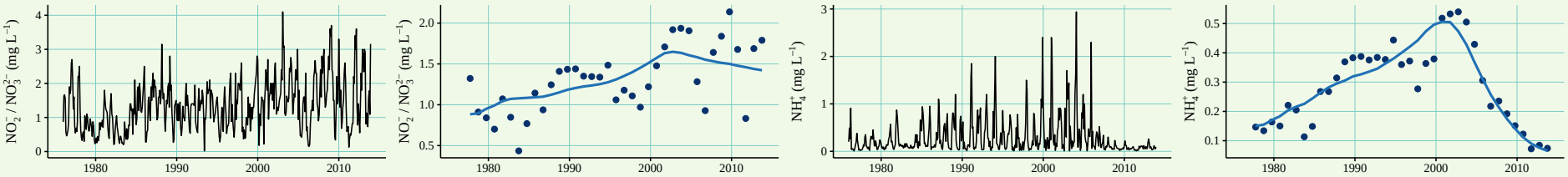
Evaluation of Delta RMP nutrient data using weighted regression for trend analysis

Marcus W. Beck, PhD

Southern California Coastal Water Research Project, marcusb@sccwrp.org, Phone: 7147553217

April 9, 2019



Evaluating Delta RMP data

Today's talk: Evaluation of forty years of Delta water quality data from the Routing Monitoring Program (RMP)

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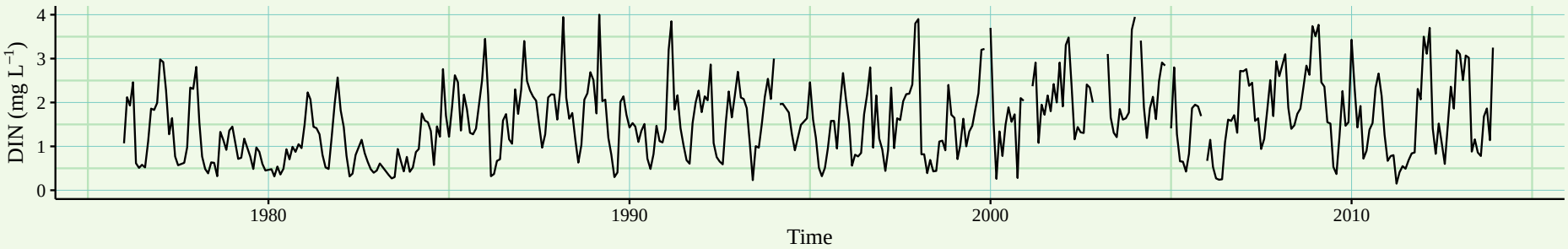
Water quality trends in the Delta:

- ***Part 1***: Model theory and application
- ***Part 2***: Trends over time and selected case study
- ***Part 3***: Use of data science tools to reach environmental managers

Model theory and background

WRTDS adaptation for tidal waters

Observed data represents effects of many processes



Climate	***Local***	***Regional/historical***
precipitation	light/turbidity	watershed inputs
temperature	residence time	point sources
wind events	invasive species	management actions
ENSO effects	trophic effects	flow changes

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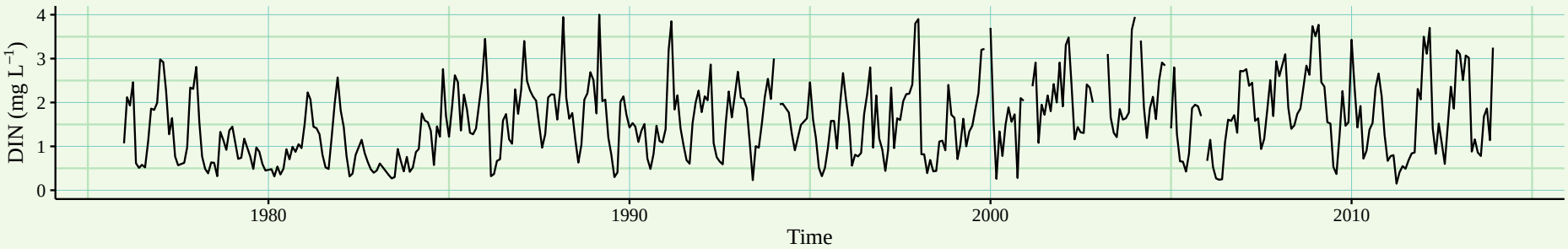

Models should describe components to evaluate effects

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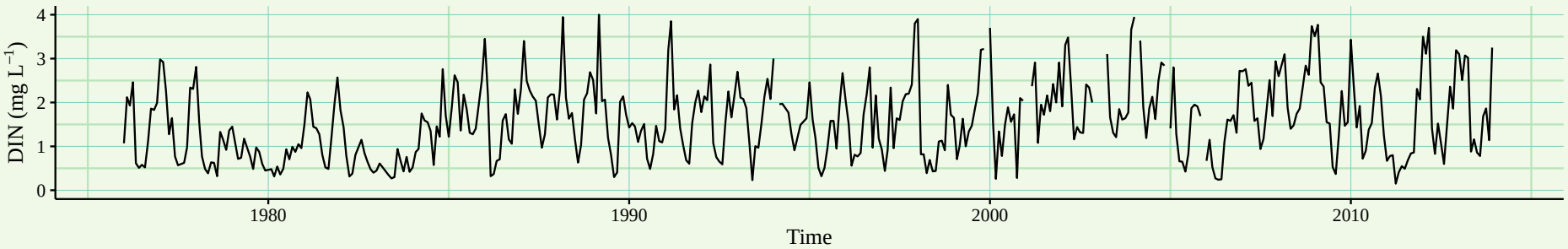

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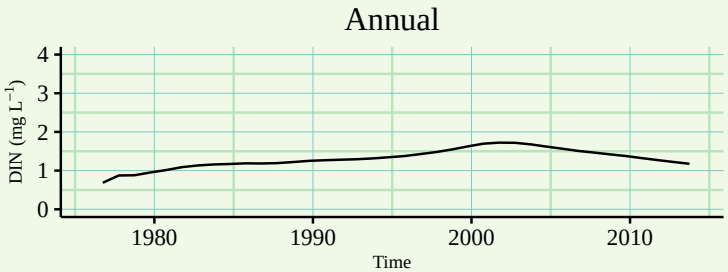

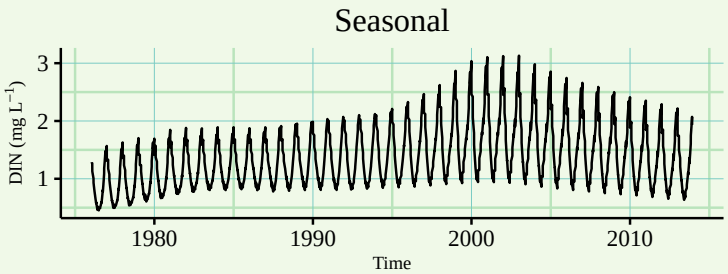

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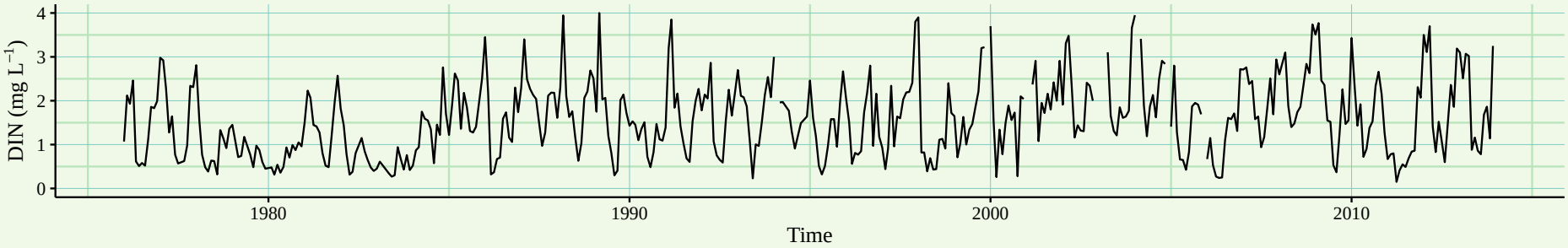

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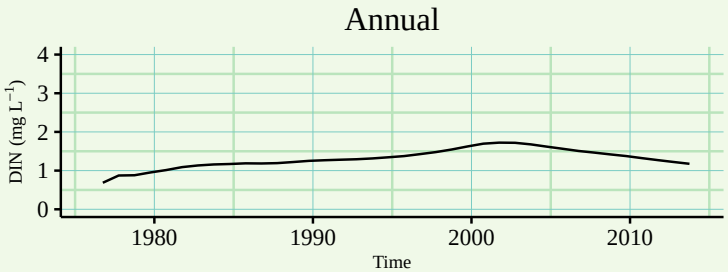

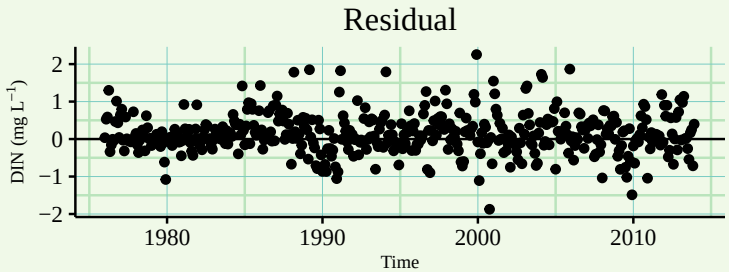

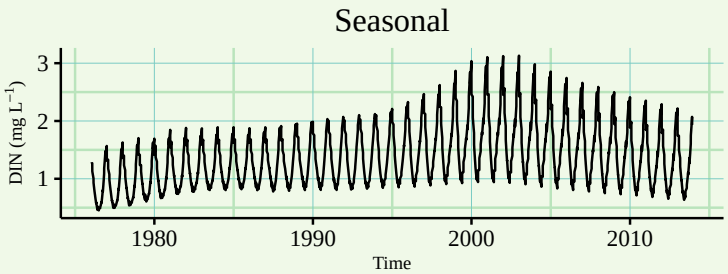

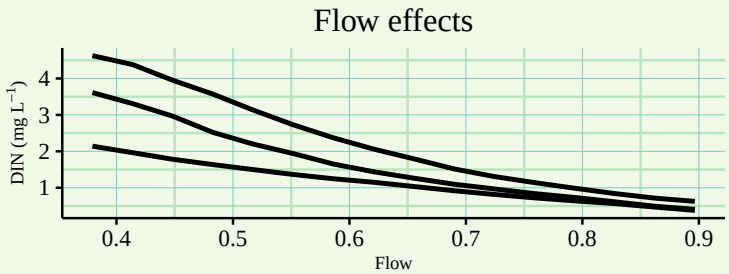

Model theory and background

WRTDS adaptation for tidal waters

Problem: Response endpoints of eutrophication vary naturally over time and with discharge or tidal patterns

Solution: Apply a model that accounts for changes in relationships between drivers of pollution over time [Beck et al., 2018]

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Adaptation: Applied to Tampa Bay [Beck and Hagy III, 2015], further validated/compared in Patuxent Estuary
[Beck and Murphy, 2017]

Model theory and background

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How does weighted regression work?

$$\ln(N) = \beta_0 + \beta_1 t + \beta_2 Sal + \beta_3 \sin(2\pi t) + \beta_4 \cos(2\pi t)$$

N: nitrogen (or other response endpoint)
t: time
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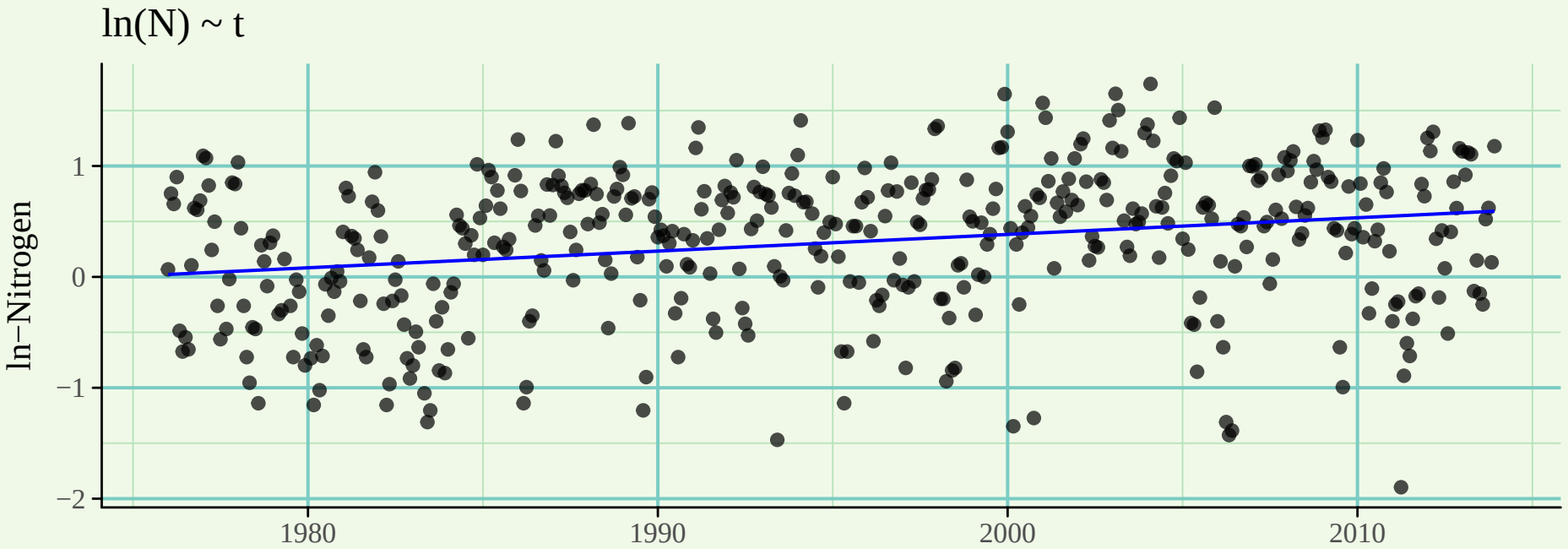

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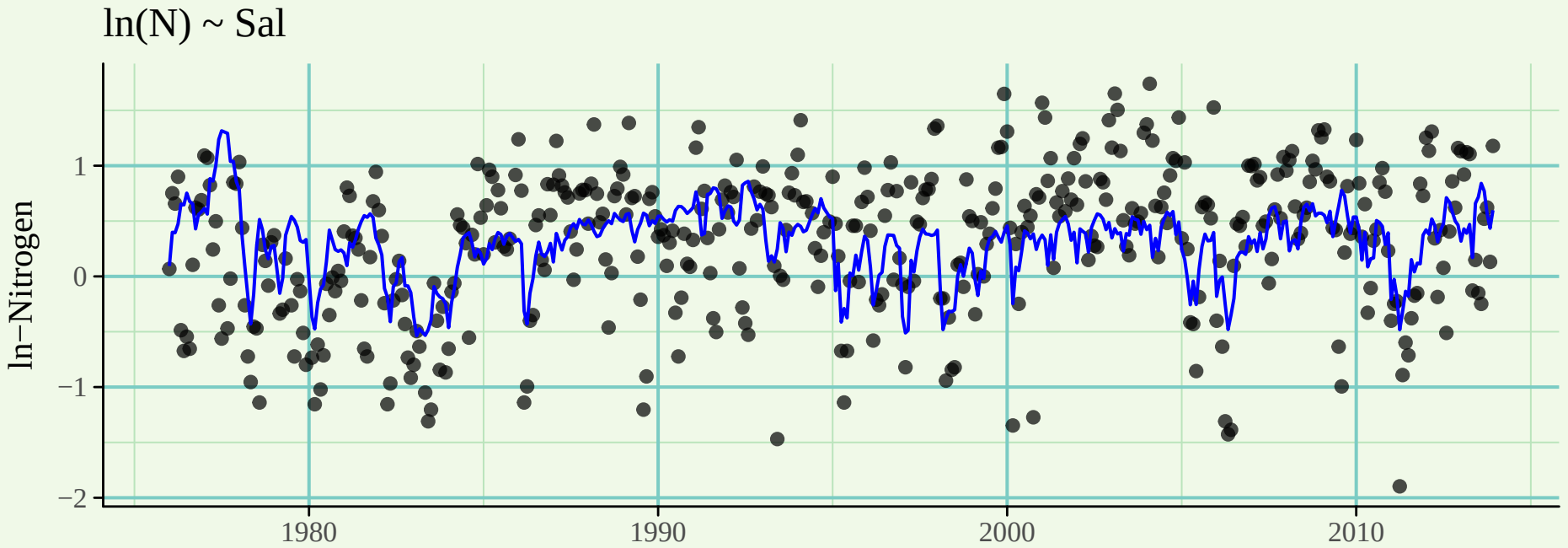

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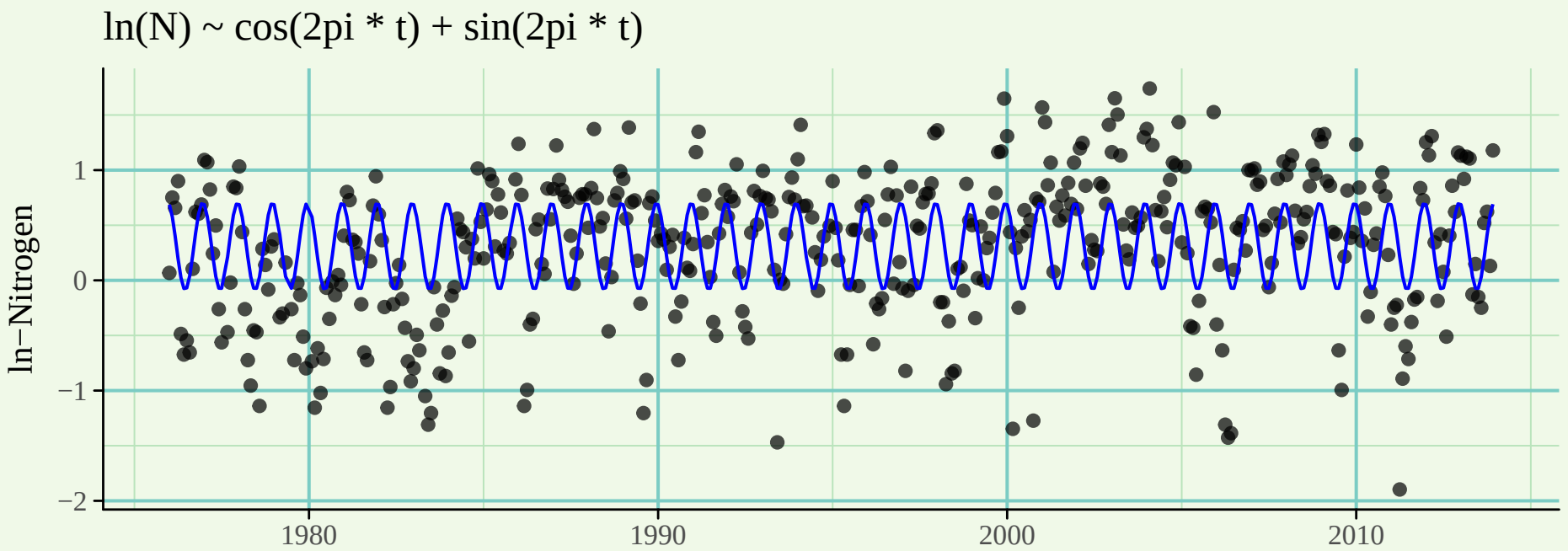

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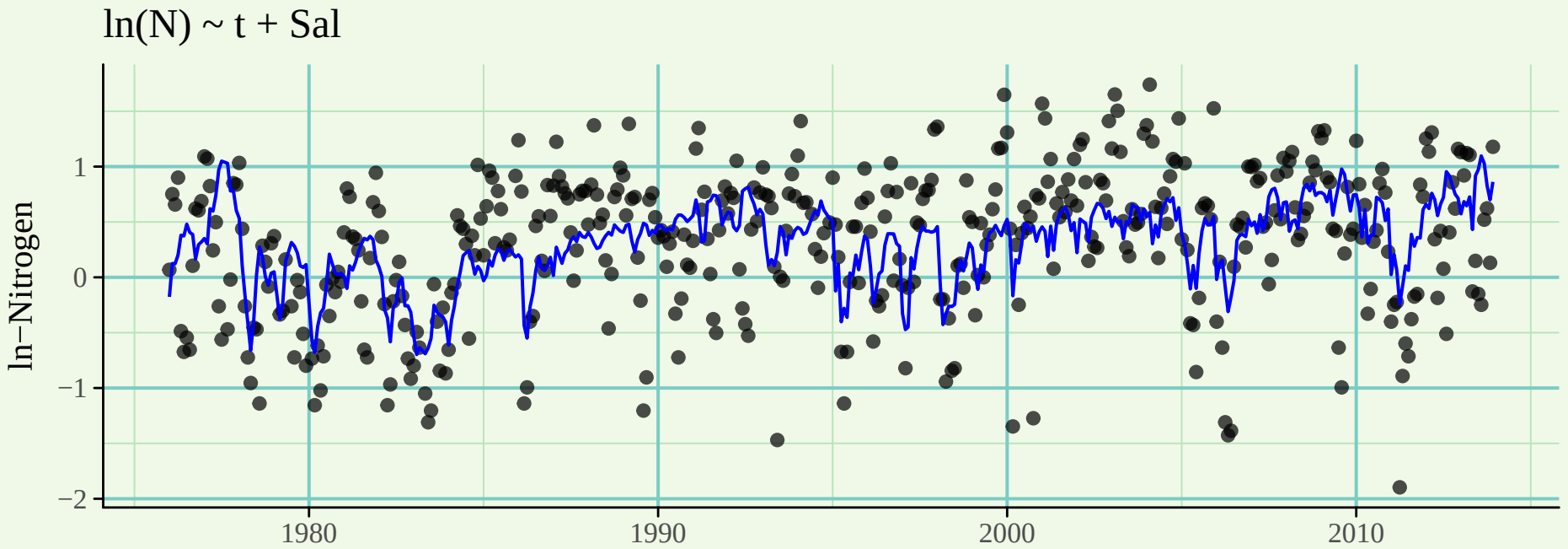

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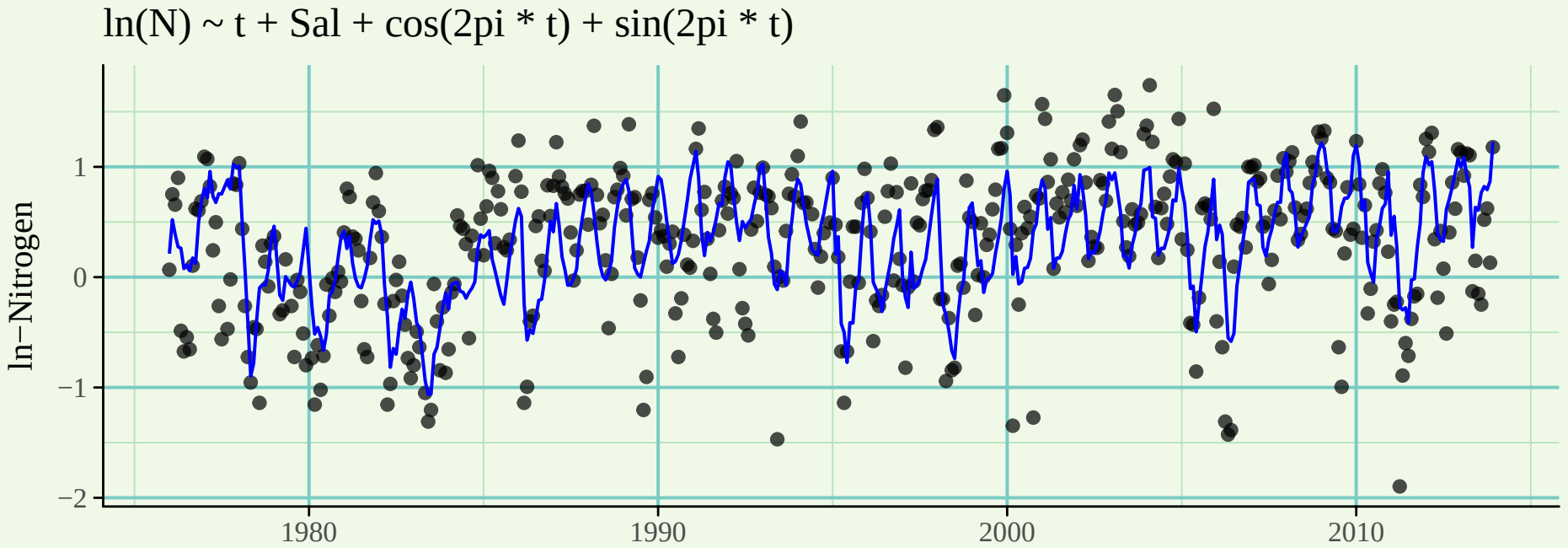

Model theory and background

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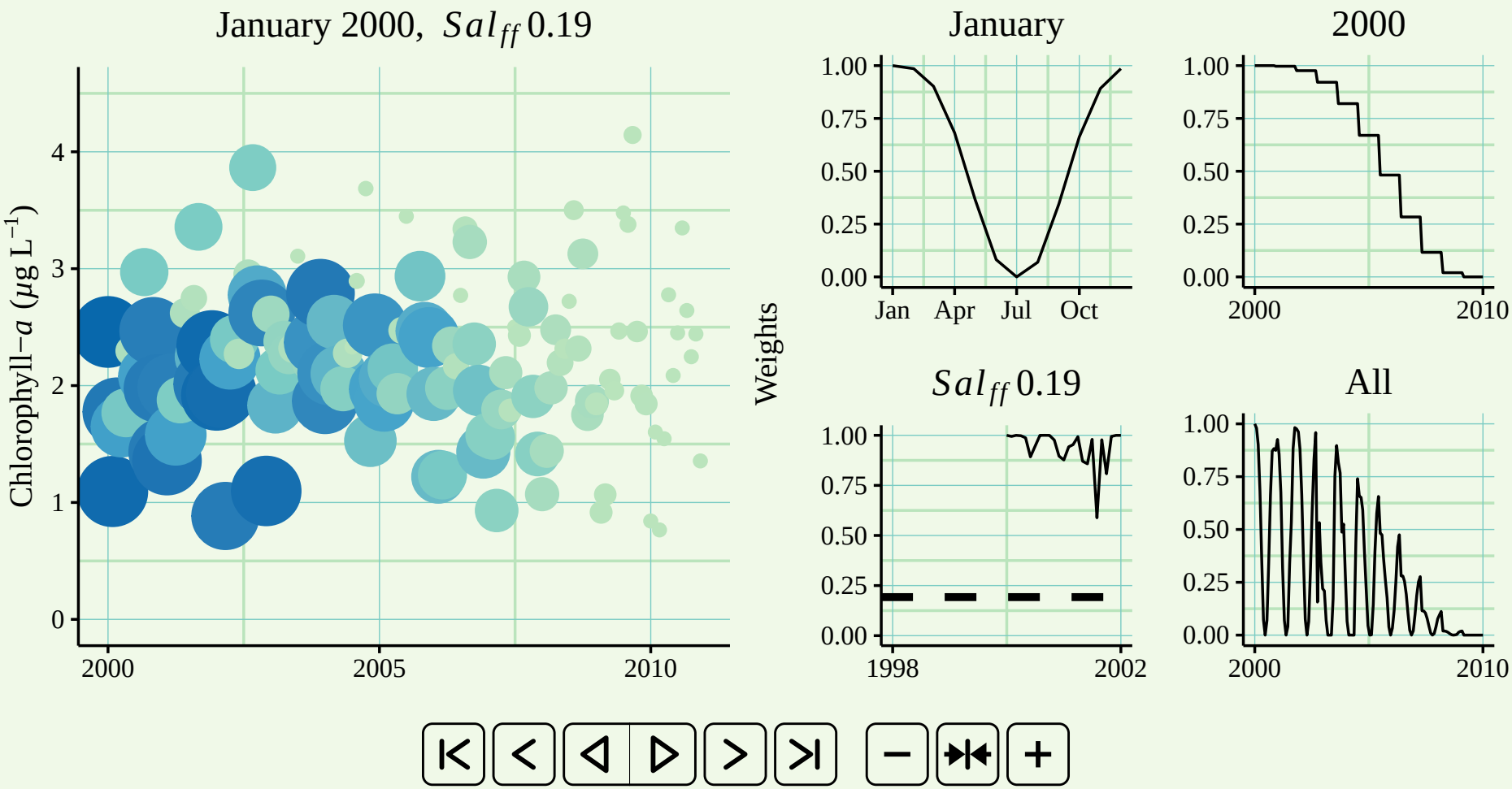

Model theory and background

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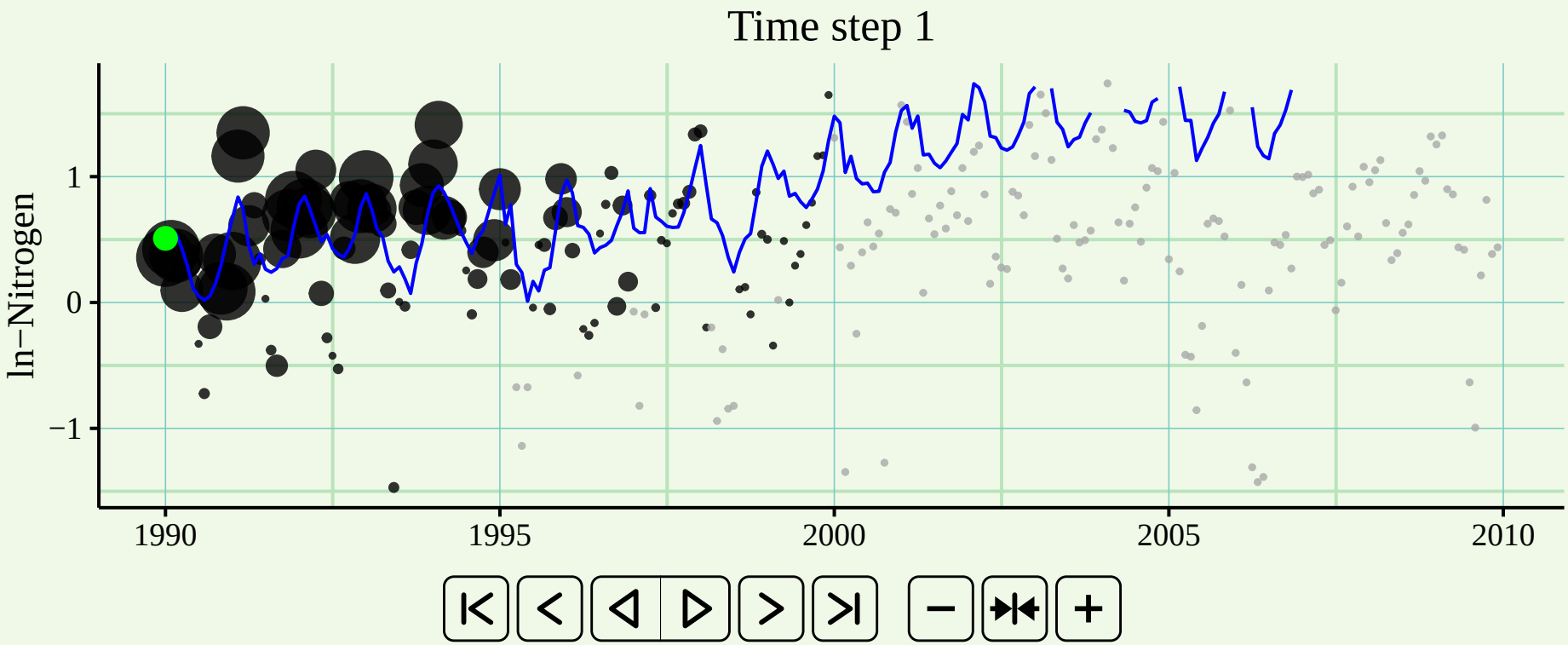
Points: observed time series (black are weighted, grey is zero weight)
Green point: observation at the center of the regression
Blue line: Global model with weights specific to the window
Red line: Accumulated WRTDS model



Application to Delta

- Nine stations (three Suisun, three middle, three delta)
- Three analytes (DIN, ammonium, nitrite/nitrate), two flow records
- Four decades of data, 1976-2013

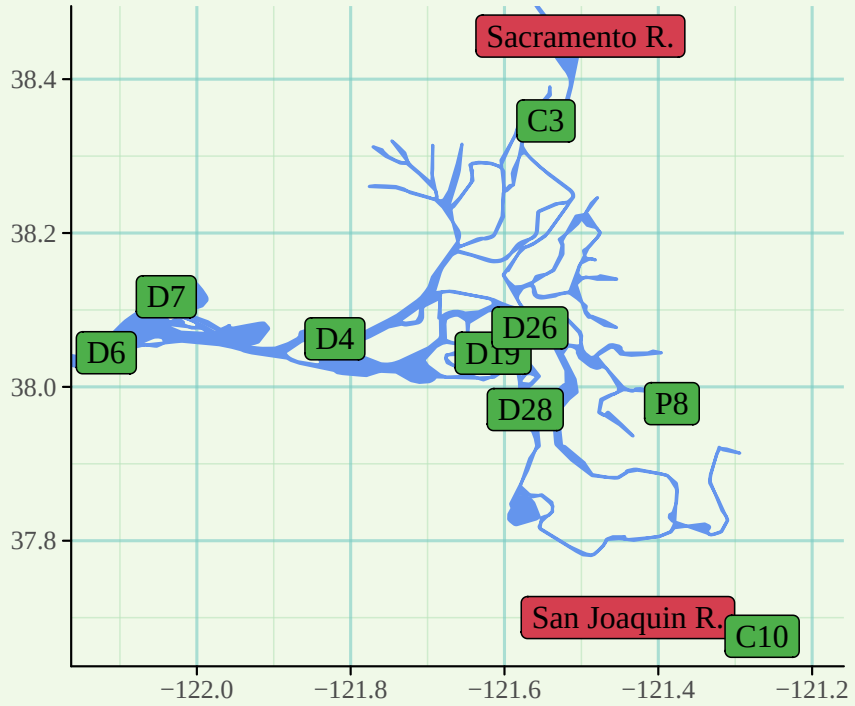
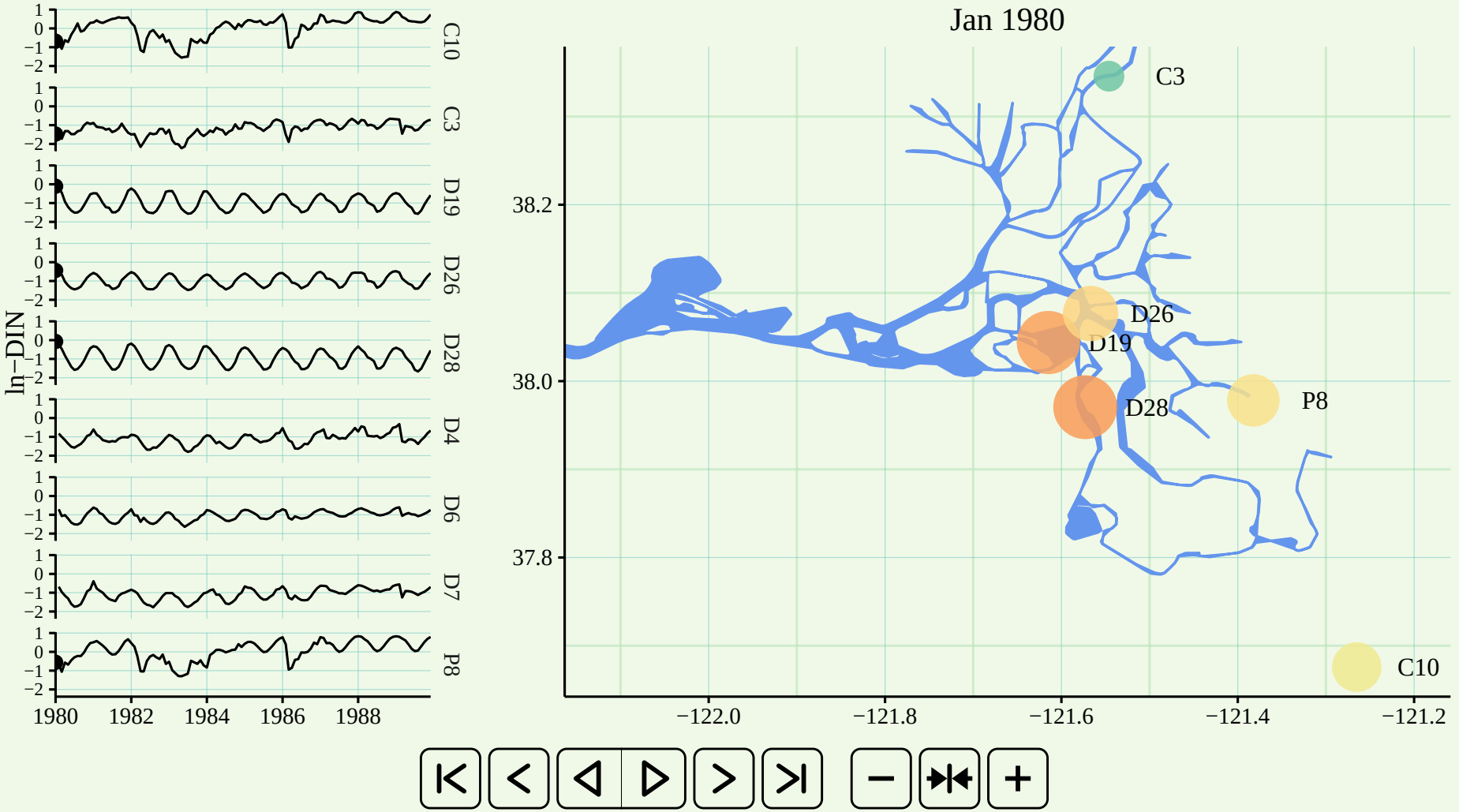


Figure: Stations (green) and flow estimates (red) modelled with WRTDS

Trends over time

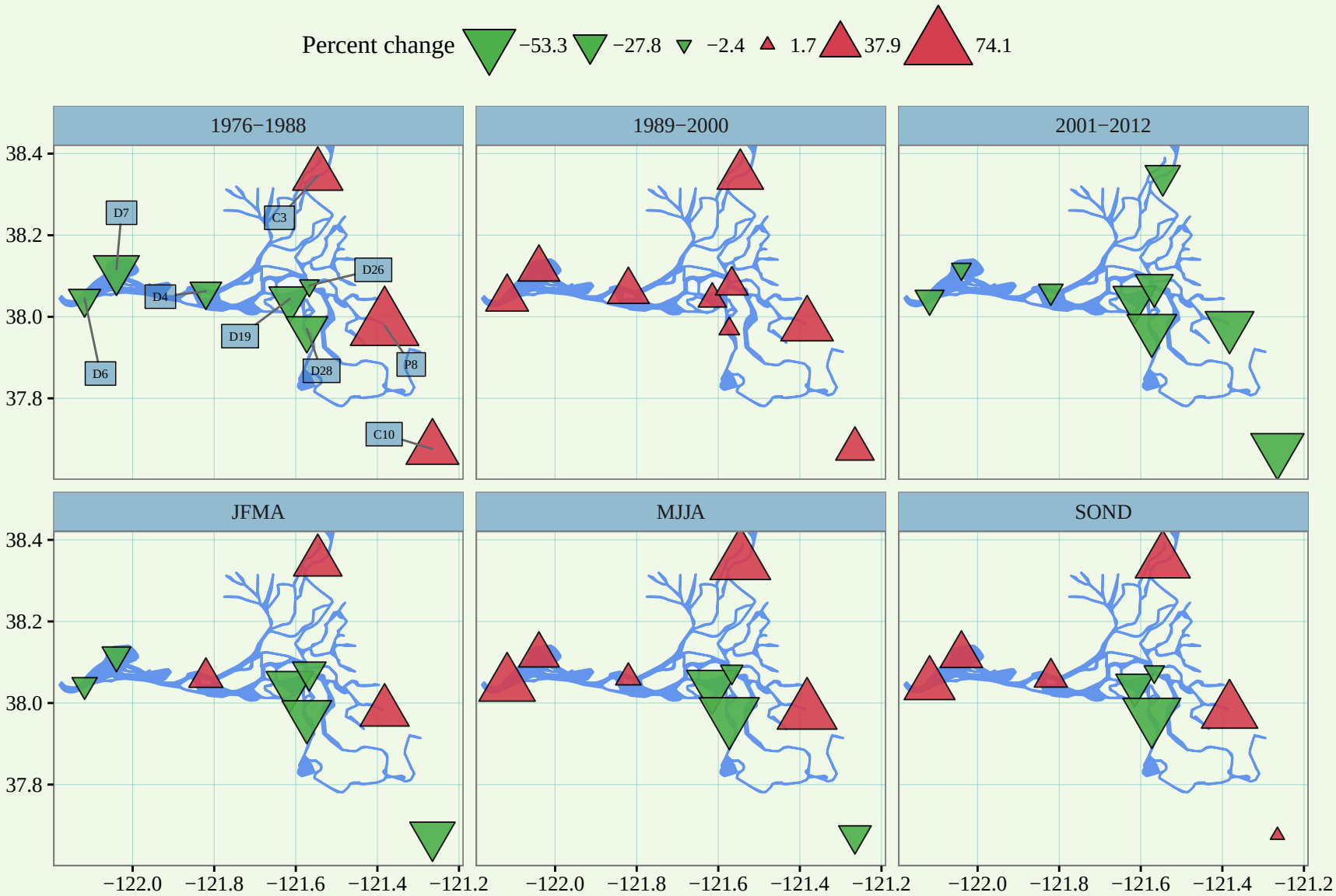
Nitrogen dynamics in the Delta

Predicted DIN trends, 1980-1990



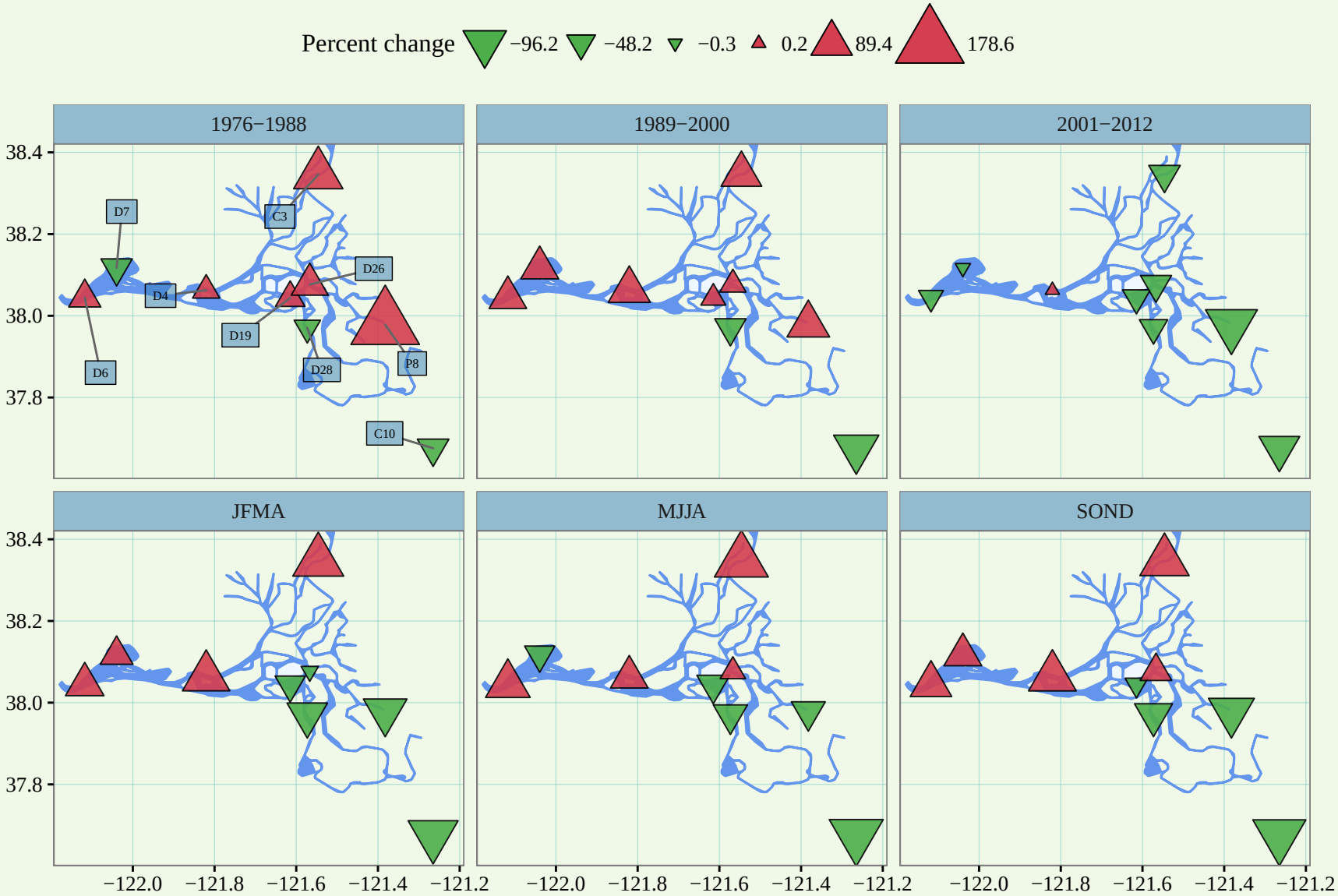
Trends over time

Nitrogen dynamics in the Delta - DIN



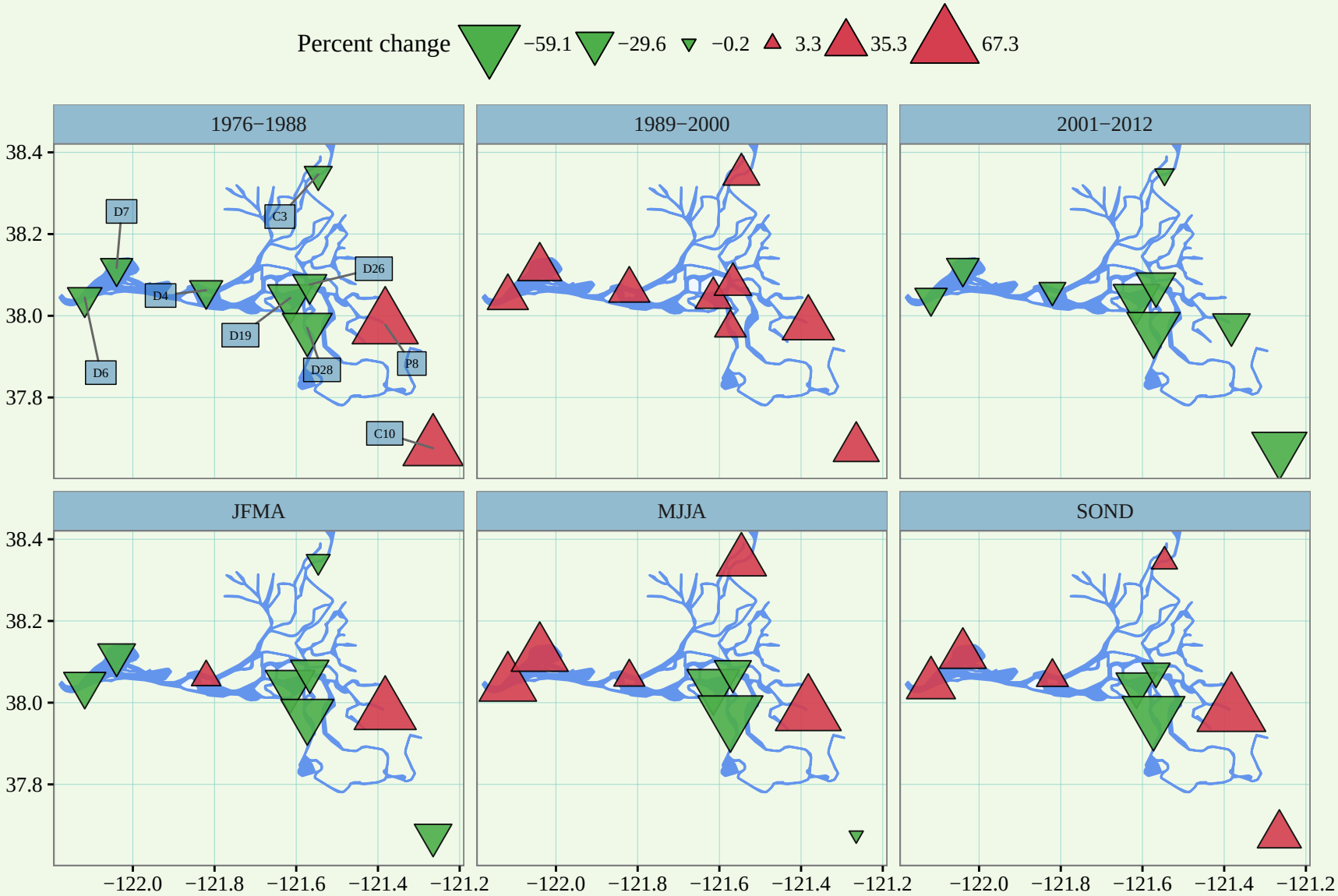
Trends over time

Nitrogen dynamics in the Delta - ammonium

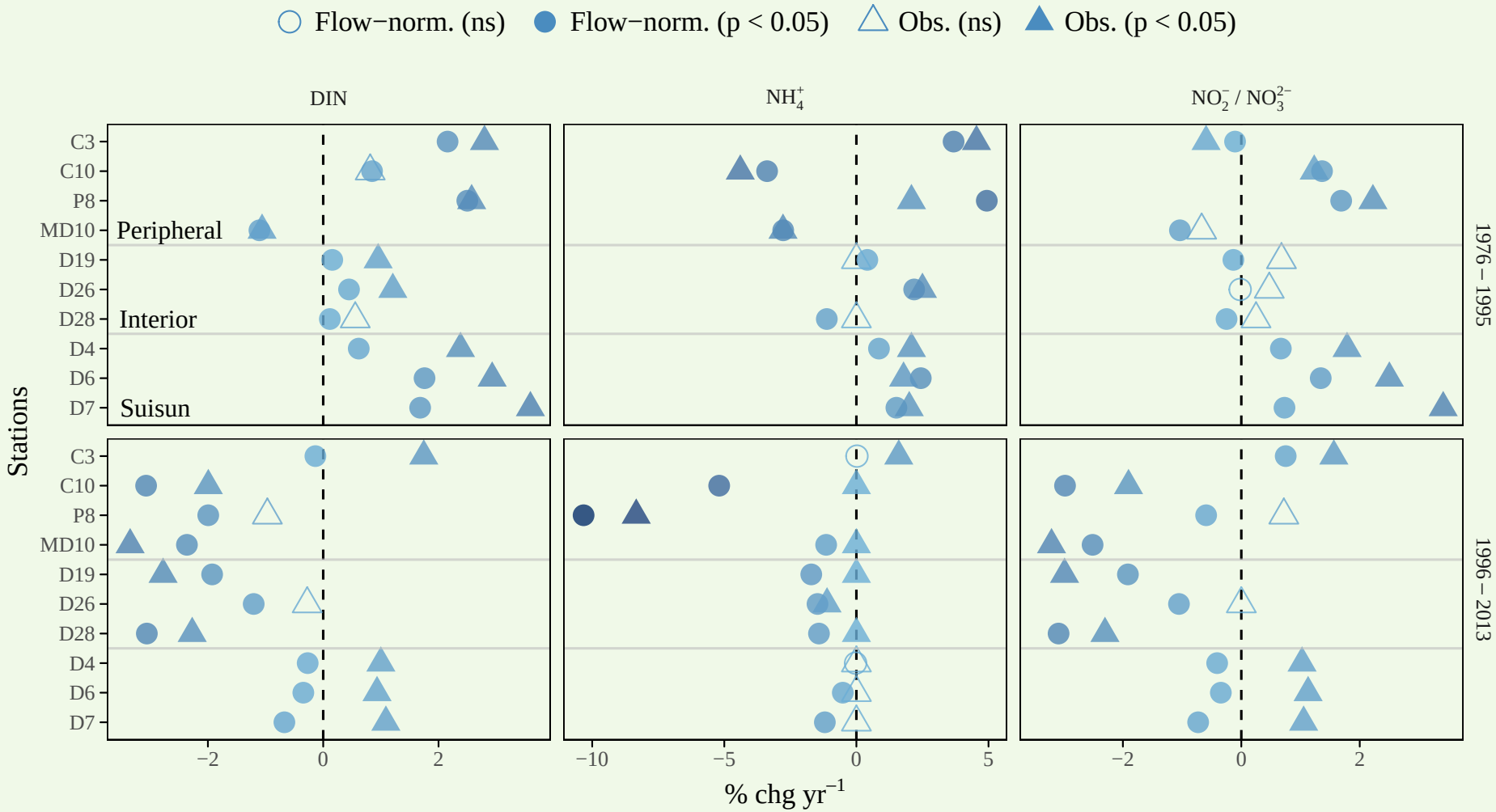


Trends over time

Nitrogen dynamics in the Delta - nitrite/nitate



Better description of nutrient endpoints can change conclusions

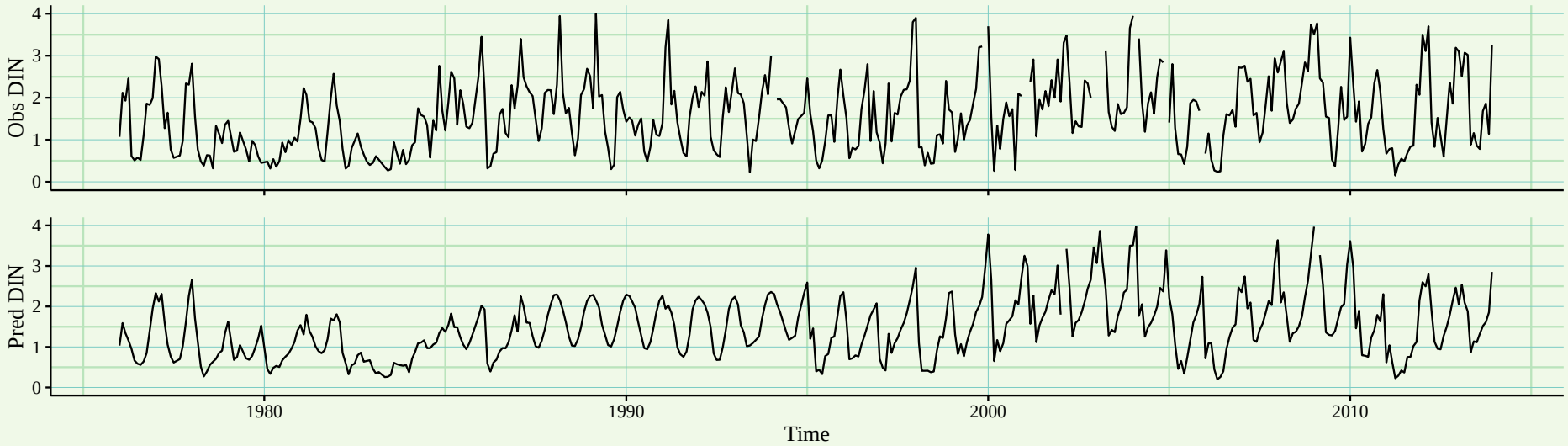


Trends over time

Nitrogen dynamics in the Delta - nitrite/nitate

The ***WRTDS*** approach lets us model historical trends in relation to ***time***, ***discharge***, and ***season***

Predicted trends follow observed... how can we leverage the results to understand drivers of environmental change?



Selected case study

Effects of wastewater treatment upgrades

How can model information be linked to causation?

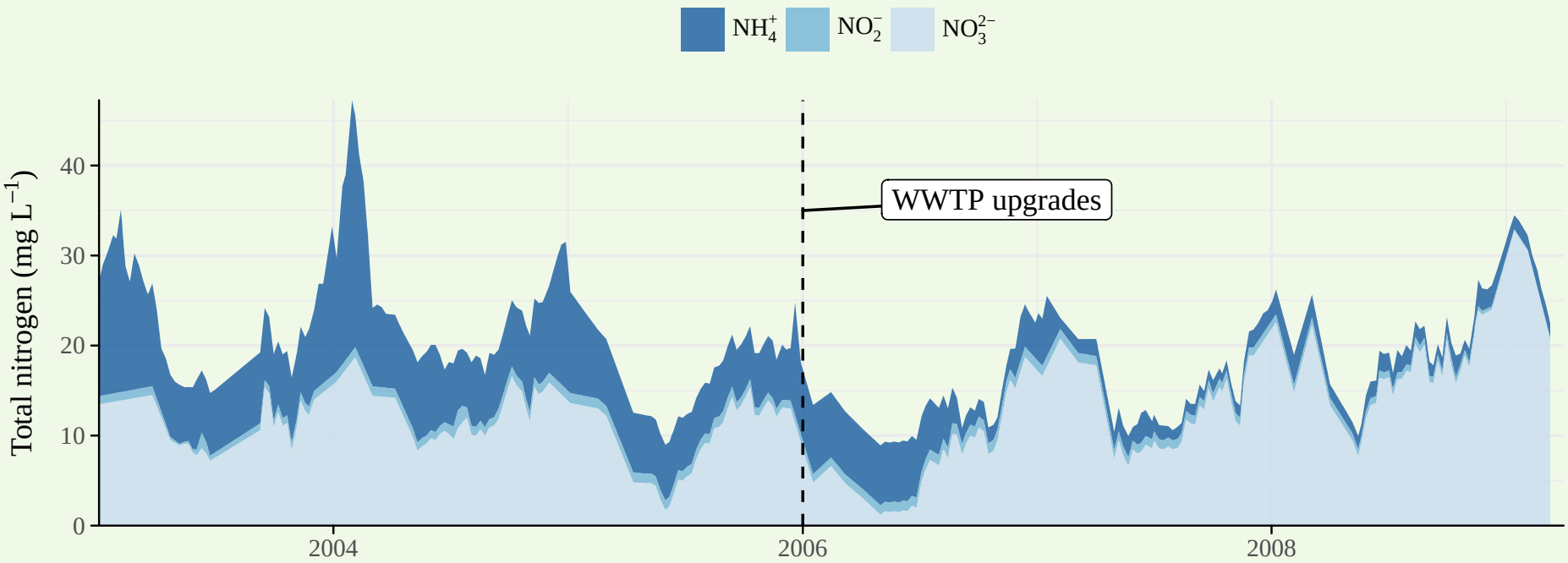


Figure: Nitrogen concentration measurements (mg L^{-1}) from the City of Stockton Wastewater Treatment Plant, San Joaquin County. Wastewater discharge requirements were implemented in 2006 for nitrification/denitrification and tertiary filtration to convert ammonium to nitrate.

Selected case studies

Effects of wastewater treatment upgrades

Hypothesis: Response of nutrient concentrations at station P8 is linked to upstream WWTP upgrades

We should be able to ***predict***:

- A flow-normalized annual trend concurrent with WWTP upgrades
- Variation in nitrogen species response depending on change in load outputs

Selected case studies

Effects of wastewater treatment upgrades

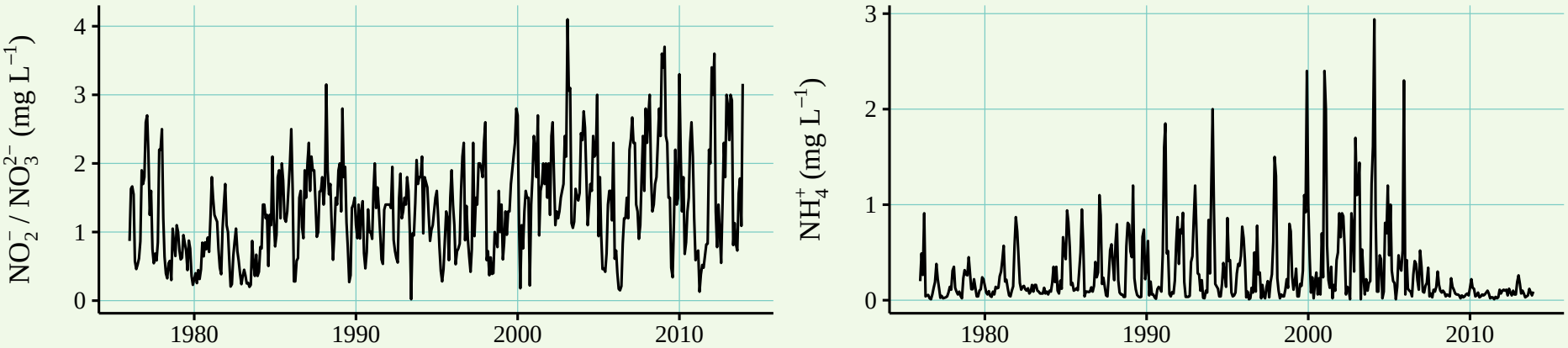


Figure: Observed nitrogen time series at P8

Selected case studies

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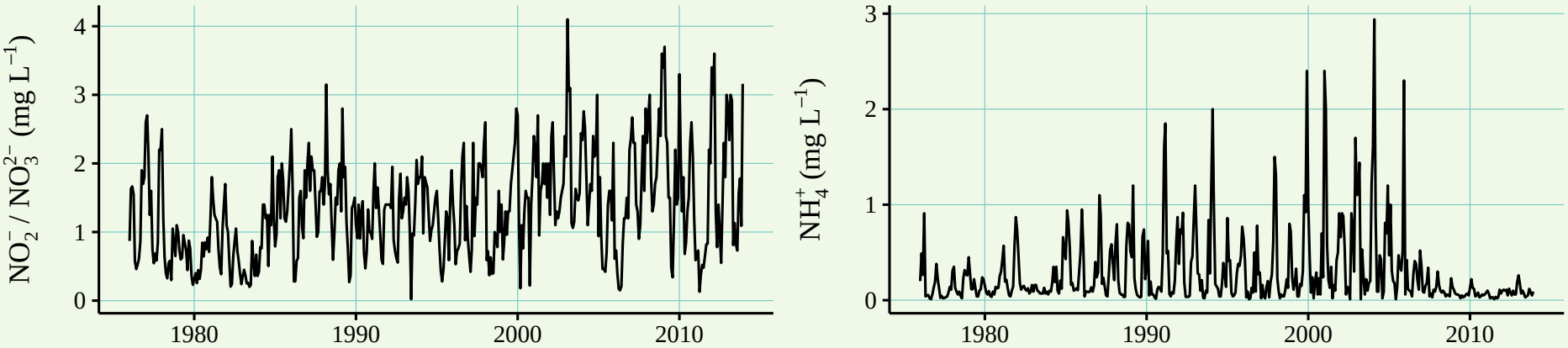

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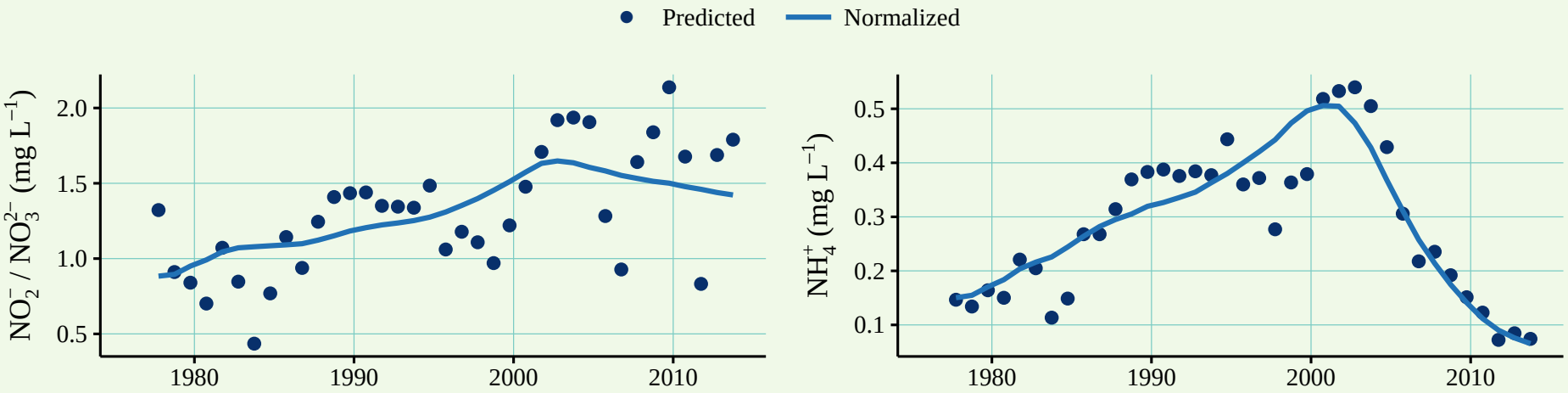

Figure: Annual predicted and flow-normalized nitrogen from WRTDS.

Selected case studies

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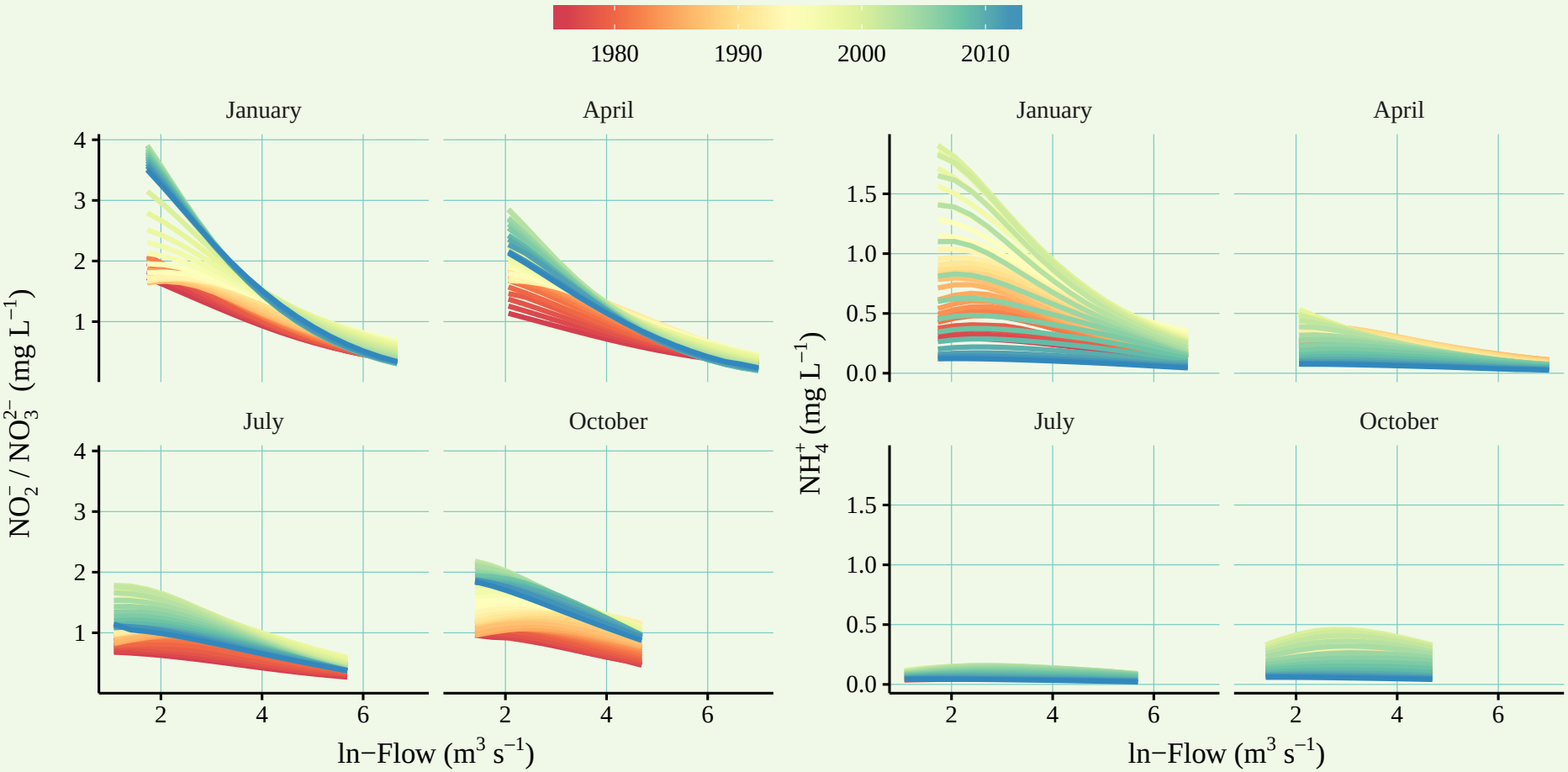


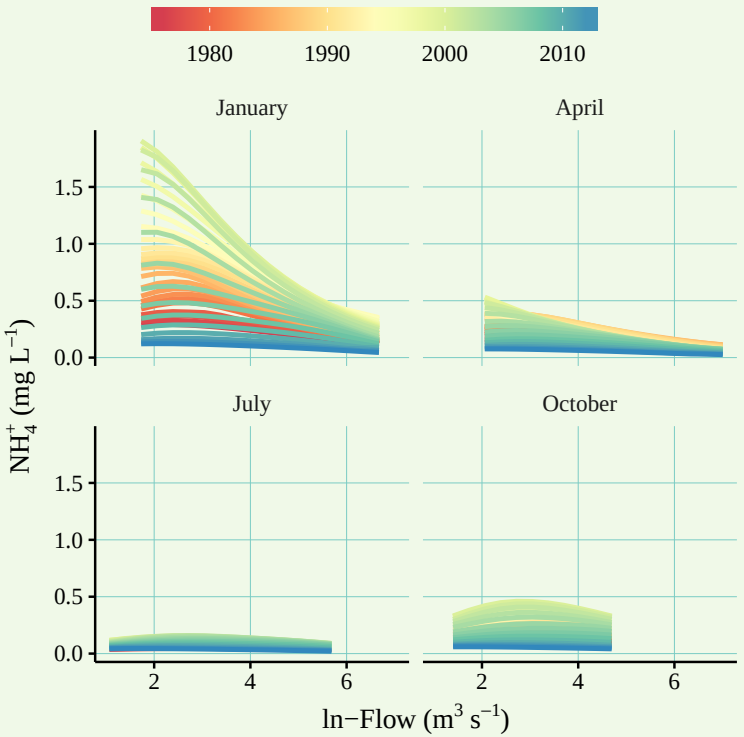
Figure: Nitrogen relationships with flow over time at P8.

Selected case studies

Effects of wastewater treatment upgrades

Results at P8 were linked to WWTP upgrades:

- Flow-normalized changes in ammonium, also nitrite/nitrate
- Ammonium reductions occurred in winter
- Largest response of ammonium at low flow... but not in summer



Conclusions

Lessons for monitoring and future work

Monitoring data are not particularly telling...
...so we use models or other methods to ***decompose*** the observations

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But we need to communicate these results to the management community and other decision makers

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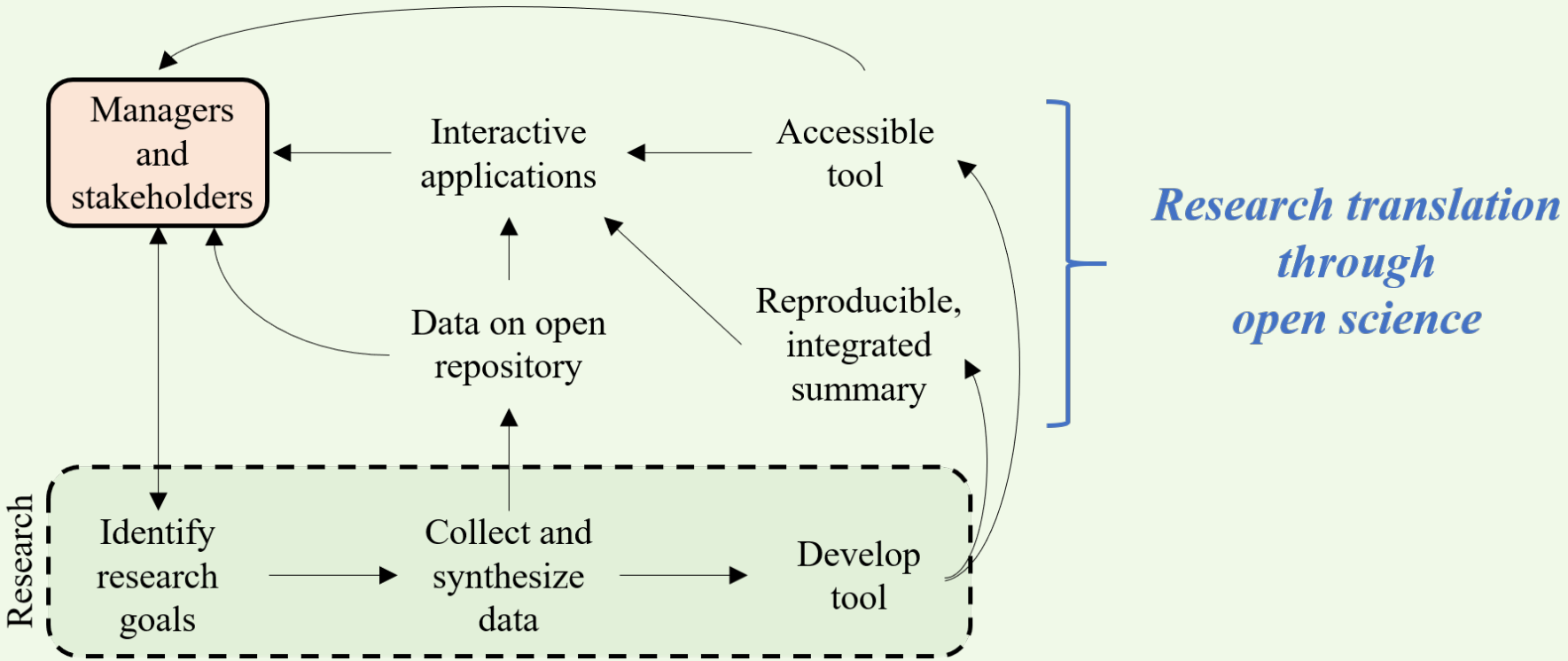
...so we use models or other methods to ***decompose*** the observations

But we need to communicate these results to the management community and other decision makers

> "Don't give me another 500-page report, I won't read t."
>
> — Overheard at recent meeting

An Open Science paradigm

Bridge the research-management divide



An Open Science paradigm

Bridge the research-management divide

Make your methods accessible!

https://cran.r-project.org/web/packages/WRTDStidal/index.html

WRTDStidal: Weighted Regression for Water Quality Evaluation in Tidal Waters

An adaptation for estuaries (tidal waters) of weighted regression on time, discharge, and season to evaluate trends in water quality time series.

Version:	1.1.1
Depends:	R (≥ 3.1.2), ggplot2
Imports:	caret, dplyr, fields, foreach, forecast, gridExtra, lubridate, purrr, quantreg, RColorBrewer, survival, tidyr
Suggests:	doParallel, grDevices, magrittr
Published:	2018-07-16
Author:	Marcus W. Beck [aut, cre]
Maintainer:	Marcus W. Beck <marcusb at sccwrp.org>
BugReports:	https://github.com/fawda123/wtreg_for_estuaries/issues
License:	CC0
NeedsCompilation:	no
In views:	Hydrology
CRAN checks:	WRTDStidal results

Downloads:

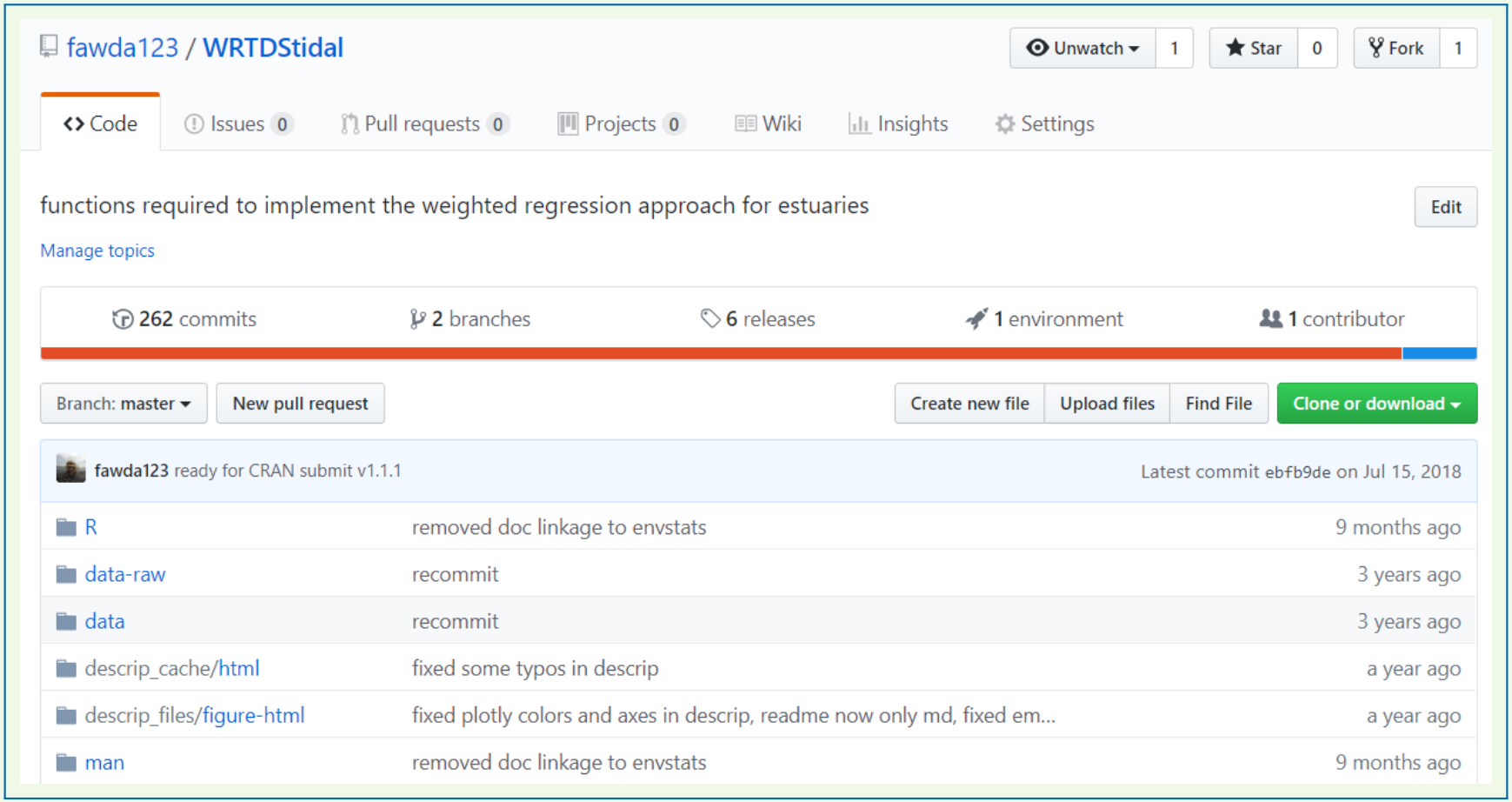
Reference manual:	WRTDStidal.pdf
Package source:	WRTDStidal_1.1.1.tar.gz
Windows binaries:	r-devel: WRTDStidal_1.1.1.zip, r-release: WRTDStidal_1.1.1.zip, r-oldrel: WRTDStidal_1.1.1.zip
OS X binaries:	r-release: WRTDStidal_1.1.1.tgz, r-oldrel: WRTDStidal_1.1.1.tgz
Old sources:	WRTDStidal archive

An Open Science paradigm

Bridge the research-management divide

Make your methods transparent!

`https://github.com/fawda123/WRTDStidal`



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Communicate your results!

https://beckmw.shinyapps.io/sf_trends/

An Open Science paradigm

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GAM evaluation - SF South Bay

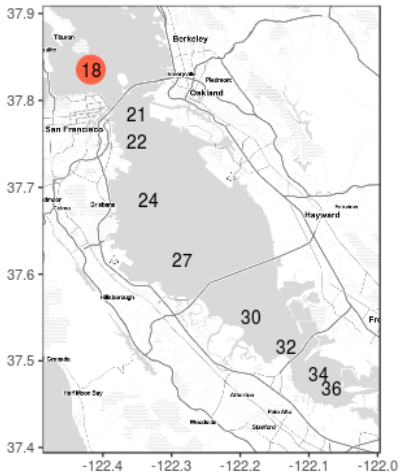
Exploratory plots

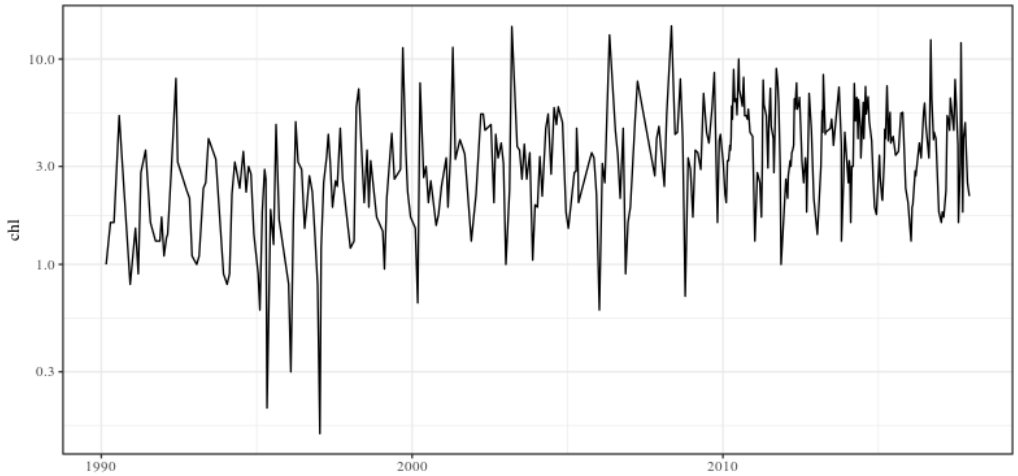
The following plots show the raw data for all monitoring stations and parameters in South Bay, 1990 - 2017. Select the parameter, plot type (total time series, by year, or by month), and variable transformation. The year and month plots are aggregated boxplots of all observations at a station for each selected time period. The variable transformation can be used to show the observations in arithmetic or logarithmic space.

Choose station: 18

Choose plot type: tot

Log-space: TRUE





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Lessons for data scientists

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...it is not an end in itself

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How do you use your products to reach those that need it?

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...it is not an end in itself

How do you use your products to reach those that need it?

- Use relevant methods within the scope of your question
- Strive for transparency, reproducibility, and accessibility
- Use open source tools with vibrant user communities
- Be a champion within your institution to promote open science

Acknowledgments and contact info:

Research staff and employees at USEPA Gulf Ecology Division, San Francisco Estuary Institute, Southern California Coastal Water Research Project

David Senn, Thomas Jabusch, Phil Bresnahan, Emily Novick

marcusb@sccwrp.org

Phone (SCCWRP): 7147553217

Links:

This presentation: `https://github.com/fawda123/sfei_pres`
Shiny app: `https://beckmw.shinyapps.io/sf_trends/`
Detailed results: `http://fawda123.github.io/sf_trends/README`
Manuscript: `http://fawda123.github.io/sftrends_manu`

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