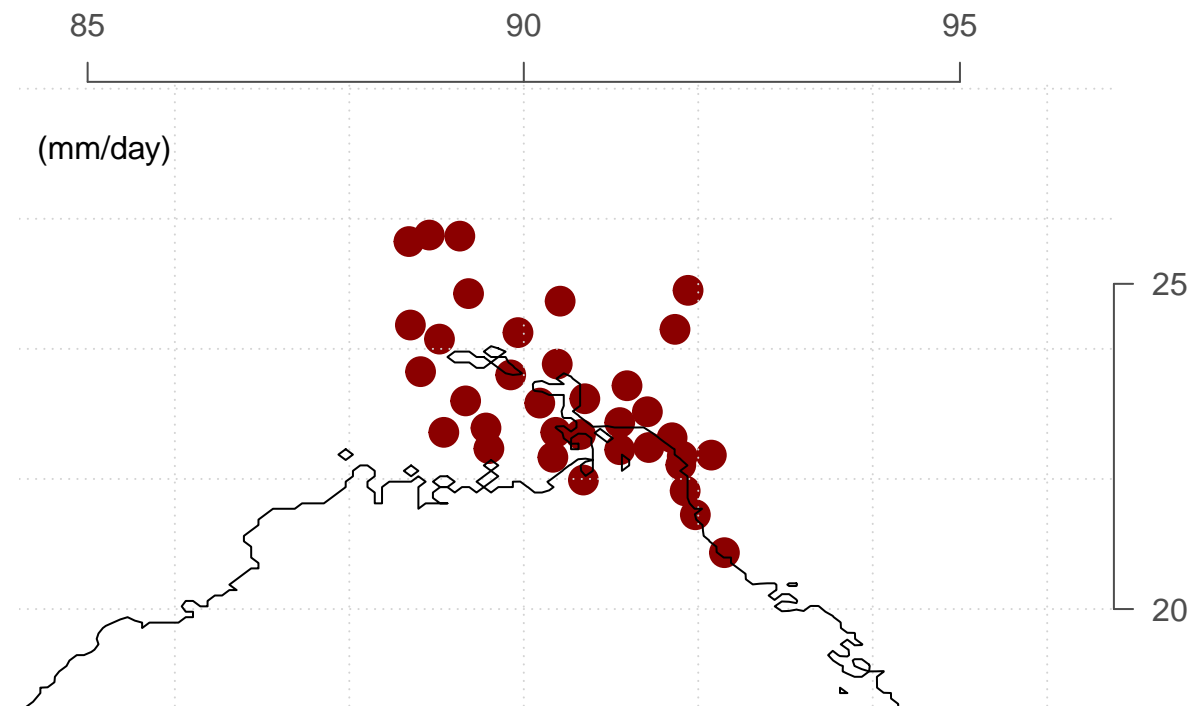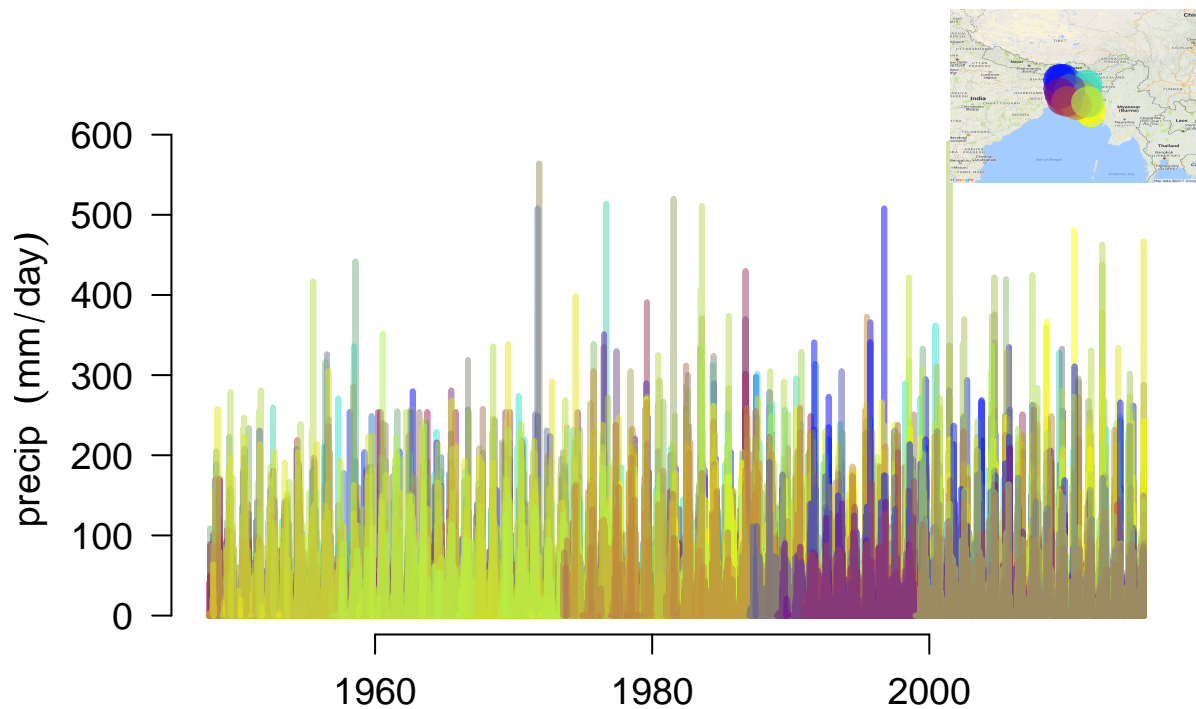
Analysis

(mm/day)

```
plot(pr.bmd,new=FALSE)
```

```
## Loading required package: RgoogleMaps
```

```
## Warning in plotmap(lat(x), lon(x), bgmap, pch = 19, col = col, cex = 2):
## NAs introduced by coercion
```

Scale the precipitation according to the indididual wet-day mean. Then take the mean of the station series to get an index of large-scale precipitation intensity.

```
mu <- apply(coredata(pr.bmd),2,'wetmean')
nv <- apply(coredata(pr.bmd),1,'nv')
X <- zoo(rowMeans(t(t(pr.bmd)/mu),na.rm=TRUE),order.by=index(pr.bmd))
X[nv < 11] <- NA
X <- as.station(X,param='rain-index',unit='dimensionless',loc='Bangladesh',
                lon=mean(lon(pr.bmd)),lat=mean(lat(pr.bmd)),alt=0)
```

Examine the index:
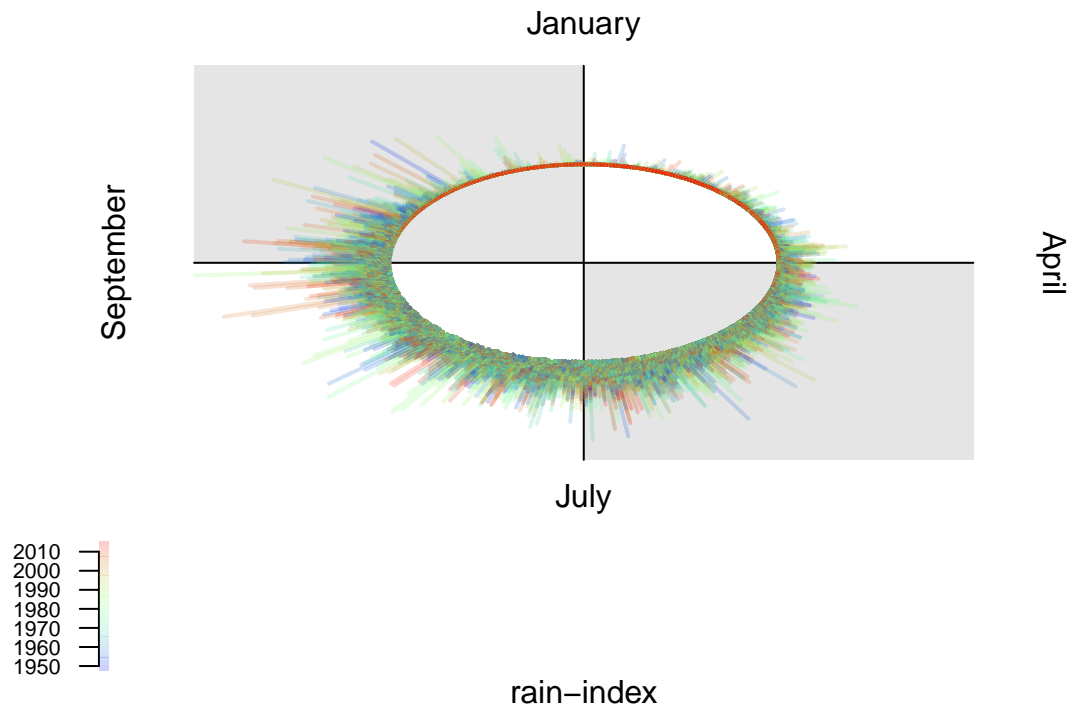
```
plot(X,new=FALSE)
```

```
## Warning in plotmap(lat(x), lon(x), bgmap, pch = 19, col = col, cex = 2):
## NAs introduced by coercion
```
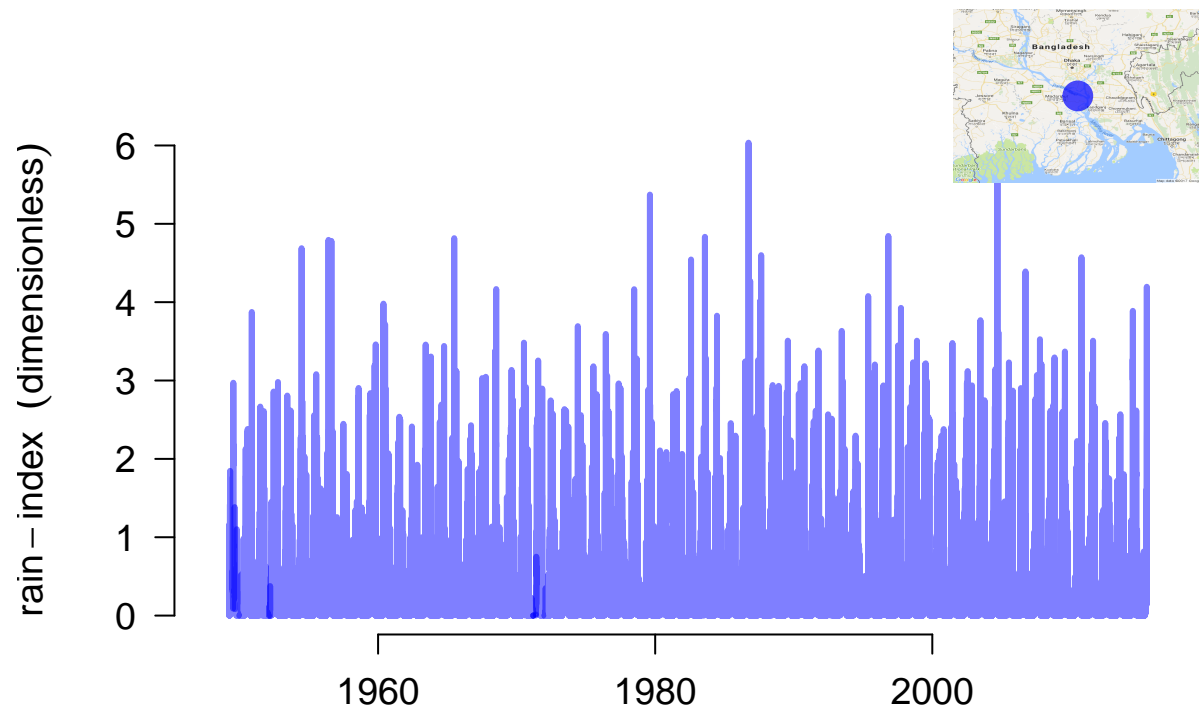
Check the seasonality

```
wheel(X,new=FALSE)
```

Seasonal 'wheel' for Bangladesh

January

September

April
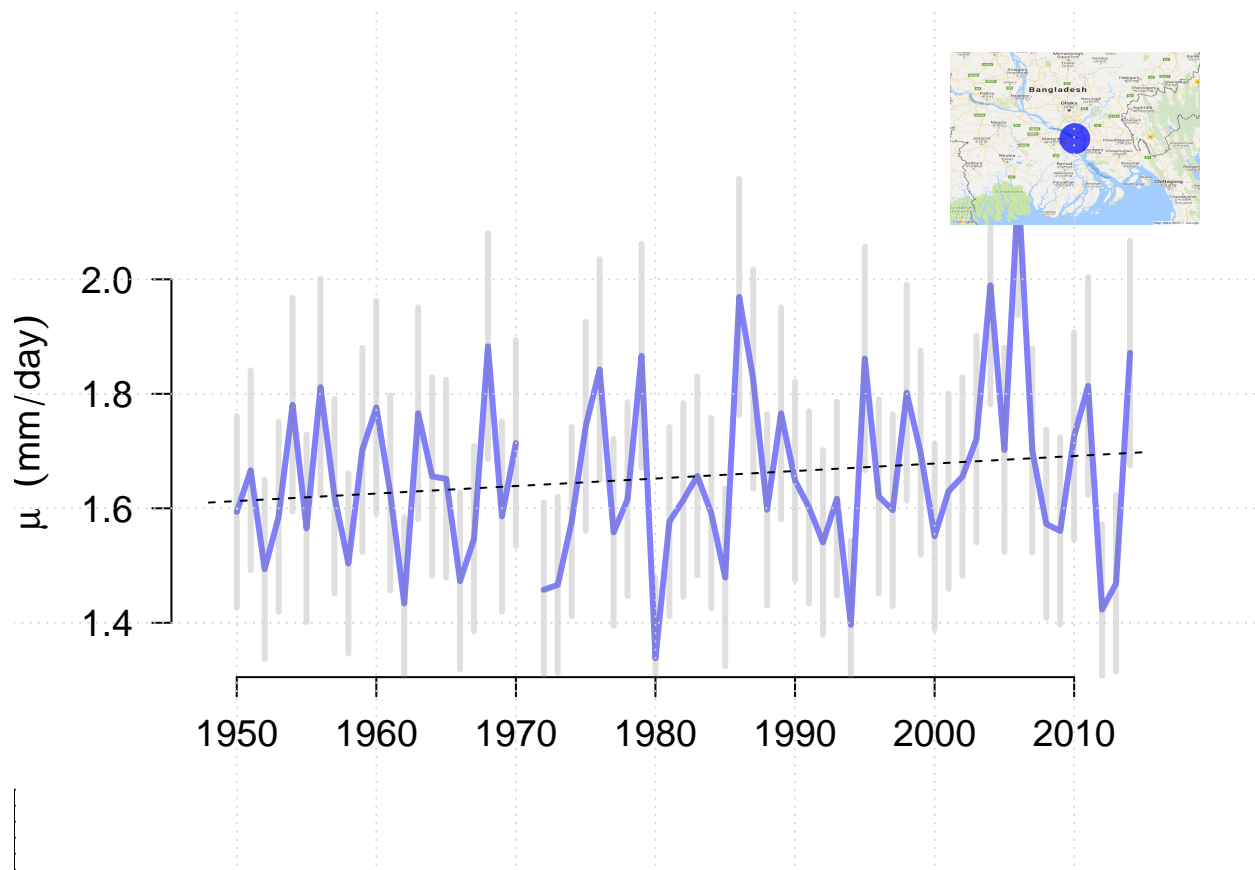
July

2010
2000
1990
1980
1970
1960
1950

rain–index

The long-term perspective of the rainfall intensity

```r
plot(annual(X,'wetmean'),new=FALSE)
```

```
## Warning in plotmap(lat(x), lon(x), bgmap, pch = 19, col = col, cex = 2):
## NAs introduced by coercion
```
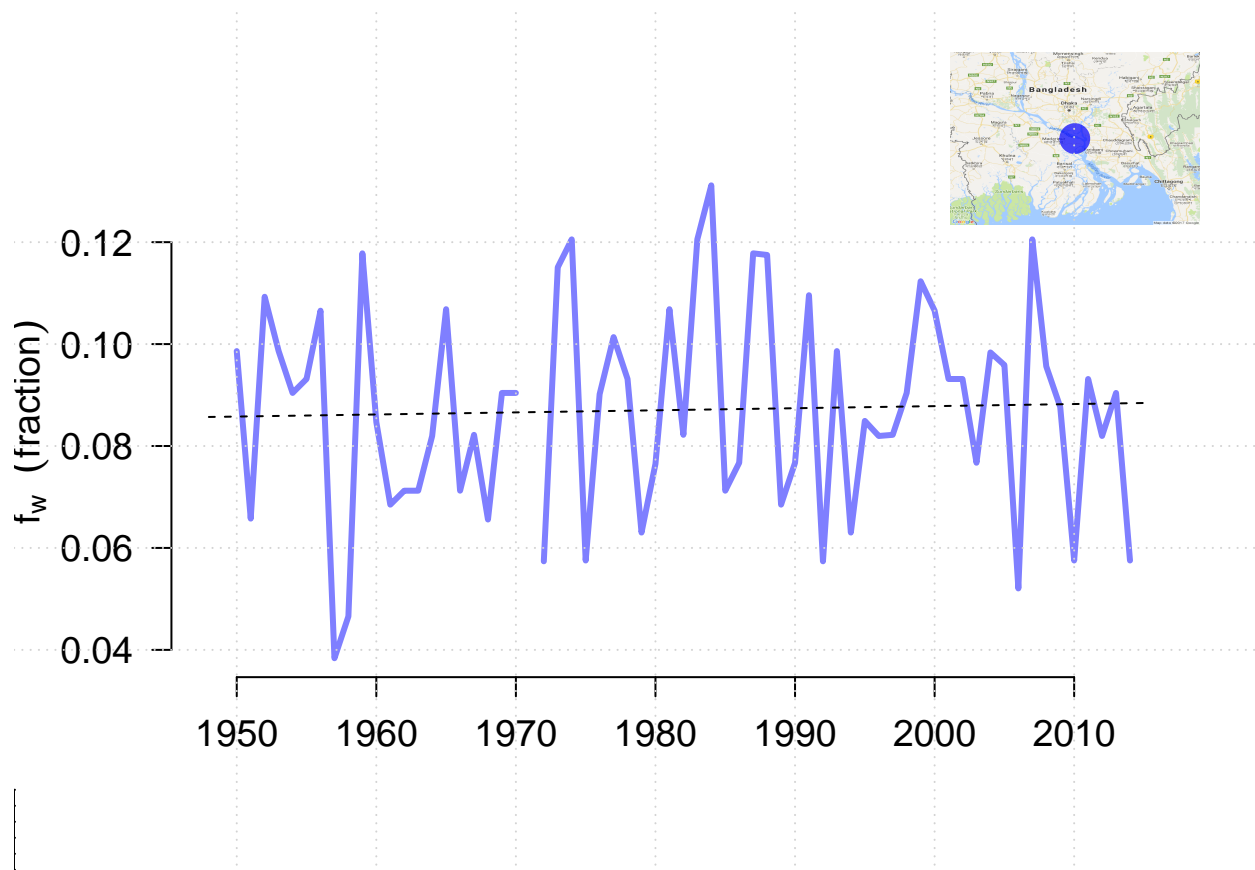
```r
grid()
lines(trend(annual(X,'wetmean')),lty=2)
```

The long-term perspective of the wet-day frequency

```
plot(annual(X,'wetfreq'),new=FALSE)
```

```
## Warning in plotmap(lat(x), lon(x), bgmap, pch = 19, col = col, cex = 2):
## NAs introduced by coercion
```

```
grid()
lines(trend(annual(X,'wetfreq')),lty=2)
```

Get data on storm tracks. IMILAST data do not cover the region as the analysis is only for storms north of 20N and south of 20S. Tropical cyclones are reported in the HURDAT2 dataset http://www.aoml.noaa.gov/hrd/hurdat/hurdat2-1851-2016-apr2017.txt, but only for the North-Atlantic. There are some data in the best-track data base http://www.usno.navy.mil/NOOC/nmfc-ph/RSS/jtwc/best_tracks/.

Best Track

```
url <- 'http://www.usno.navy.mil/NOOC/nmfc-ph/RSS/jtwc/best_tracks/'
```

Correlation between storm tracks and stations.

Tidal measurements

Time series and map of the tidal data from

```
load('Bangladesh-tidal-stations.rda')
plot(Z,zoom=8,new=FALSE)
```

```
## Warning in plot.window(...): "zoom" is not a graphical parameter

## Warning in plot.xy(xy, type, ...): "zoom" is not a graphical parameter

## Warning in axis(side, at = z, labels = labels, ...): "zoom" is not a
## graphical parameter

## Warning in axis(side = side, at = at, labels = labels, ...): "zoom" is not
```

```
## a graphical parameter

## Warning in box(...): "zoom" is not a graphical parameter

## Warning in title(...): "zoom" is not a graphical parameter

## Warning in plot.xy(xy.coords(x, y), type = type, ...): "zoom" is not a
## graphical parameter

## Warning in plot.xy(xy.coords(x, y), type = type, ...): "zoom" is not a
## graphical parameter

## Warning in plot.xy(xy.coords(x, y), type = type, ...): "zoom" is not a
## graphical parameter

## Warning in plot.xy(xy.coords(x, y), type = type, ...): "zoom" is not a
## graphical parameter

## Warning in plot.xy(xy.coords(x, y), type = type, ...): "zoom" is not a
## graphical parameter

## Warning in plotmap(lat(x), lon(x), bgmap, pch = 19, col = col, cex = 2):
## NAs introduced by coercion
```
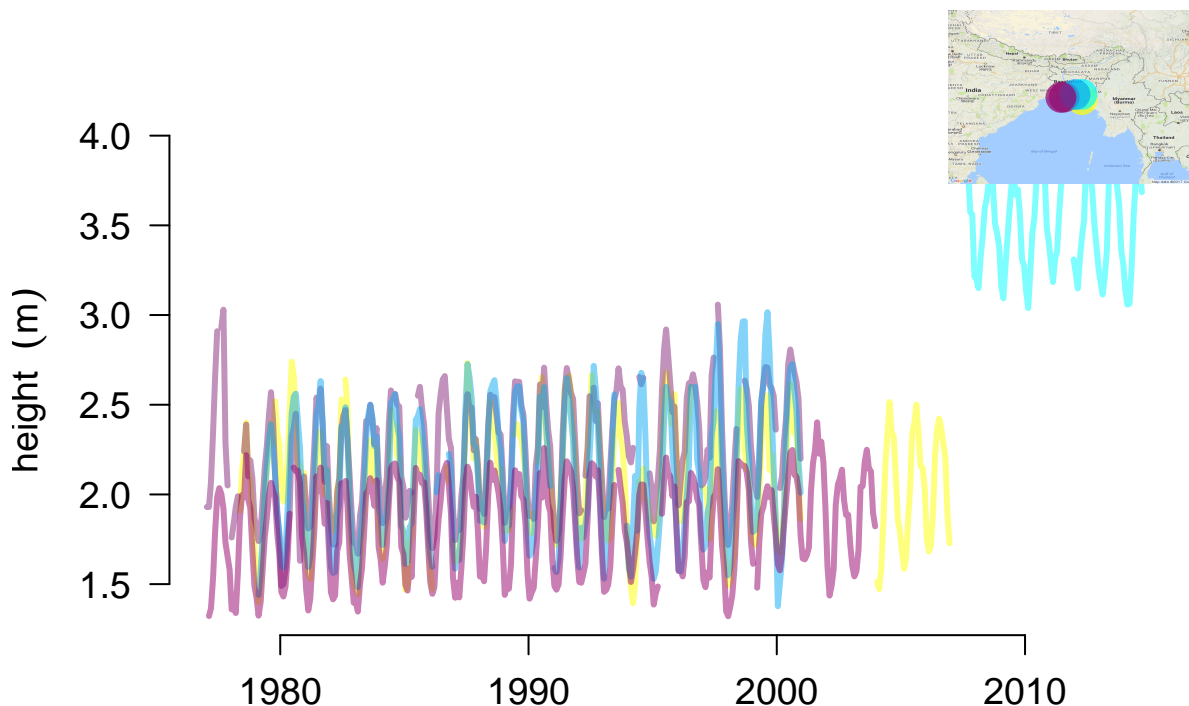

Check the annual cycle in the tidal time series. Is it caused by seasonally changing wind patterns? That would be reflected in the SLP.

```
SLP <- retrieve('~/Downloads/slp.mon.mean.nc',lon=c(75,105),lat=c(5,30))
```
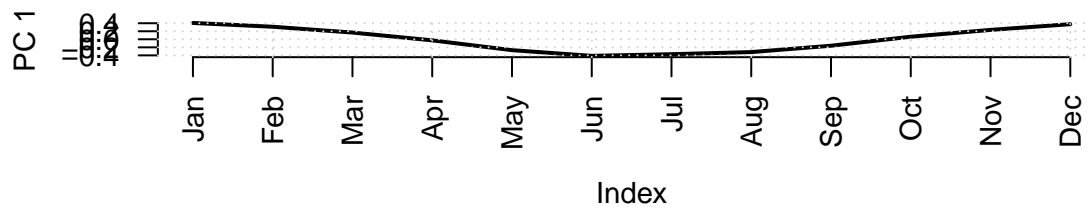
```
## [1] "Warning : Calendar attribute has not been found in the meta data and will be set automatically.
```

```
amslp <- mask(aggregate(SLP,month,FUN='mean'),land=TRUE)
eof.amslp <- EOF(amslp,n=3)
plot(eof.amslp)
```


First 3 leading EOFs: 99.9 % of variance
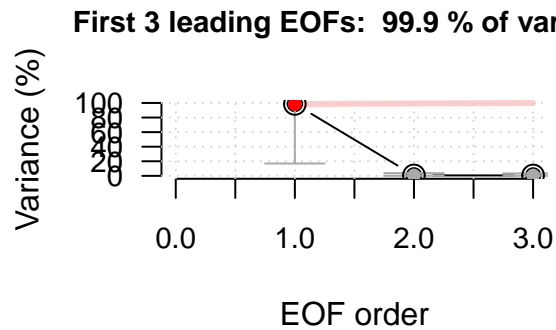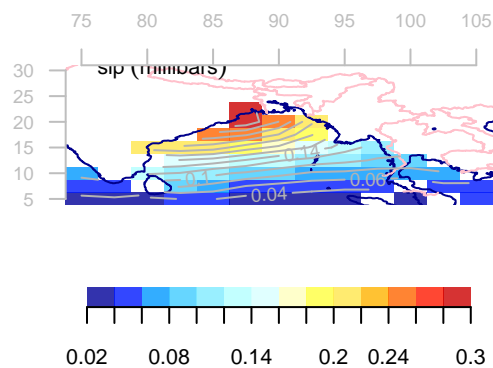
Examine the seasonal cycle in the tidal data: extract the mean seasonal cycle using `aggregate`

```
amsl <- aggregate(Z,month,'mean')
pca.amsl <- PCA(amsl,n=3)
plot(pca.amsl)
```

Use `DS` to apply a multiple regression analysis to the PCAs and EOFs describing the seasonal cycle. This is ok for short series when we know the connection is due to known physics - shifting wind patterns:

```
ds.asl <- DS(pca.amsl,eof.amslp,n=3)
```

```
##
  |
  |                                                                |   0%
  |
  |=====================                                           |  33%

## Warning in DS.station(ys, X, biascorrect = biascorrect, m = m, ip = ip, :
## DS.station: different indices: Date numeric

##
  |
  |===========================================                     |  67%

## Warning in DS.station(ys, X, biascorrect = biascorrect, m = m, ip = ip, :
## DS.station: different indices: Date numeric

##
  |
  |================================================================| 100%
```

```
## Warning in DS.station(ys, X, biascorrect = biascorrect, m = m, ip = ip, :
## DS.station: different indices: Date numeric
```

```
plot(ds.asl)
```
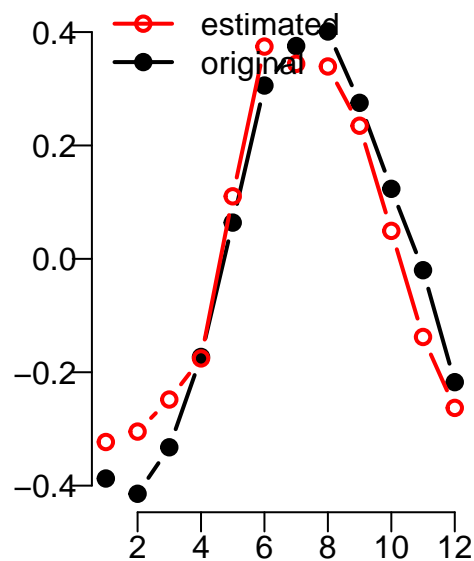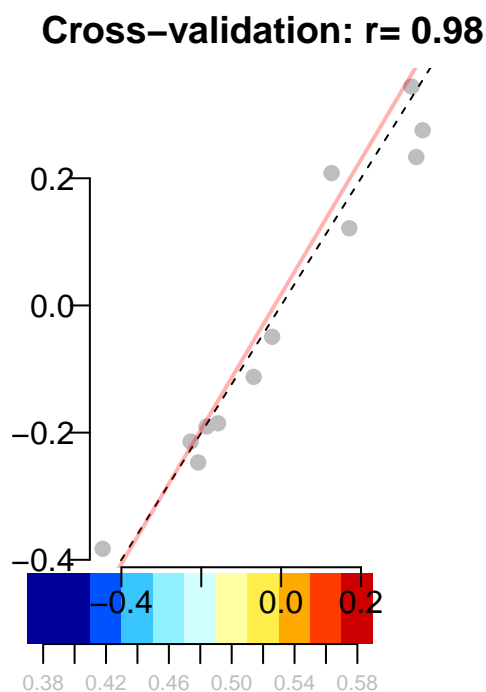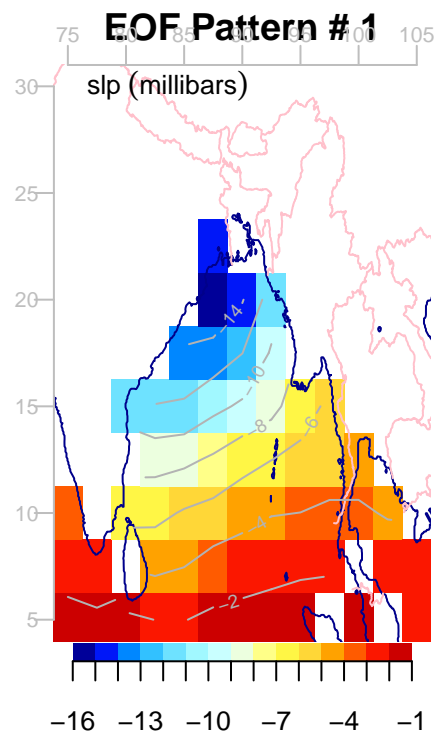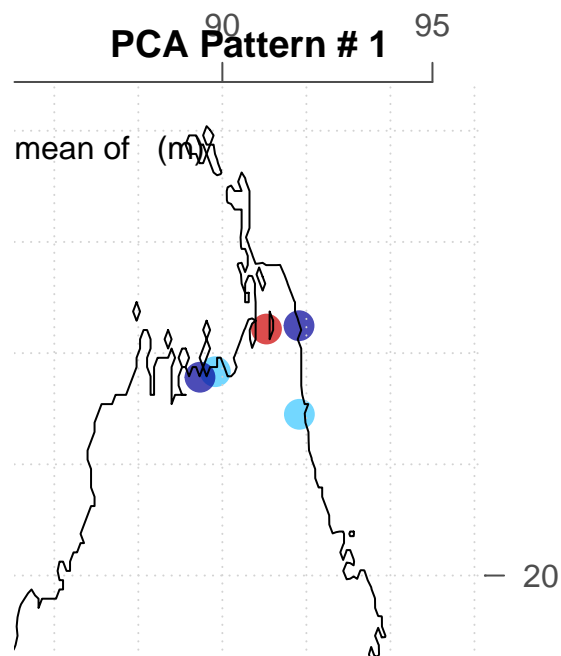


```
## NULL
```

The seasonal variations are indeed caused by seasonally shifting winth patterns. This gives an idea of the sensitivity of the local sea level to changing winds in general, as the physical forces will be similar. We cal

downscale the SLP from GCMs in multi-model ensembles to try to get a robust picture. There may be some problems in the SLP simulation over the Indian sub-continent, which means that we may need to mask out the land.