Presentation for Workshop on:

Enhancing Approaches to Explain Management Effects on Water Quality Trends

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Elgin Perry
eperry@chesapeake.net

Using GAMs to describe water quality trends in estuarine and freshwater systems.

Gam – Generalized Additive Model

- Use spline function to estimate nonlinear trends
- Thin plate splines for relationships changing over time
- Easy to add and subtract variables
- Off the shelf inference procedures

The Drawing Board

Broad Stroke Model

$$y = f(\text{natural stimuli}) + f(\text{anthropogenic stimuli}) + \text{noise}$$

Bottom Up Paradigm

fall line nutrients **->**
estuarine nutrients **->**
phytoplankton (Chlorophyll) **->**
o2 demand **->**
hypoxia

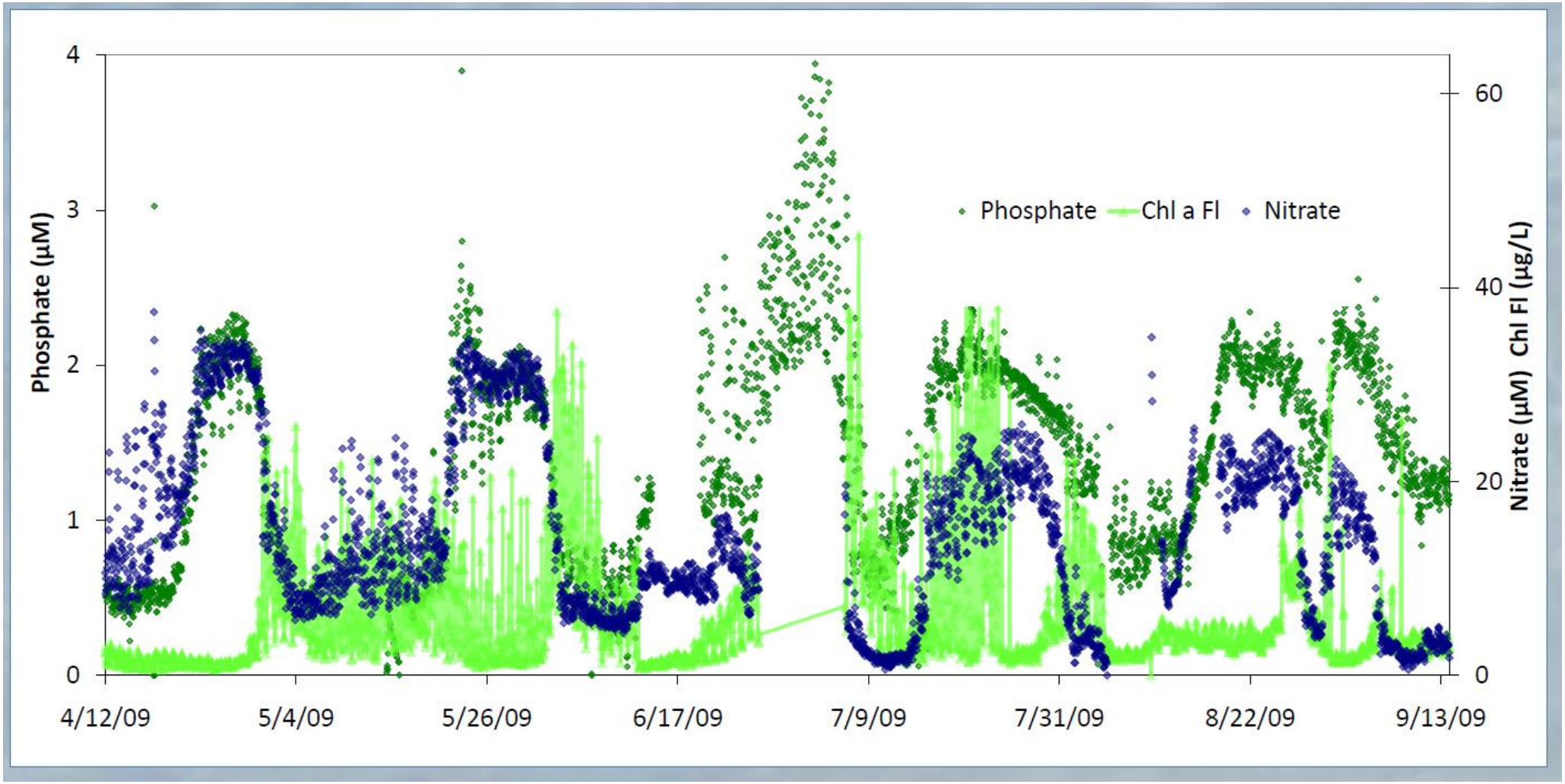


Figure 1. Koch et al., CERF, 2009

Estuarine Factors to consider:

Lags – How much time between fall-line stimulus and estuarine response?

Location - where is the effect of the stimulus expressed?

- Binning identifying the appropriate geographic boundaries
- Estuarine Circulation / stratification

Other rate controls

- Temperature
- Sunlight
- Water Clarity

Top Down Factors

zooplankton grazing

menhaden grazing

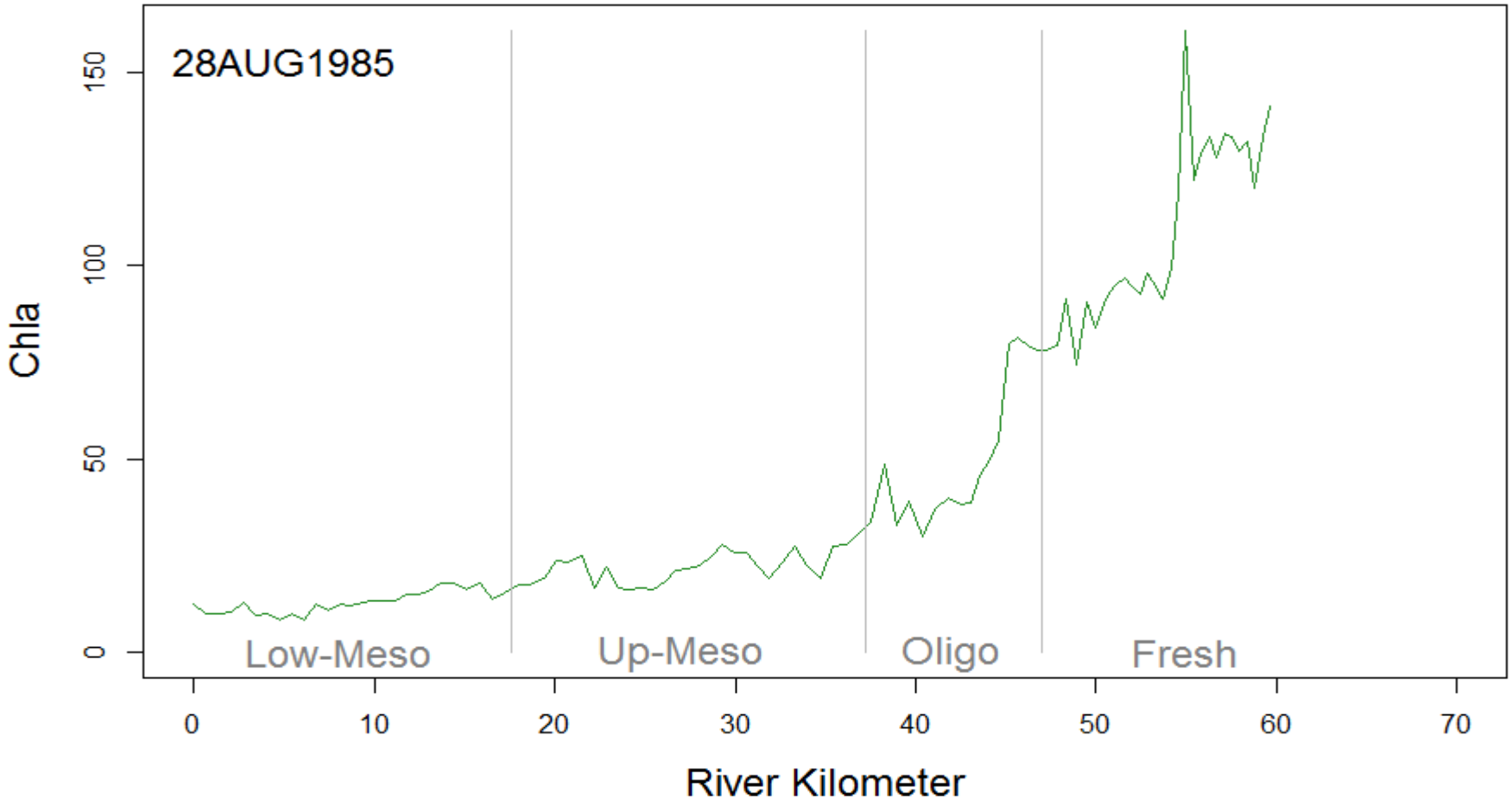
Below fall line land source contributions?

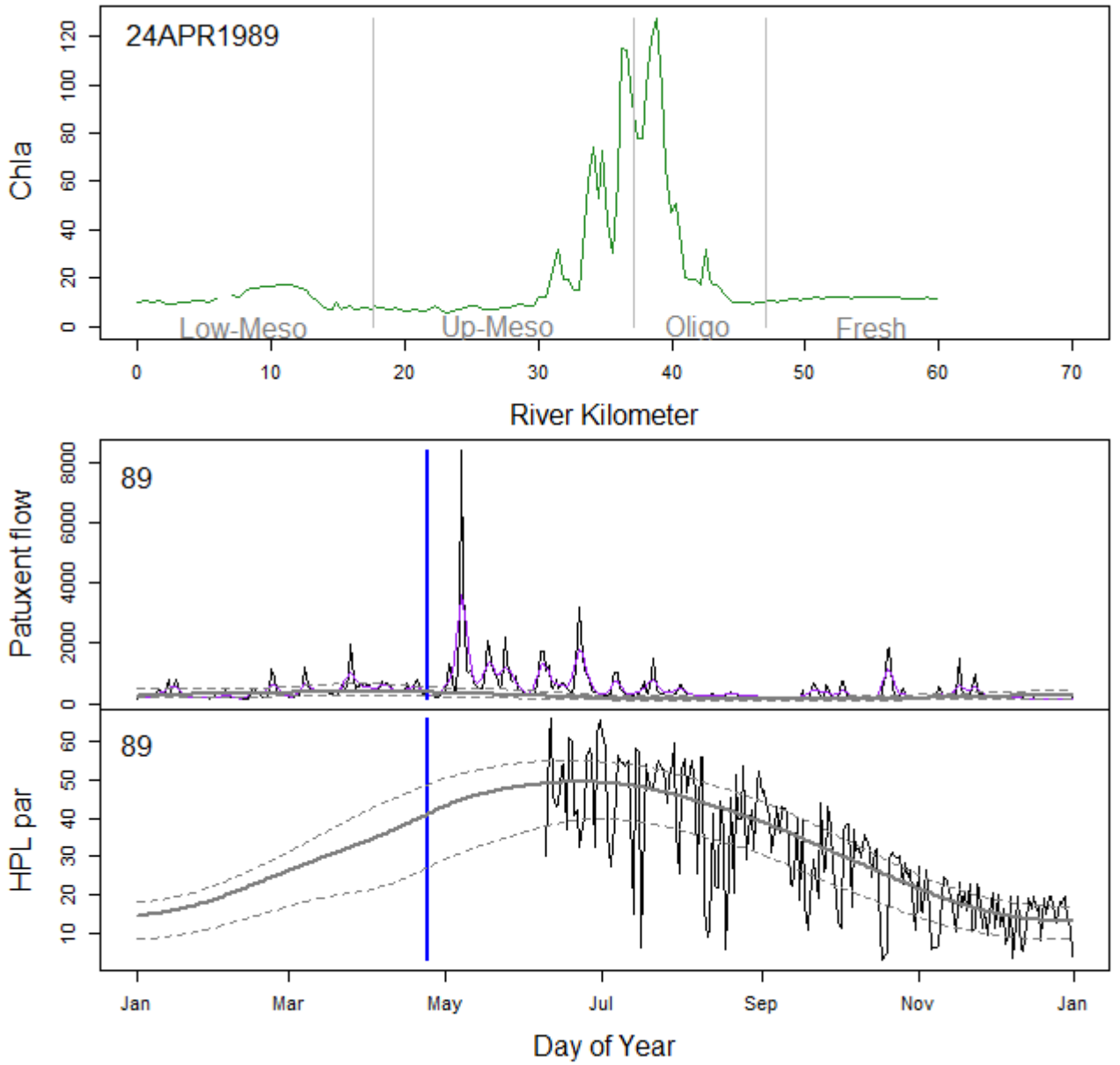
Feed Back loops hypoxia – nutrient recycling?

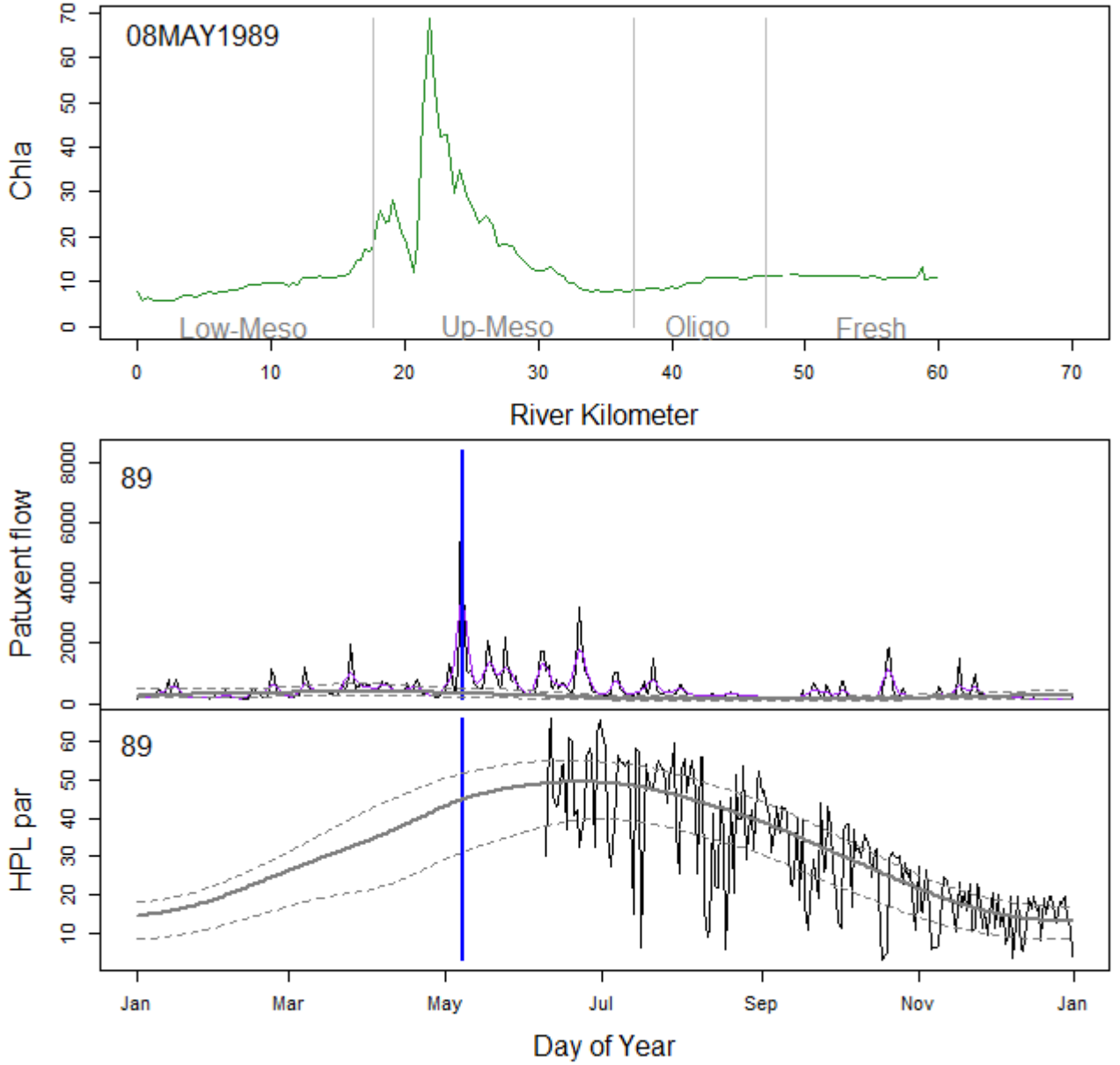
Steps

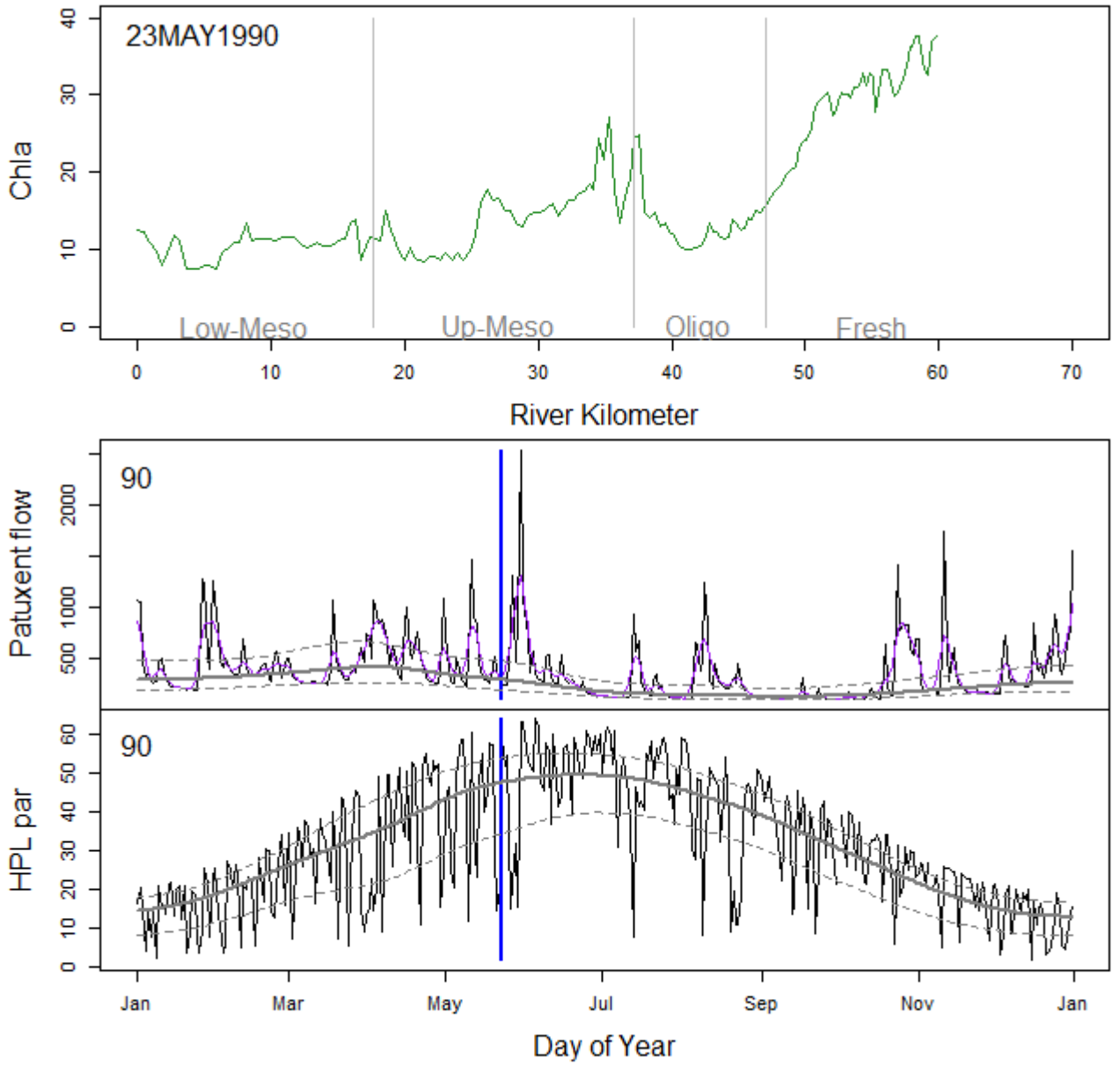
1. Look at response data
2. Look at data relative to forcing functions
3. Develop quantitative measures of forcing functions
4. GAM development.

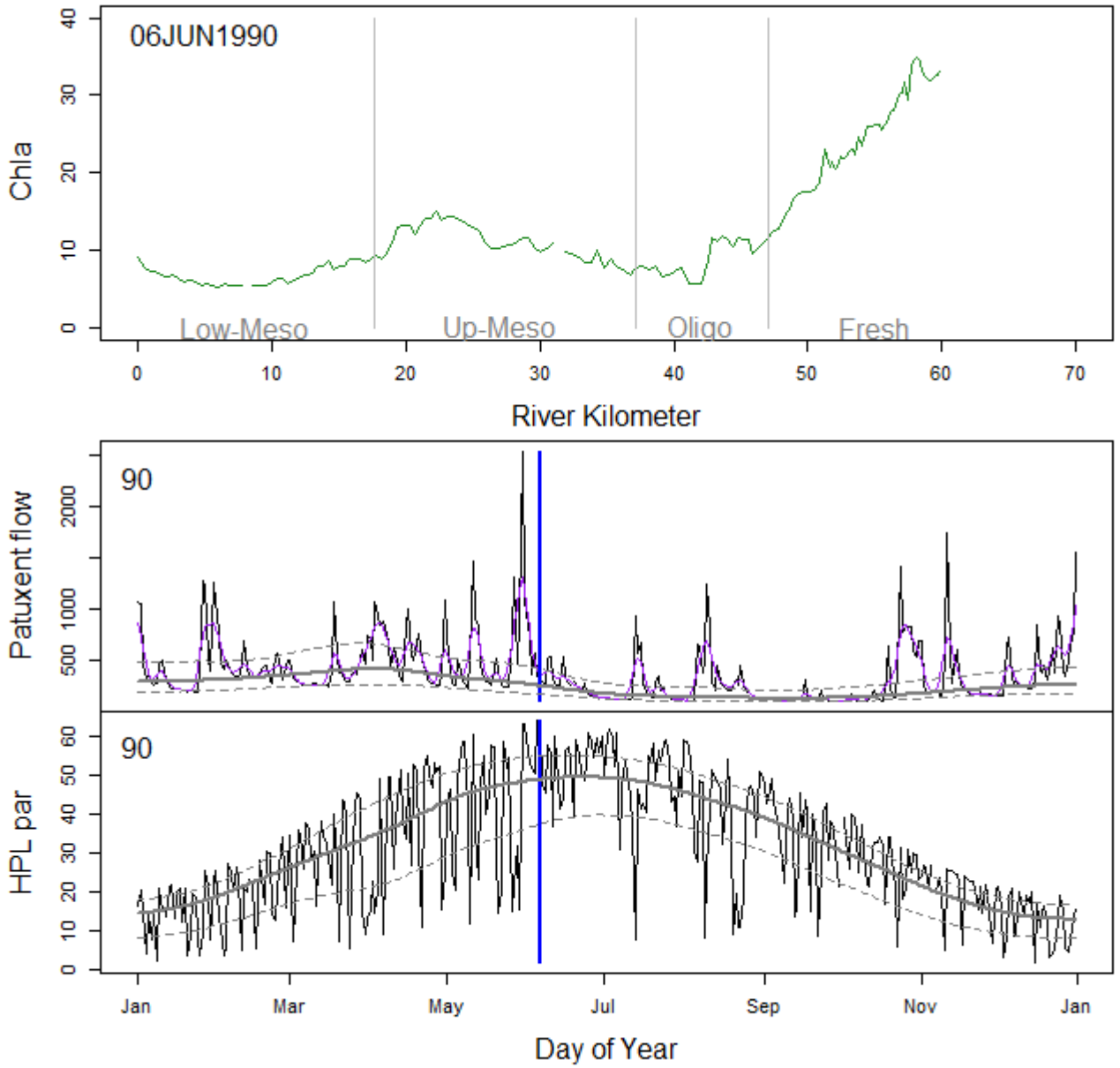
Response data (388 dates)




24APR1989
Chla
0
20
40
60
80
100
120
Low-Meso
Up-Meso
Oligo
Fresh
0
10
20
30
40
50
60
70
River Kilometer
89
Patuxent flow
0
2000
4000
6000
8000
89
HPL par
10
20
30
40
50
60
Jan
Mar
May
Jul
Sep
Nov
Jan
Day of Year


08MAY1989
Chla
Low-Meso
Up-Meso
Oligo
Fresh
River Kilometer
89
Patuxent flow
89
HPL par
Jan
Mar
May
Jul
Sep
Nov
Jan
Day of Year

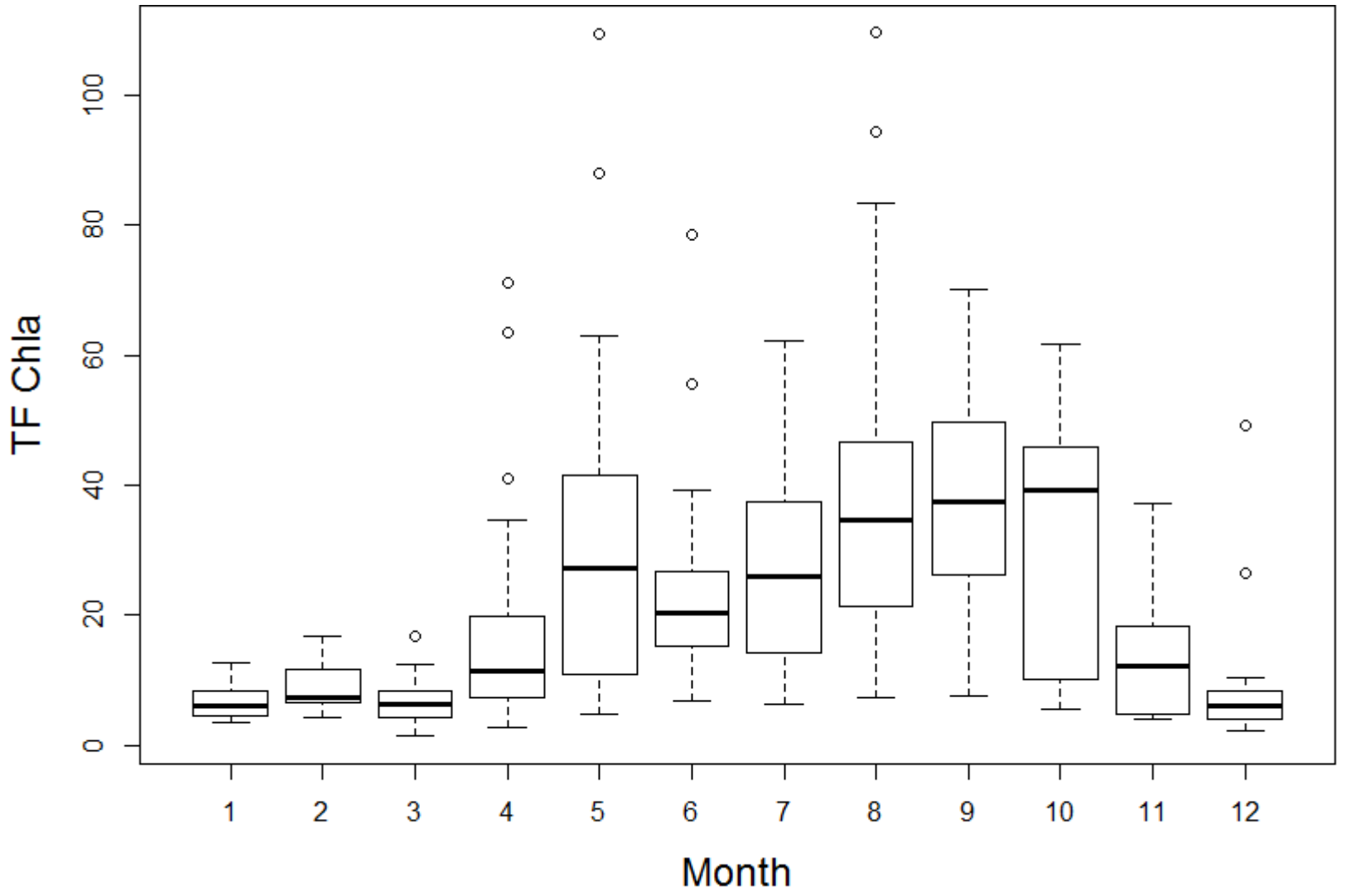

23MAY1990
Chla
Low-Meso
Up-Meso
Oligo
Fresh
River Kilometer
Patuxent flow
90
HPL par
90
Jan
Mar
May
Jul
Sep
Nov
Jan
Day of Year


06JUN1990
Chla
Low-Meso
Up-Meso
Oligo
Fresh
River Kilometer
Patuxent flow
90
HPL par
90
Jan
Mar
May
Jul
Sep
Nov
Jan
Day of Year

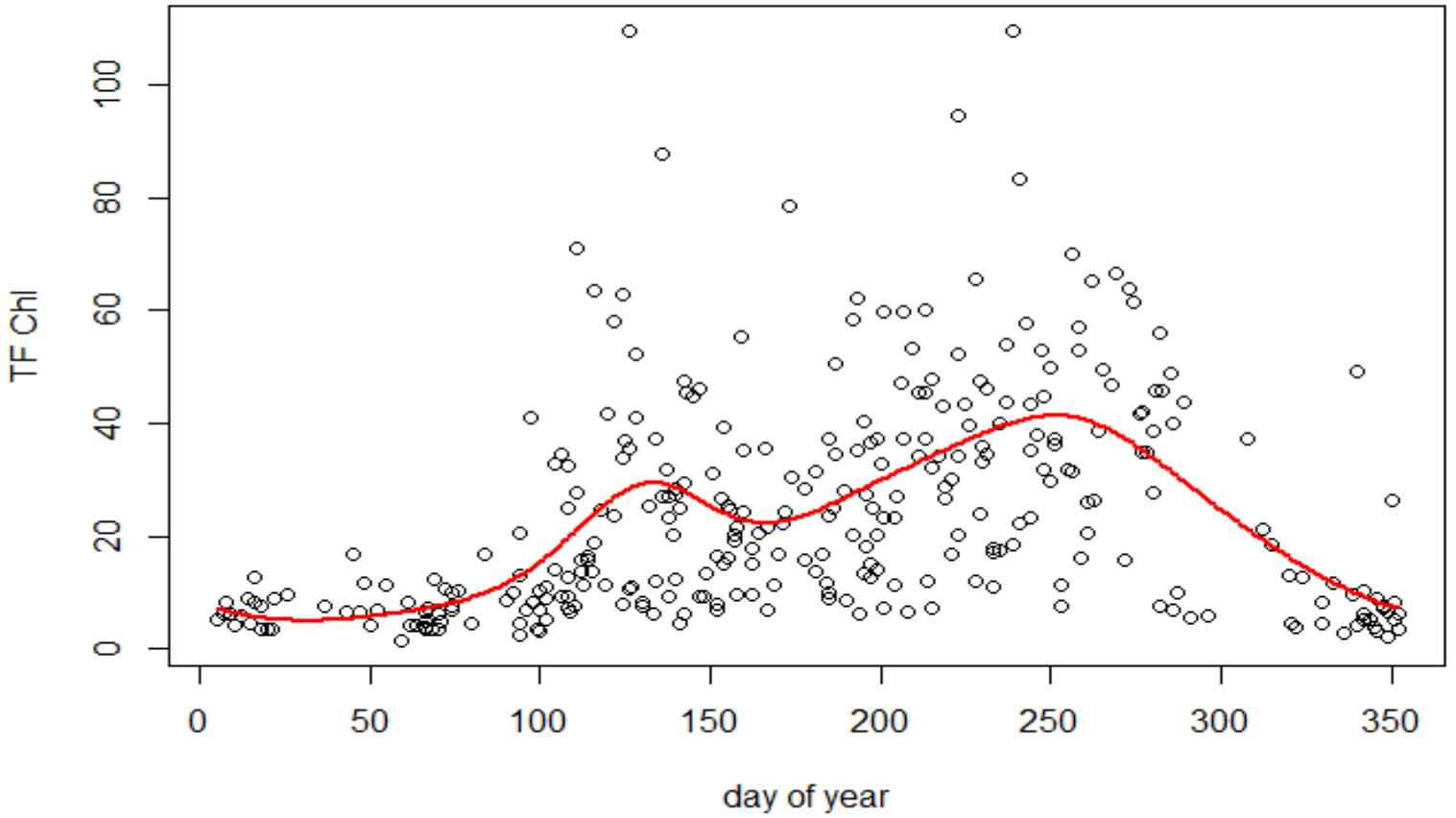
Patterns

High flow reduces Chl in TF.
High Chl in TF sets up during low flow periods
Flow appears to have little effect downriver
Flow and light are connected
Maybe cloudy days lead to lower Chl.

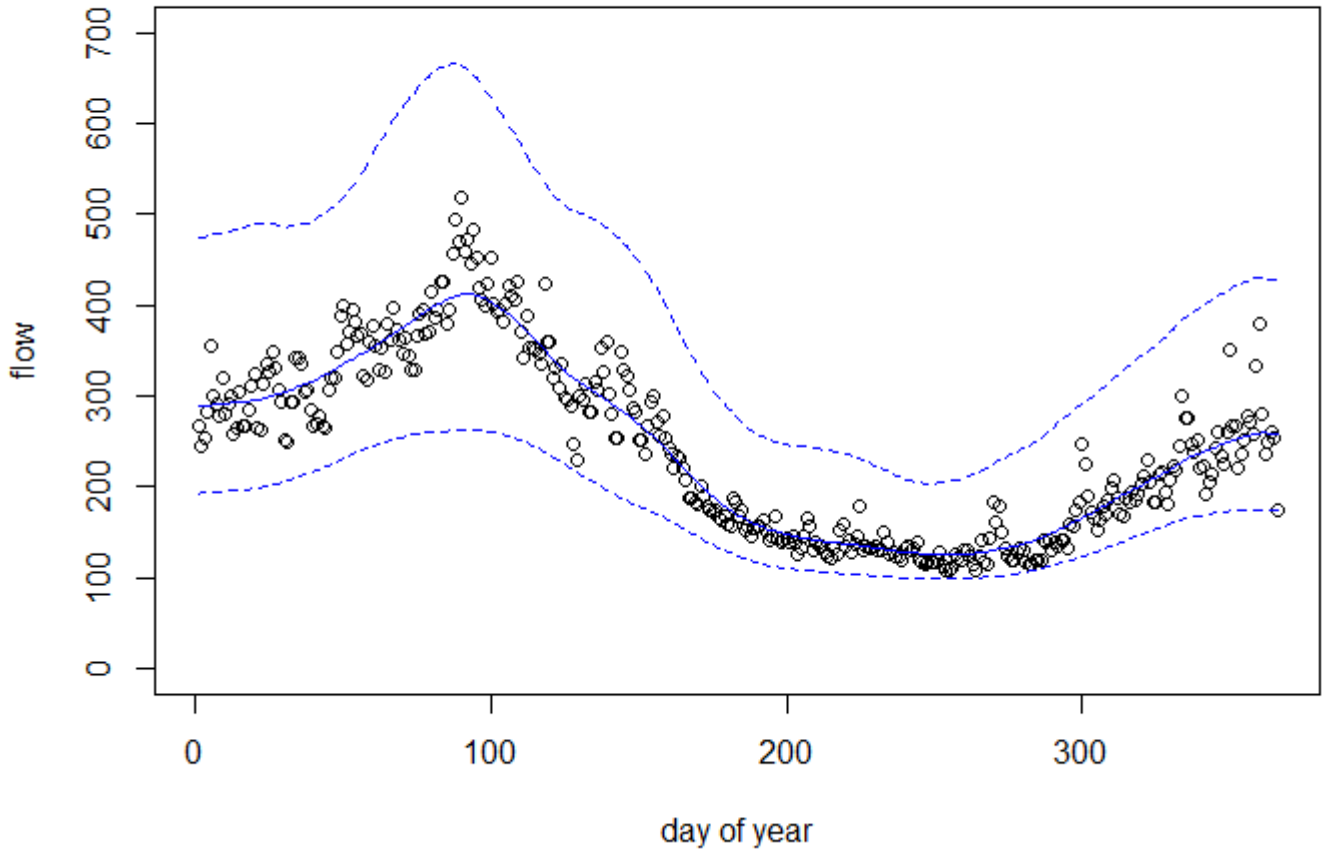
Seasonal Patterns



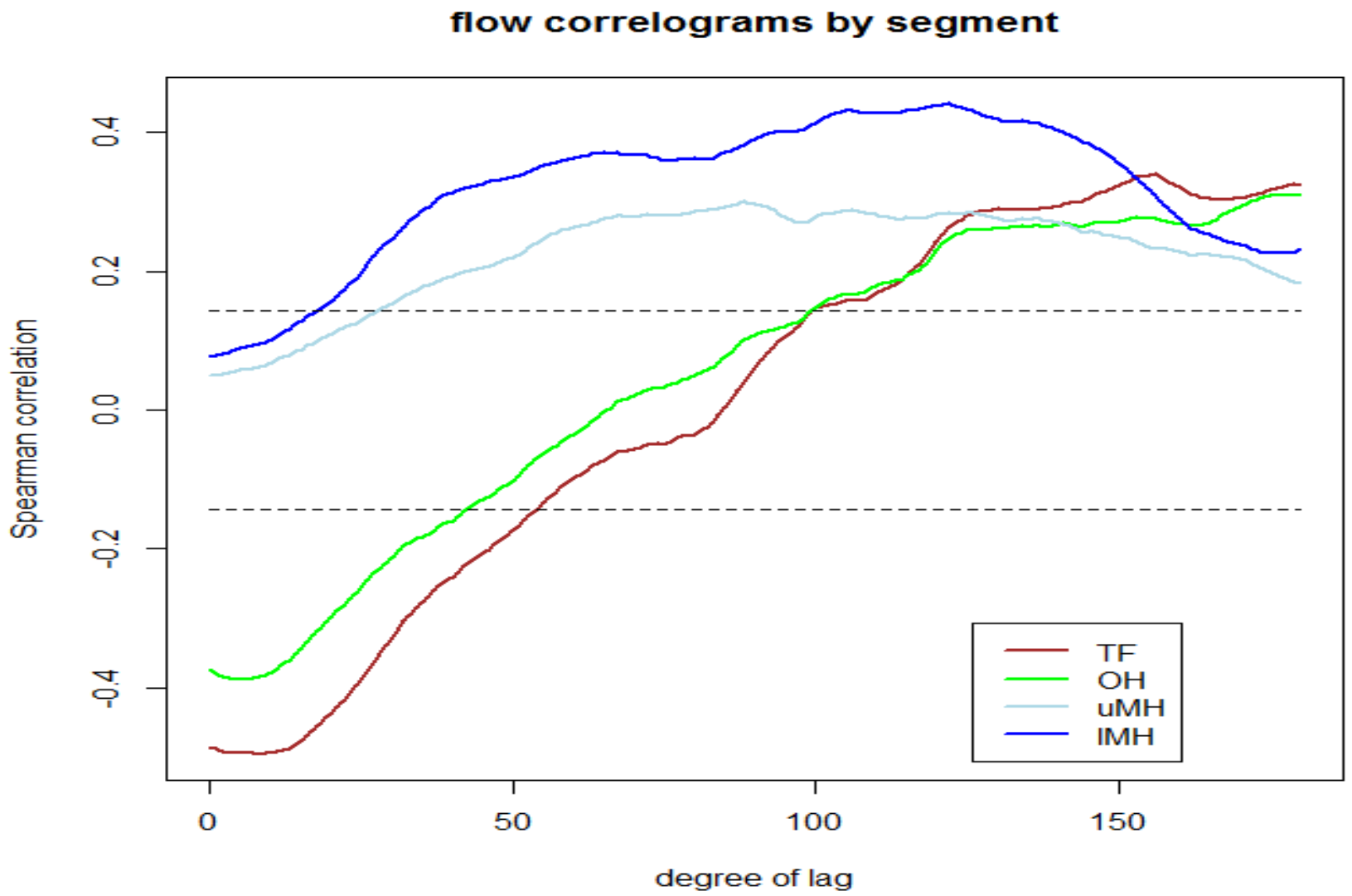
Gam model for season

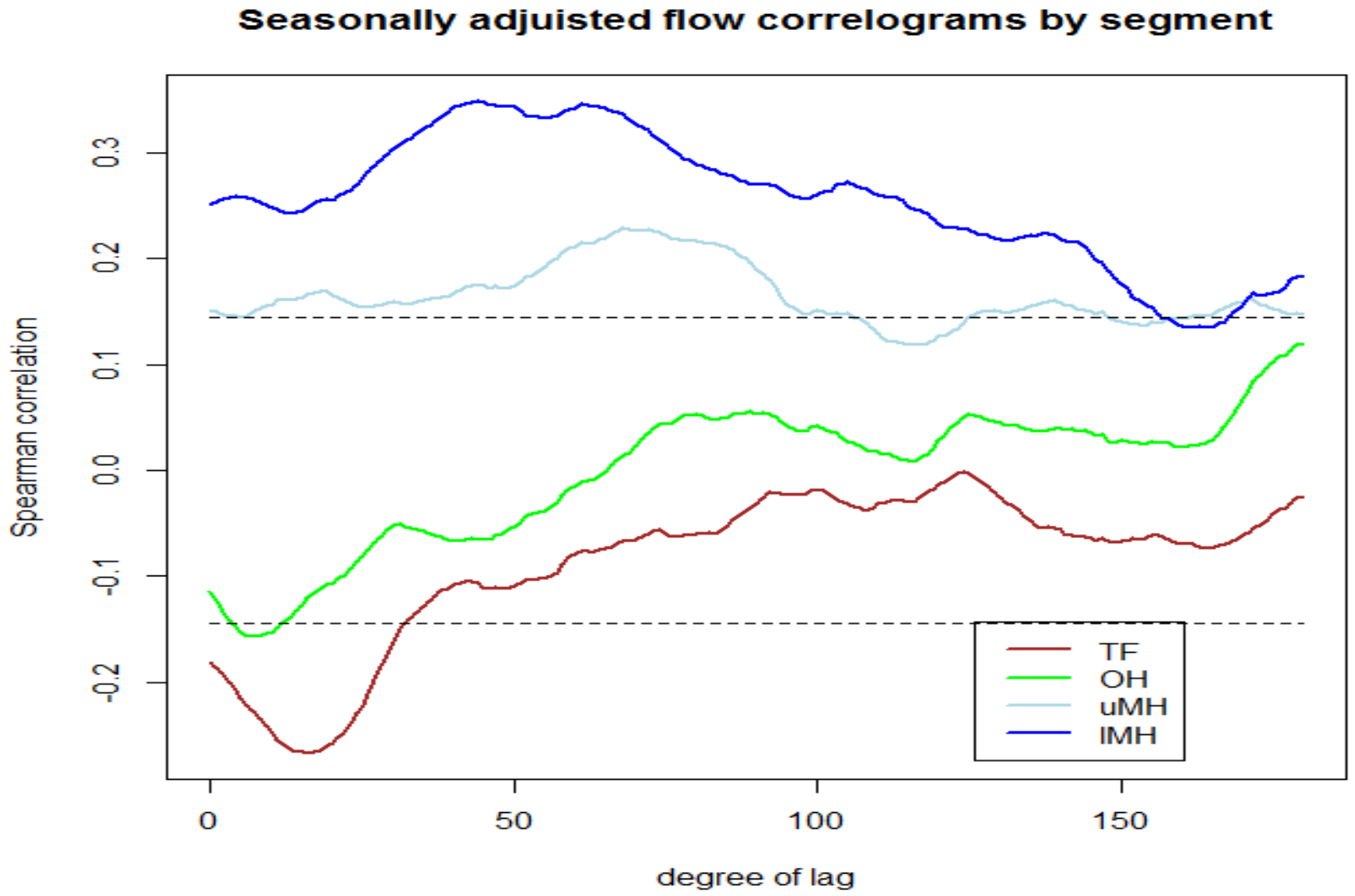


Seasonal Pattern of Flow

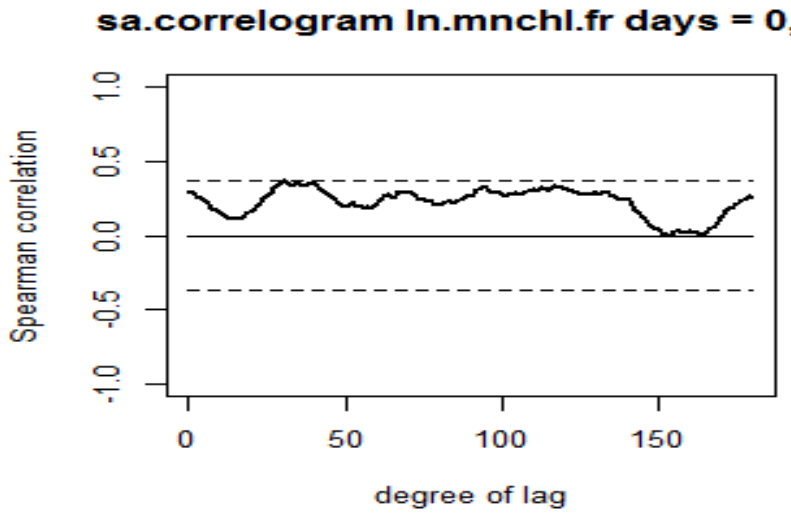


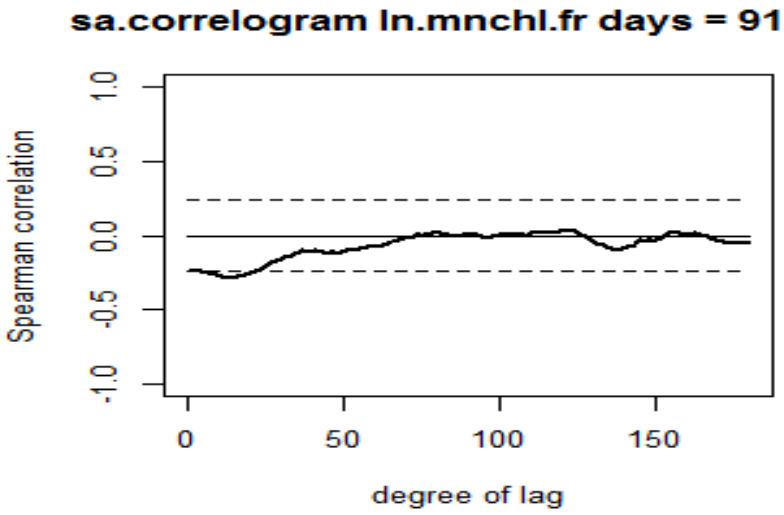
Flow Correlogram

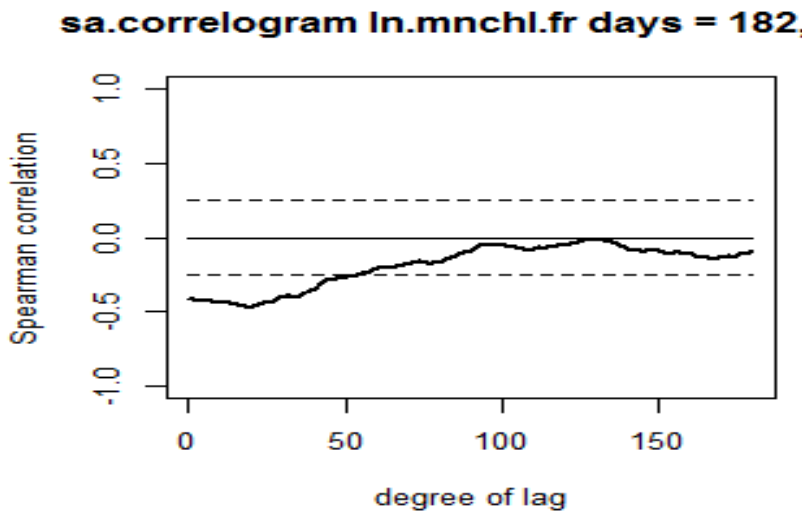


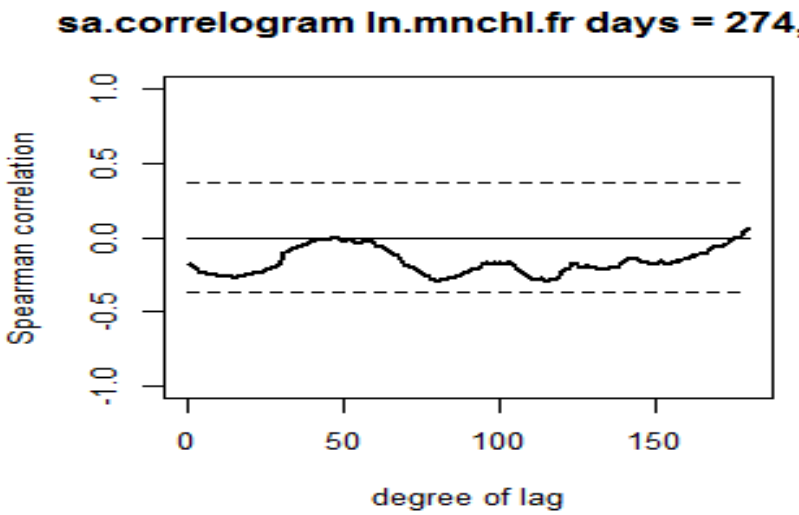

Seasonally adjuisted flow correlograms by segment
Spearman correlation
0.3
0.2
0.1
0.0
-0.1
-0.2
0
50
100
150
degree of lag
TF
OH
uMH
lMH

SA correlogram by Season







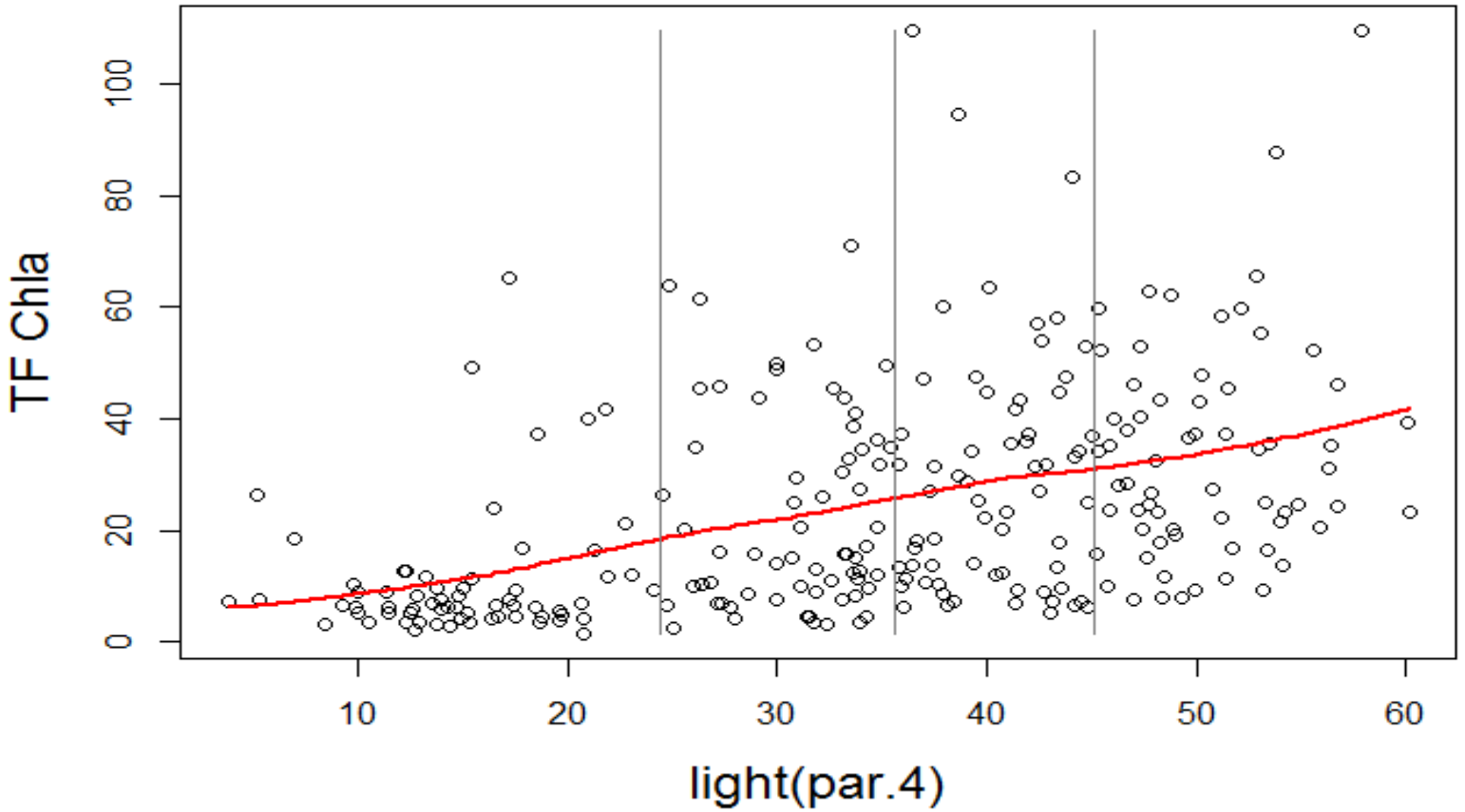


Quantitative Measures

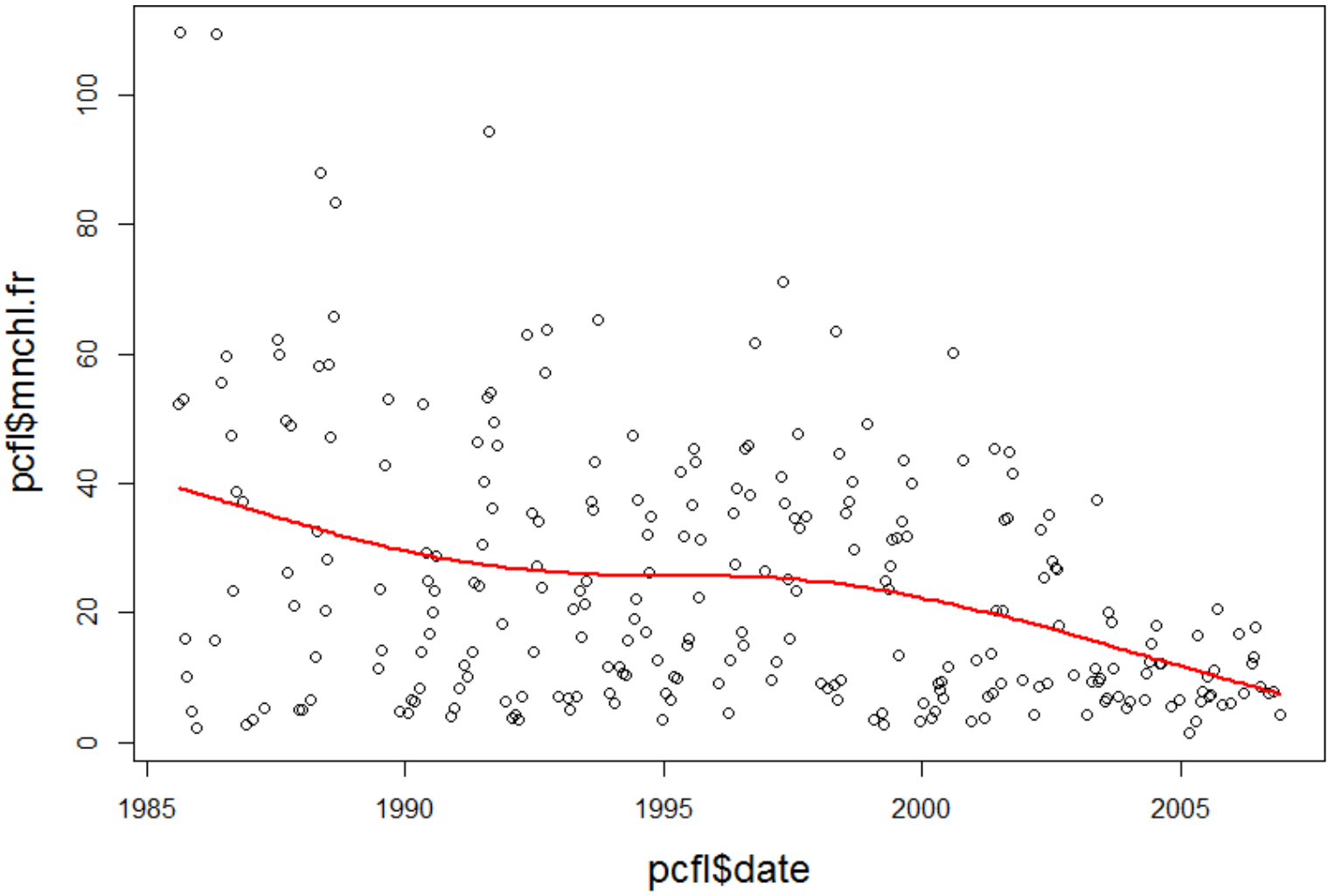
- Dependent – Integral of chl by salinity zone
- Season
  - Monthly means
  - Cyclical day of year (doy)
- Flow
  - Moving average of flow with lags (up to 7 weeks)
  - Days since flow event
  - Size of flow event

Quantitative Measures

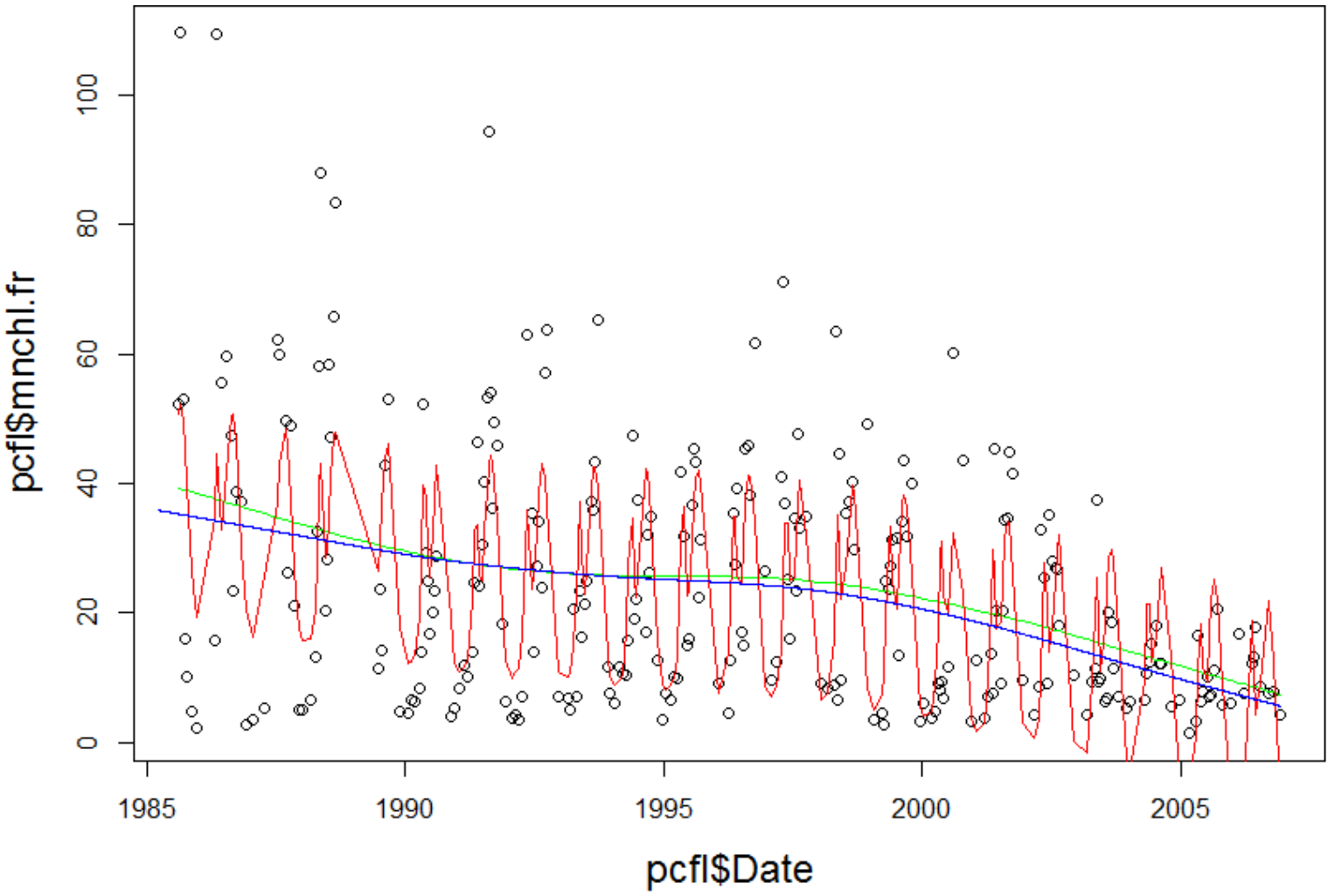
- Light
  - Series of averages (1 day, 2 day, . . . 7 day)
  - Sunny days (par > 0.75 quantile)
  - Cloudy days (par < 0.25 quantile)
  - Sunny days-cloudy days


TF Chla
0
20
40
60
80
100
10
20
30
40
50
60
light(par.4)

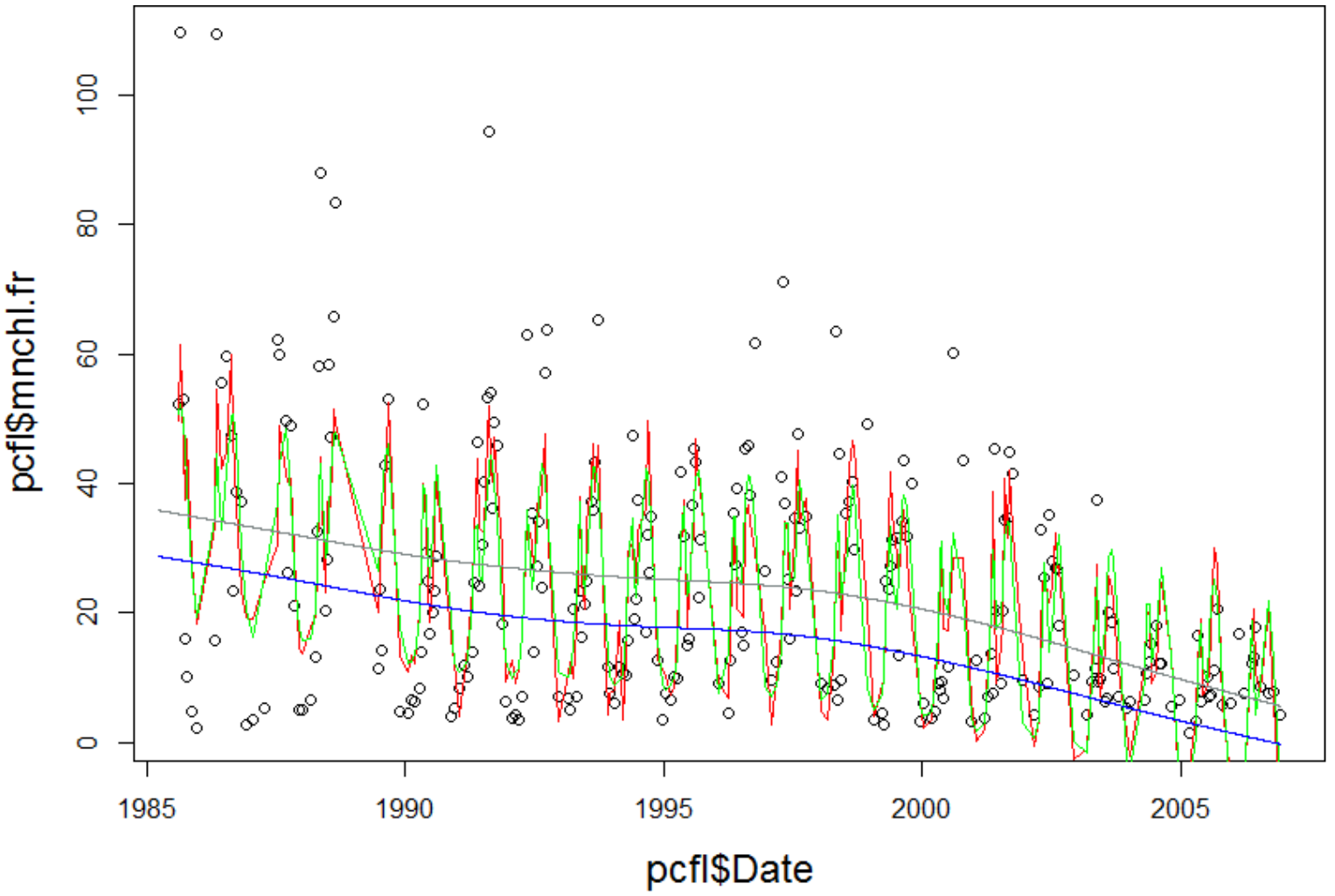
Finally a gam trend line



Seasonally adjusted trend



Trend(season,flow)

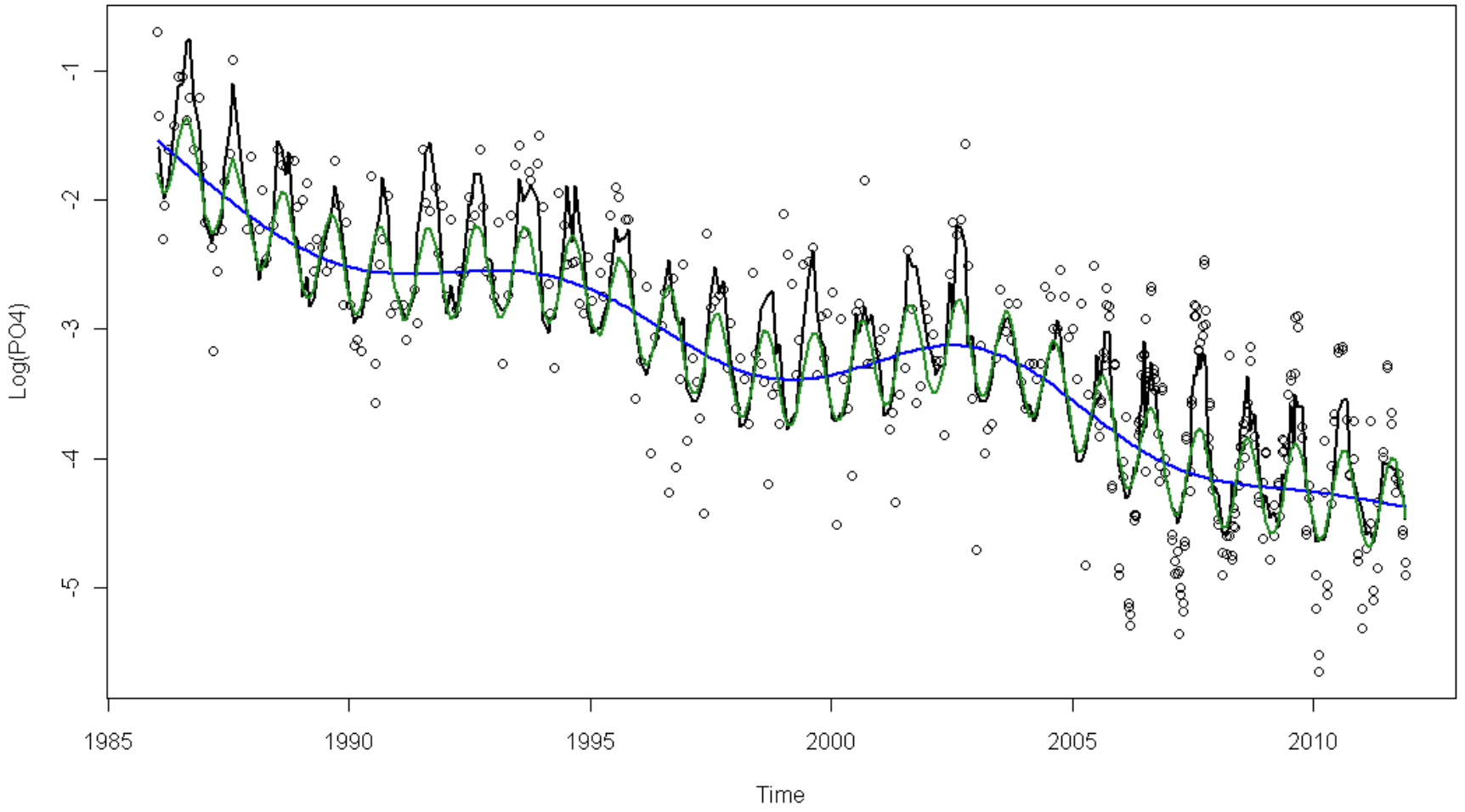


Conclusions

TF chorophyll is going down

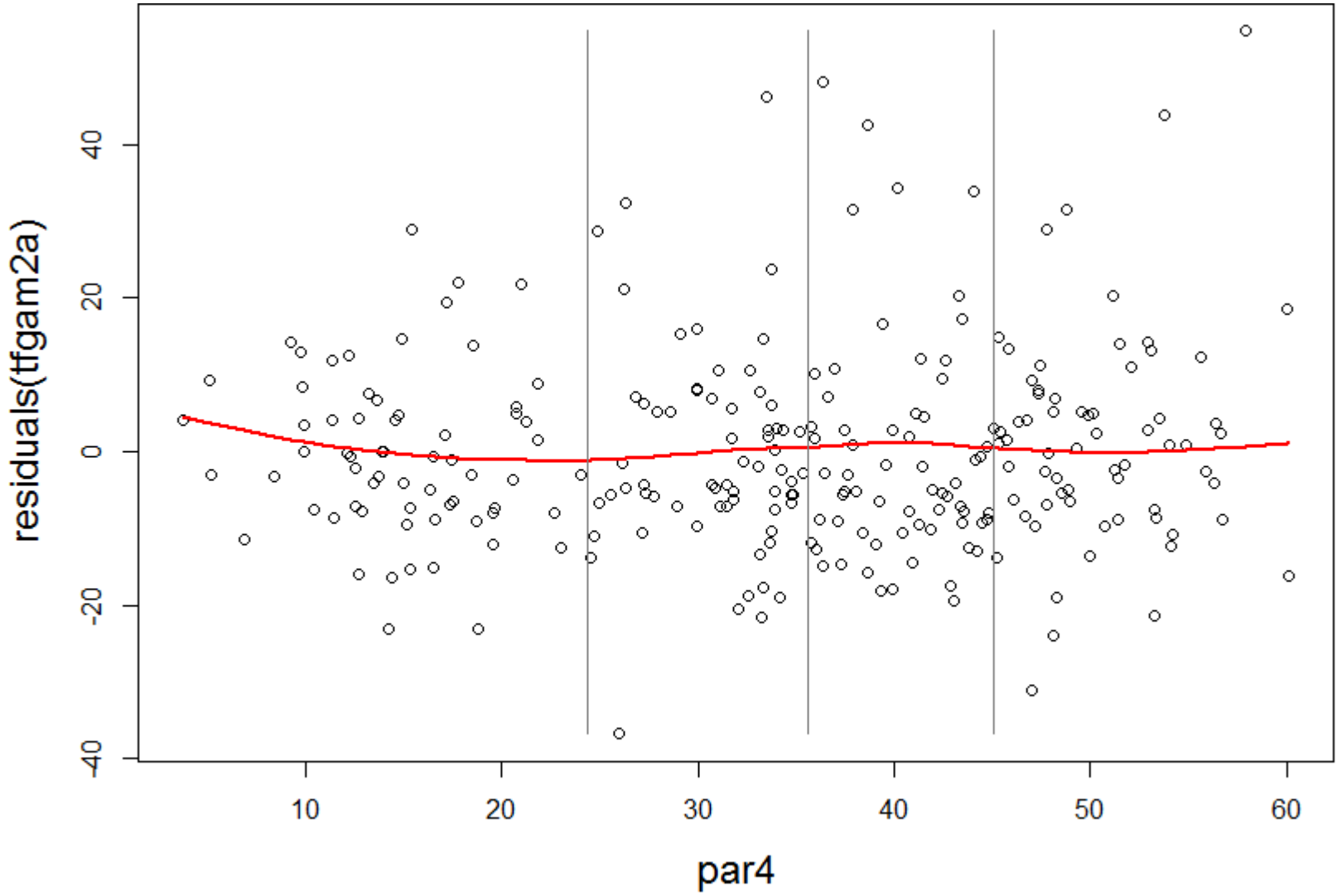
Effective management actions were in 1980's and post 2000.

Pax fall line PO4 Concentration

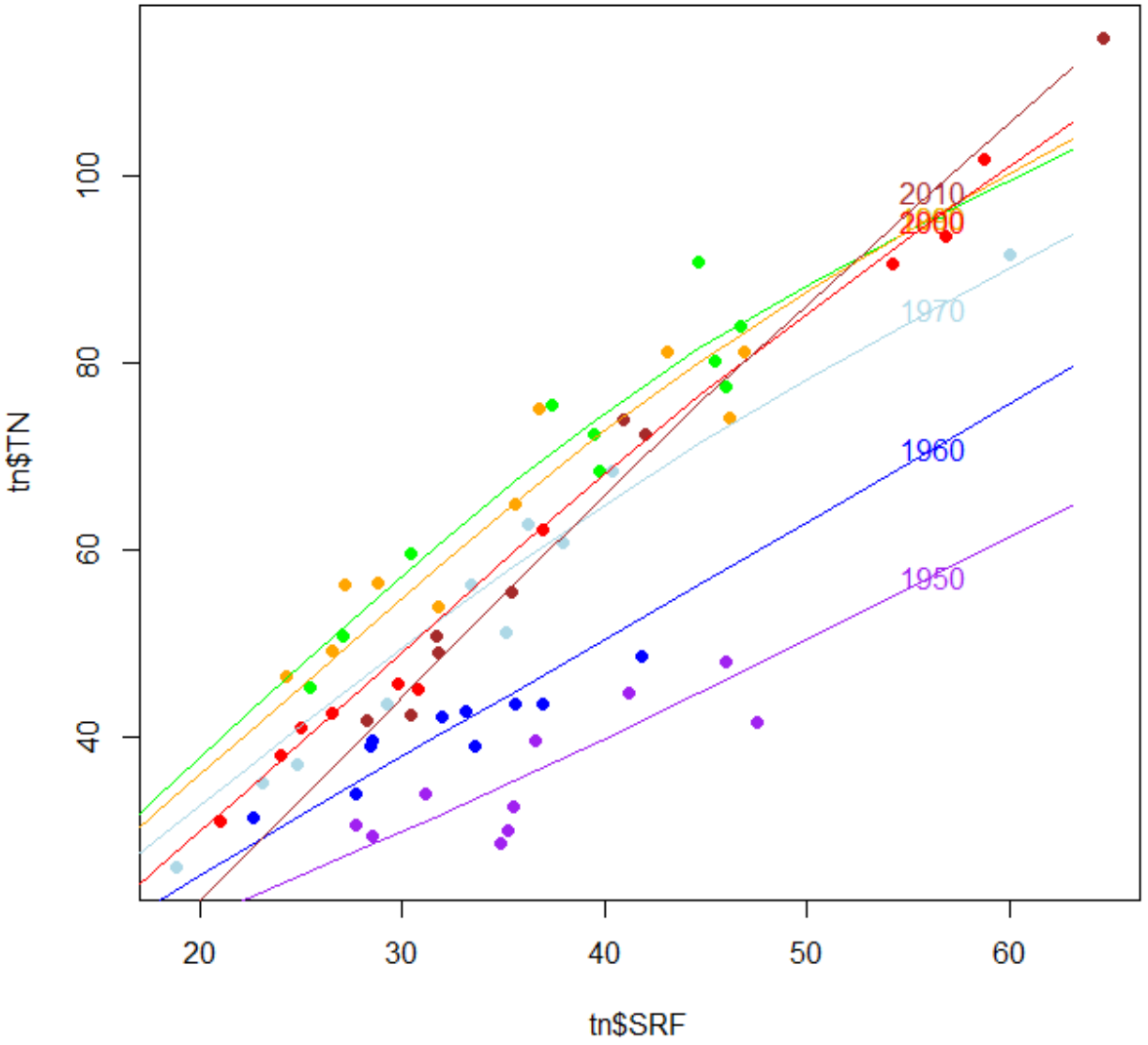


Analysis Conclusions

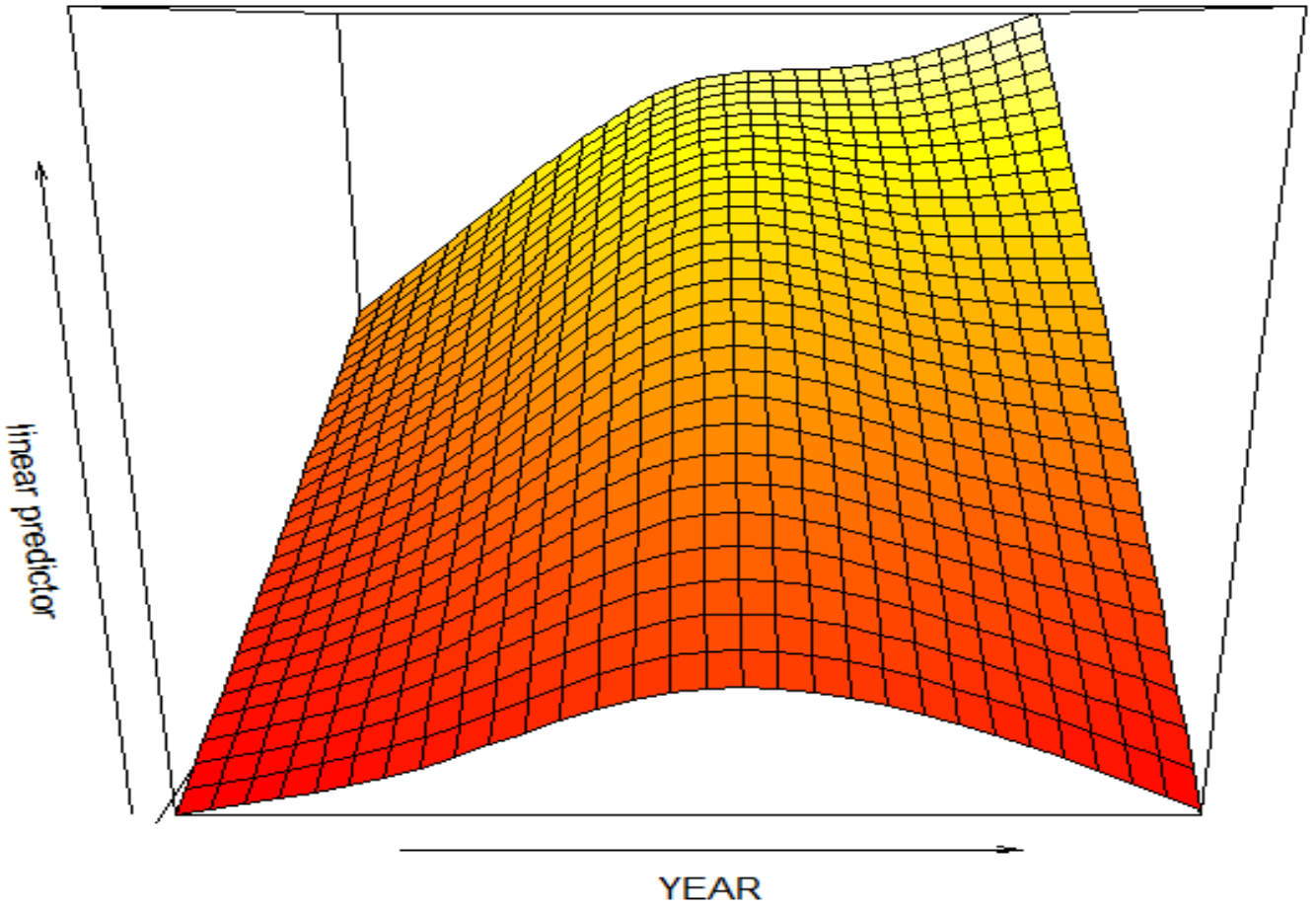
- Cyclical DOY is good seasonal method
- Event.days, Event.size = deadend
- Light = deadend
- No season x time interaction
- No flow x time interaction


residuals(tfgam2a)
40
20
0
-20
-40
10
20
30
40
50
60
par4

Susquehanna TN load versus flow over time



TN load = f(time,flow)



New Approaches to Explain Management Effects

Need to itemize f(anthropogenic stimuli)

Percent of Point Source water passing through BNR plants
Index of BMP implementation
Quantify Atmospheric Contribution

Look at expanding f(natural stimuli)

New Analytical Methods

Smoothing methods (loess and gam)

Lag analysis – correlograms

Optimizing ‘Where to look’?

Structural Equations and Path Analysis?