EGU General Assembly 2020

Predicting spatio-temporal variability in river water quality using Bayesian Hierarchical Models

Danlu Guo[1], Anna Lintern[2], Angus Webb[1], Dongryeol Ryu[1], Ulrike Bende-Michl[3], Shuci Liu[1], Andrew Western[1]

danlu.guo@unimelb.edu.au

[1]Department of Infrastructure Engineering, The University of Melbourne, Parkville, VIC Australia

[2]Department of Civil Engineering, Monash University, Clayton, VIC Australia

[3]Bureau of Meteorology, Parkes, ACT Australia

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Australian Government Bureau of Meteorology

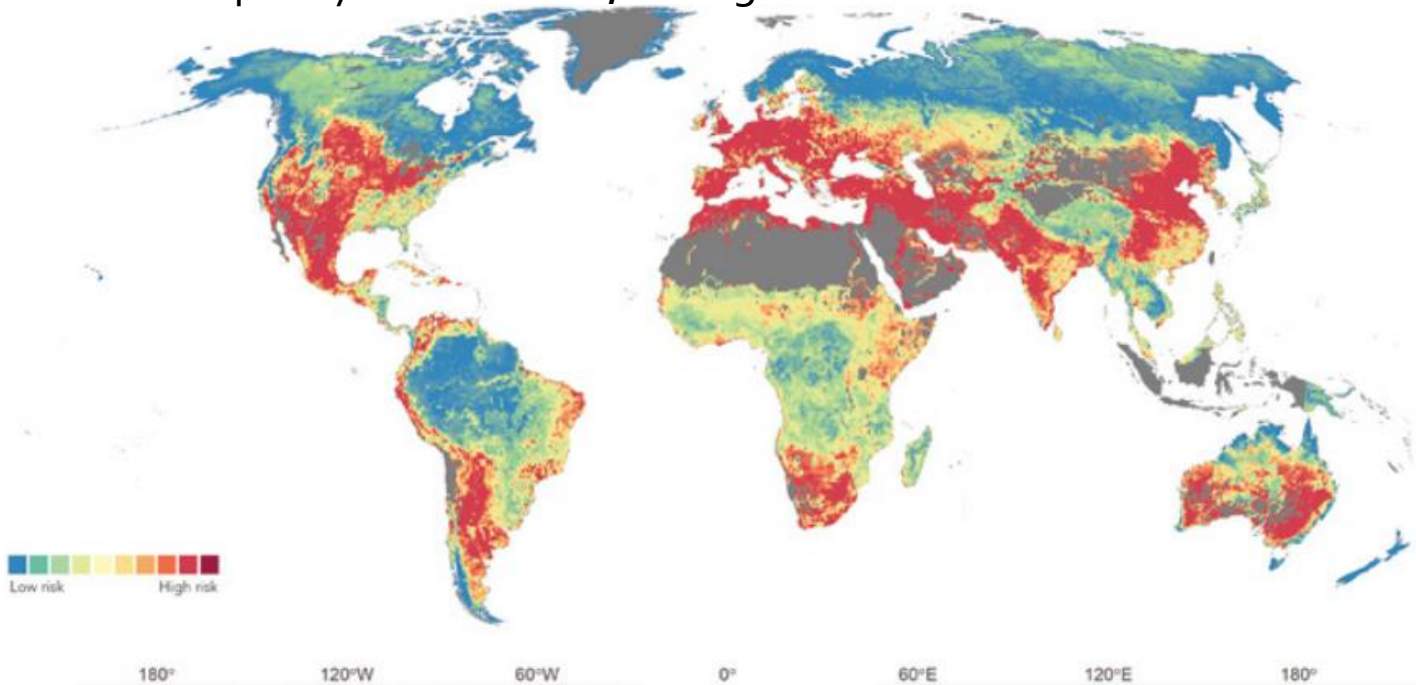
VICTORIA State Government | Environment, Land, Water and Planning

EPA VICTORIA | Environment Protection Authority Victoria

Queensland Government

Surface water quality deterioration is a global problem, which has large socio-economic and ecological impacts

Global water quality risks of BOD, Nitrogen and EC

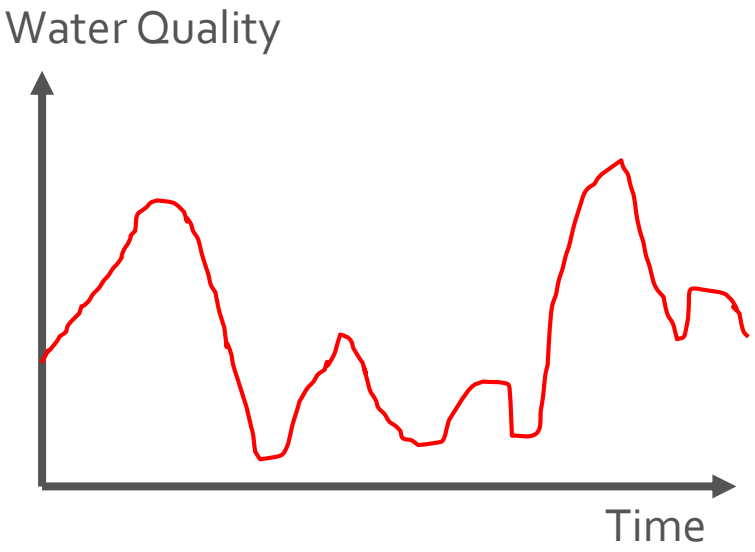


Eutrophication at Lake Tai,
the 3rd largest freshwater lake in China

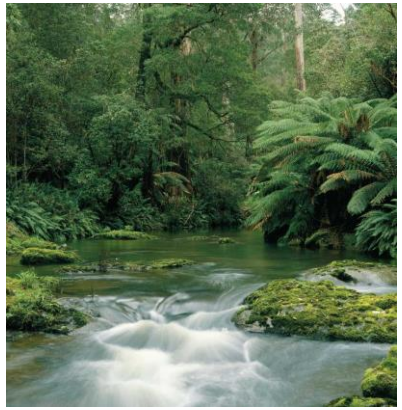
Corel bleaching at Great Barrier Reef,
Northern Australia

Stream water quality is highly variable over both space and time

Variation over time



Variation over space



Low pollution

High pollution

3-year project aiming to improve understanding and modelling capacity of water quality variability

1. Understand the controls on spatio-temporal variability in stream water quality

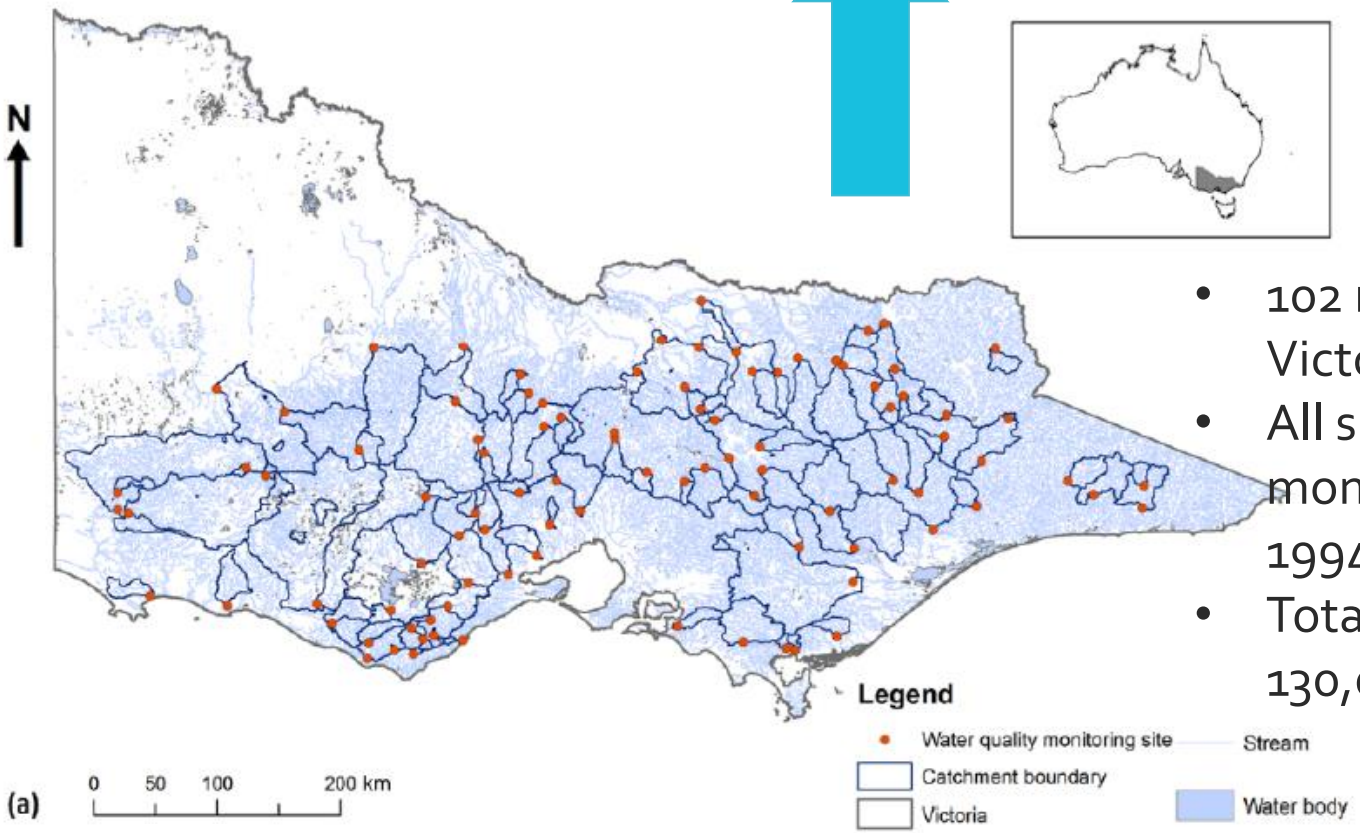
2. Develop a predictive model for future water quality assessment

Statistical (data-driven) modelling
+
Long-term large-scale monitoring data

3-year project aiming to improve understanding and modelling capacity of water quality variability

1. Understand the controls on spatio-temporal variability in stream water quality

2. Develop a predictive model for future water quality assessment



- 102 monitoring sites in Victoria, SE Australia
- All sites maintain monthly WQ data for 1994-2014 (21 years)
- Total catchment area > 130,000 km2

3-year project aiming to improve understanding and modelling capacity of water quality variability

1. Understand the controls on spatio-temporal variability in stream water quality

Overview

wires.wiley.com/water

Key factors influencing differences in stream water quality across space

A. Lintern,[1] J.A. Webb,[1] D. Ryu,[1] S. Liu,[1] U. Bende-Michl,[2] D. Waters,[3] P. Leahy,[4] P. Wilson[5] and A. W. Western[1]*

AGU100 ADVANCING EARTH AND SPACE SCIENCE

Water Resources Research

RESEARCH ARTICLE
10.1029/2017WR022172

Key Points:
- Human-influenced (land use) and natural catchment characteristics

What Are the Key Catchment Characteristics Affecting Spatial Differences in Riverine Water Quality?

A. Lintern[1,2], J. A. Webb[1], D. Ryu[1], S. Liu[1], D. Waters[3], P. Leahy[4], U. Bende-Michl[5], and A. W. Western[1]

AGU100 ADVANCING EARTH AND SPACE SCIENCE

Water Resources Research

RESEARCH ARTICLE
10.1029/2018WR023370

This article is a companion to Lintern et al. (2018), https://doi.org/10.1029/2017WR022172.

Key Factors Affecting Temporal Variability in Stream Water Quality

D. Guo[1], A. Lintern[1,2], J. A. Webb[1], D. Ryu[1], S. Liu[1], U. Bende-Michl[3], P. Leahy[4], P. Wilson[5], and A. W. Western[1]

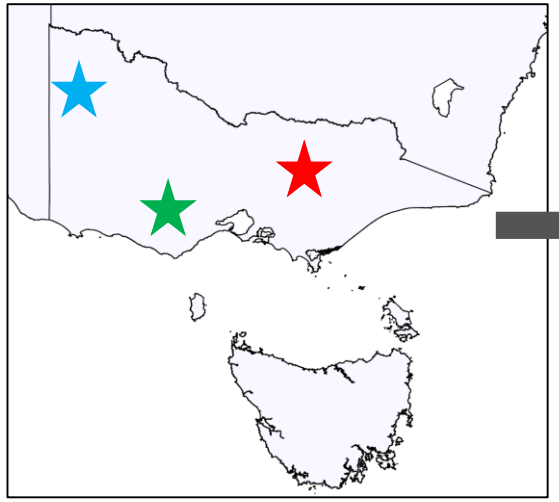
1. Understanding key controls for each variability component

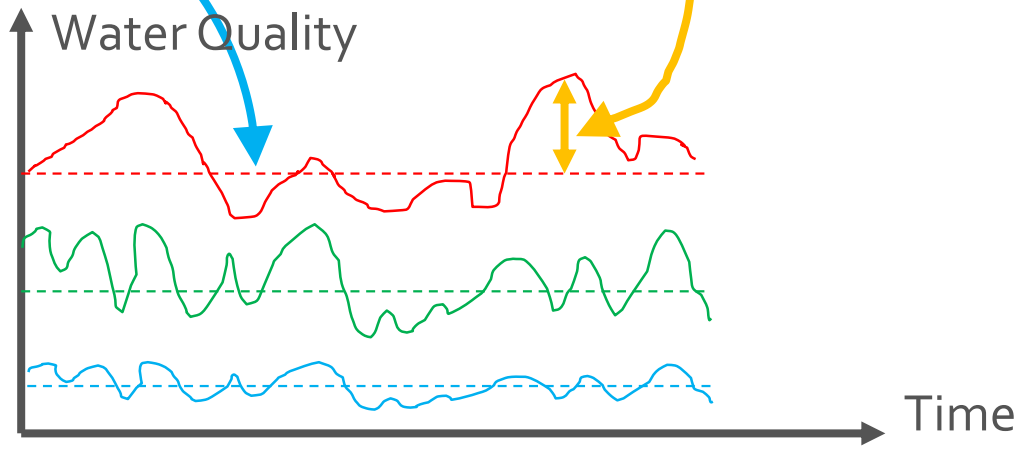
1. Understand the controls on spatio-temporal variability in stream water quality

$$WQ_{site,\ time} = meanWQ_{site} + shift\ from\ meanWQ_{site,\ time}$$

Between site (spatial) variation
= *f*(Land use, Climate, …)

Within site (temporal) variation
= *f*(Temperature, Streamflow, …)





1. Understanding key controls for each variability component

1. Understand the controls on spatio-temporal variability in stream water quality

$$TSS_{site,\ time} = meanTSS_{site} + shift\ from\ meanTSS_{site,\ time}$$

Between site (spatial) variation

Mean TSS site=
f(Hot month temp,
Vegetation cover,
Cropping, Elevation, % clay area)

Within site (temporal) variation

Shift TSS site,time=
f(Streamflow,
Water temperature,
Soil moisture)

2. Developing integrated spatio-temporal model

2. Develop a predictive model for future water quality assessment

$$TSS_{site,\ time} = meanTSS_{site} + shift\ from\ meanTSS_{site,\ time}$$

Between site (spatial) variation

Mean TSS site=
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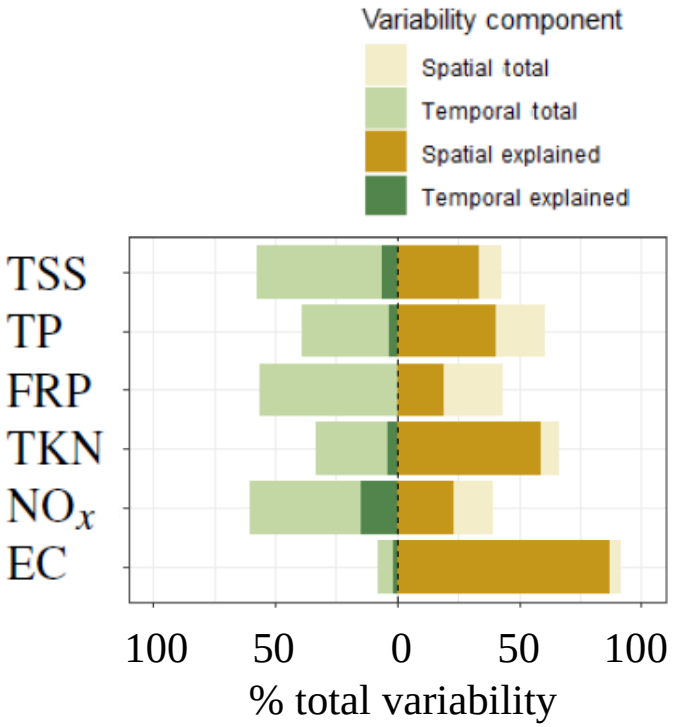
A data-based predictive model for spatiotemporal variability in stream water quality

Danlu Guo[1], Anna Lintern[1,2], J. Angus Webb[1], Dongryeol Ryu[1], Ulrike Bende-Michl[3], Shuci Liu[1], and Andrew William Western[1]

[1]Department of Infrastructure Engineering, The University of Melbourne, Parkville, VIC, Australia
[2]Department of Civil Engineering, Monash University, Clayton, VIC, Australia
[3]Bureau of Meteorology, Parkes, ACT, Australia

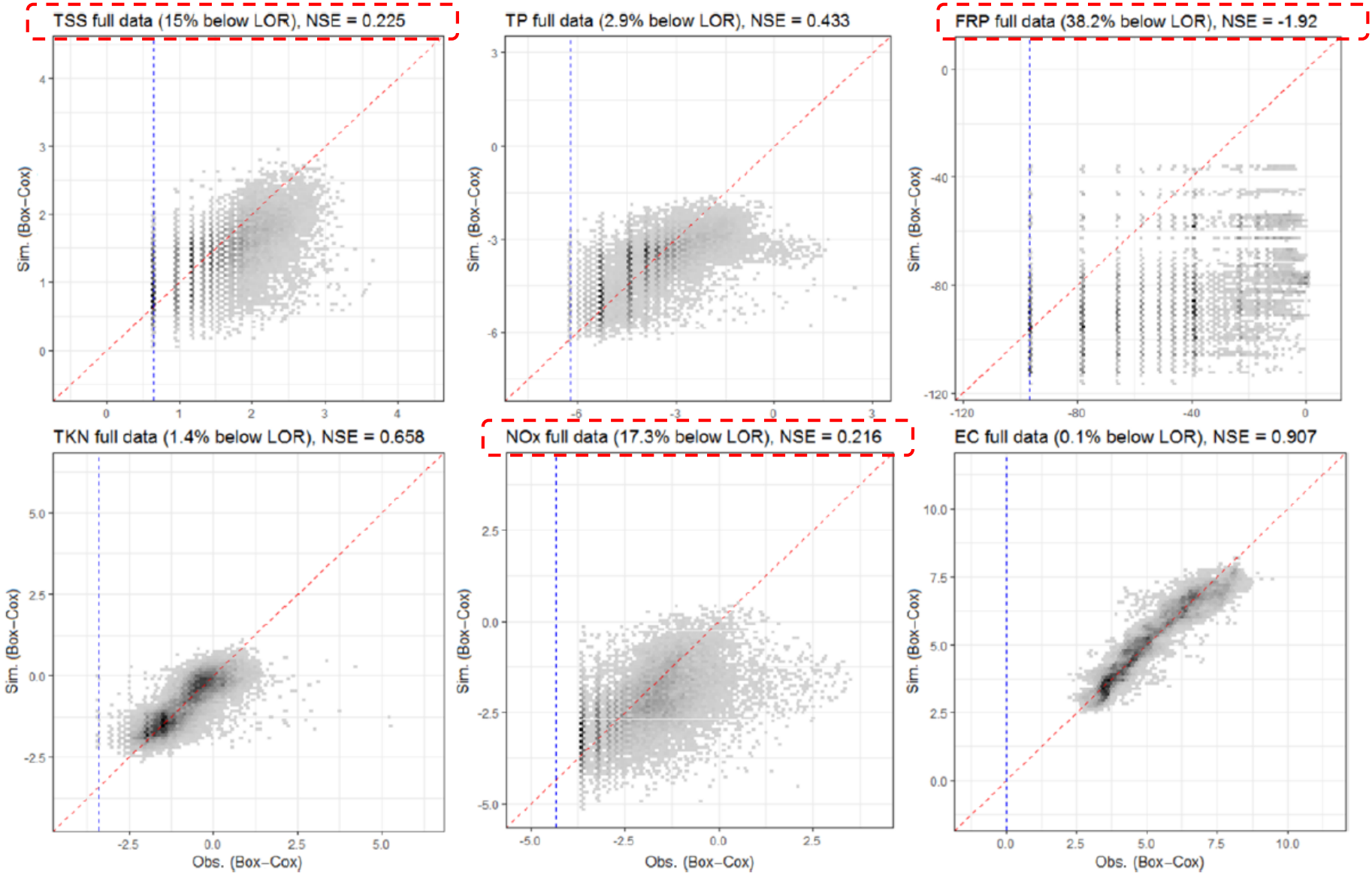
Apart from FRP, the model explains 38.2% (NOx) to 88.6% (EC) of the total spatiotemporal variability in water quality

Constituent	Above-DL records only	All records
TSS	0.225	0.397
TP	0.433	0.445
FRP	−1.920	0.199
TKN	0.658	0.630
NO_x	0.216	0.382
EC	0.907	0.886

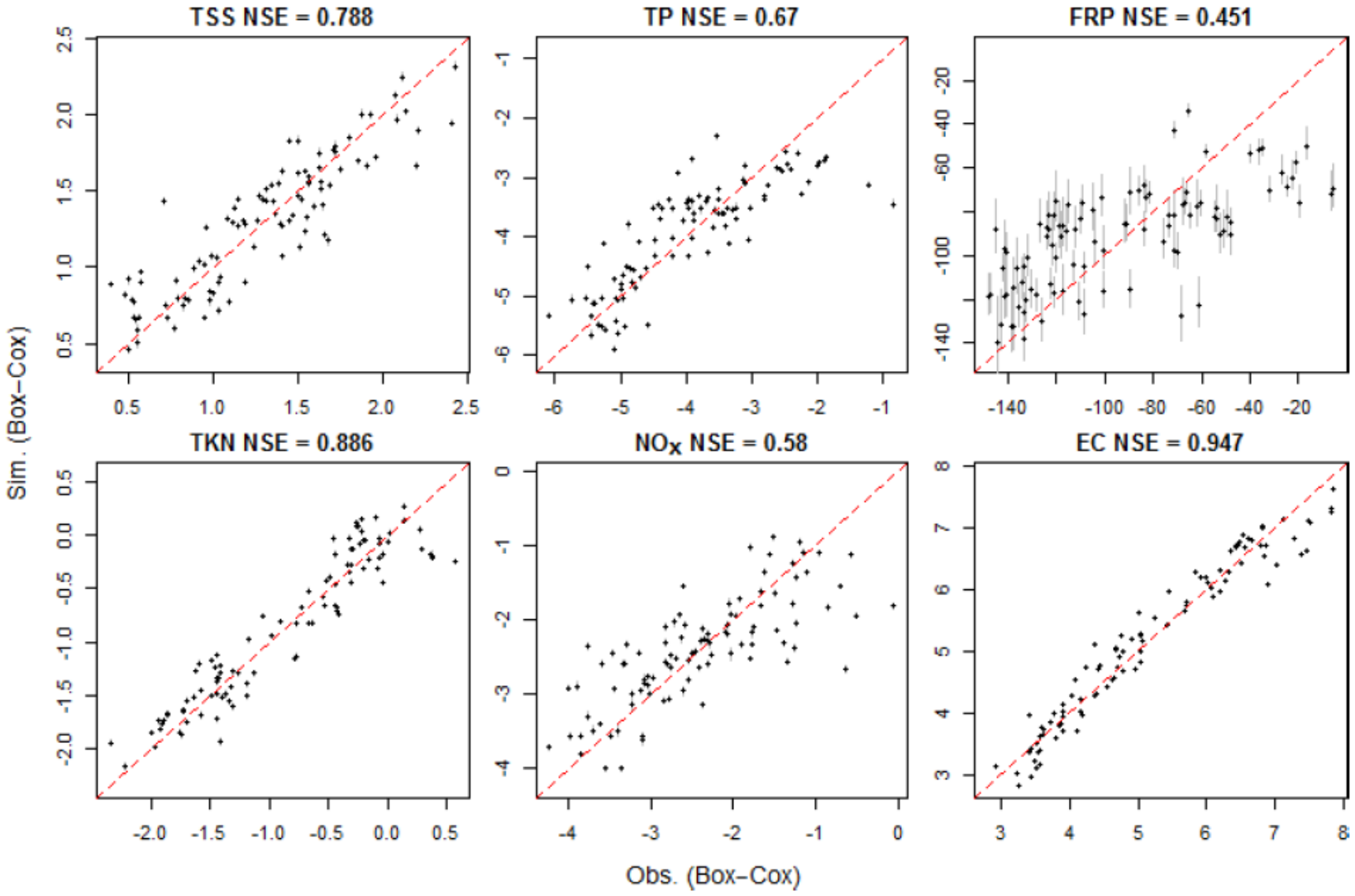


- The model is more capable of representing spatial variability
- Specifically, the model generally captures over half of the observed spatial variability across constituents
- Temporal variability remains largely unexplained for all constituents

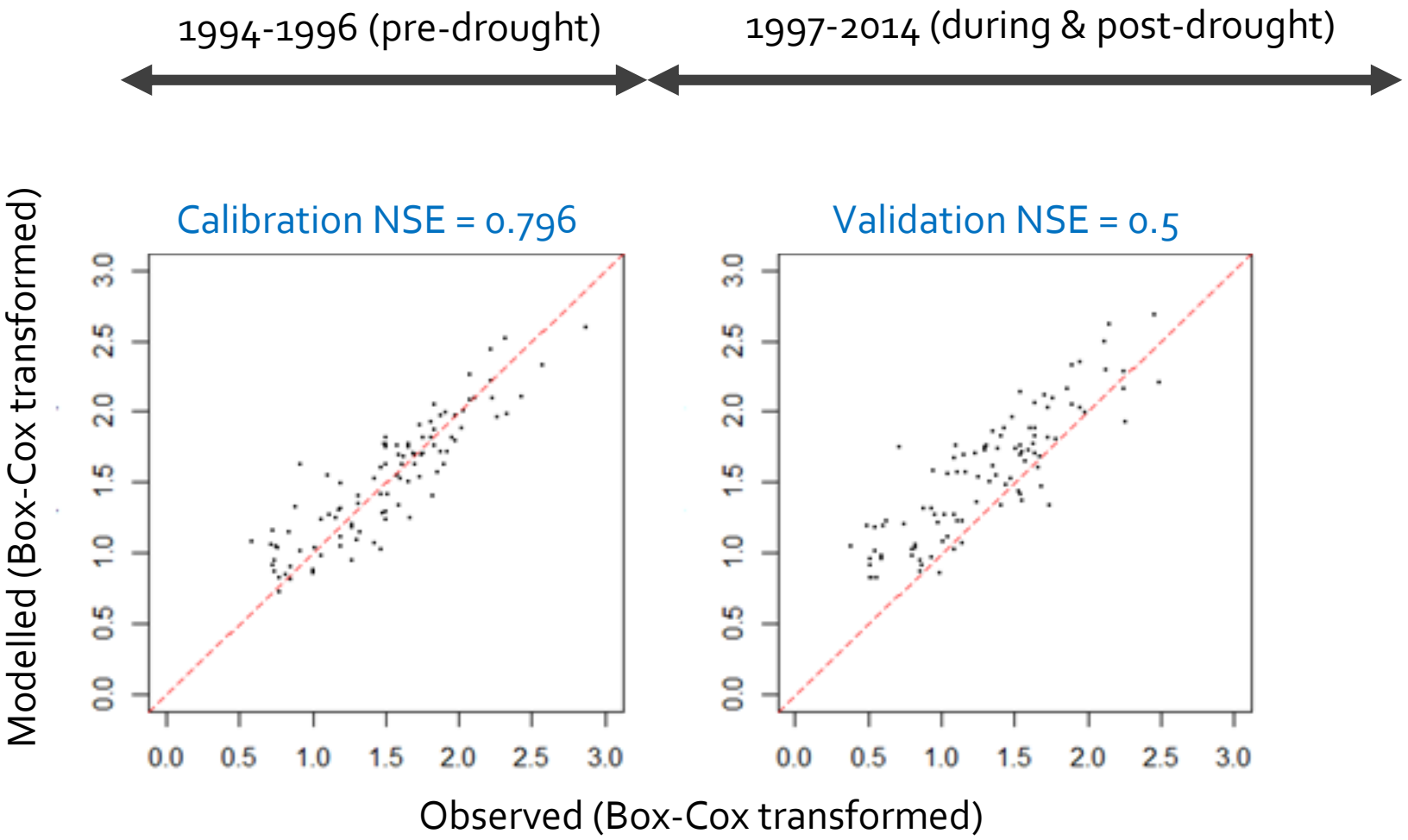
The proportion of below-LOR data may affect model performance across constituents



The model is generally good at representing the spatial variability in all constituents except for FRP within the study region



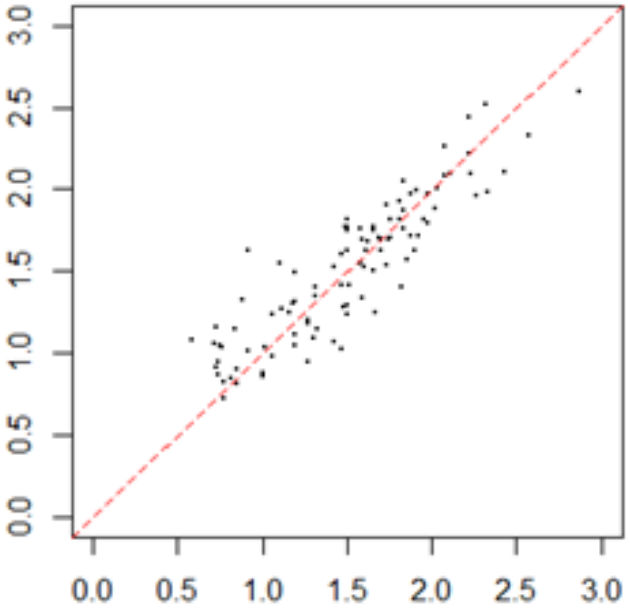
Cross-validation with different periods identified inconsistency of model performance for TSS



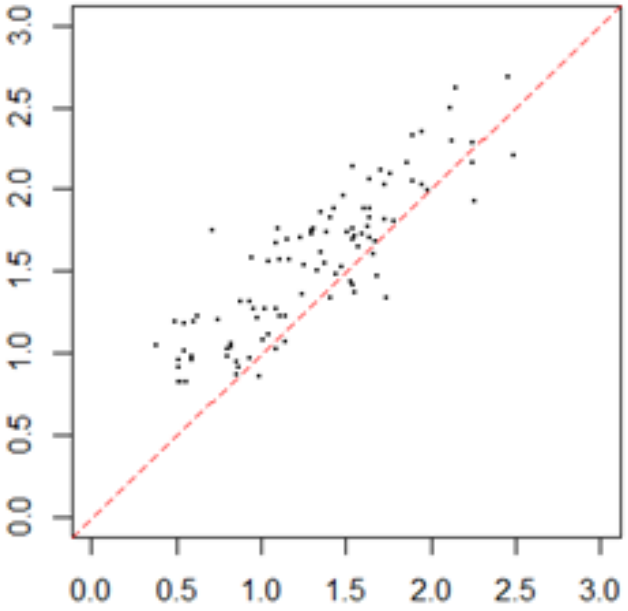
Suggesting a shift in sediment relationships between TSS and its key controls since drought

1994-1996 (pre-drought) ⟷ 1997-2014 (during & post-drought) ⟷

Calibration NSE = 0.796



Validation NSE = 0.5



$TSS_{site,\ time}$ =

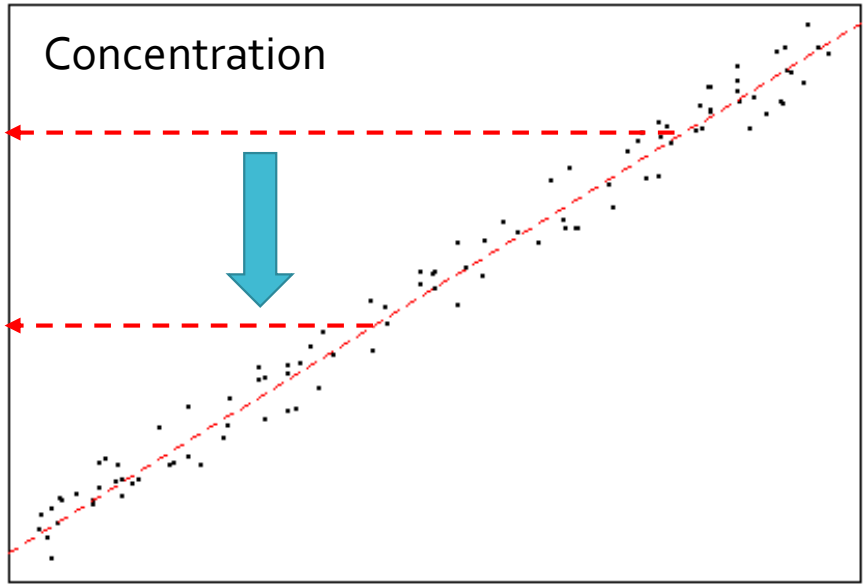
<u>Between site (spatial) variation</u>
Mean TSS site=
f(Hot month temp,
Vegetation cover,
Cropping, Elevation, % clay area)

+

<u>Within site (temporal) variation</u>
Shift TSS site,time=
f(Streamflow,
Water temperature,
Soil moisture)

In the context of previous literature…

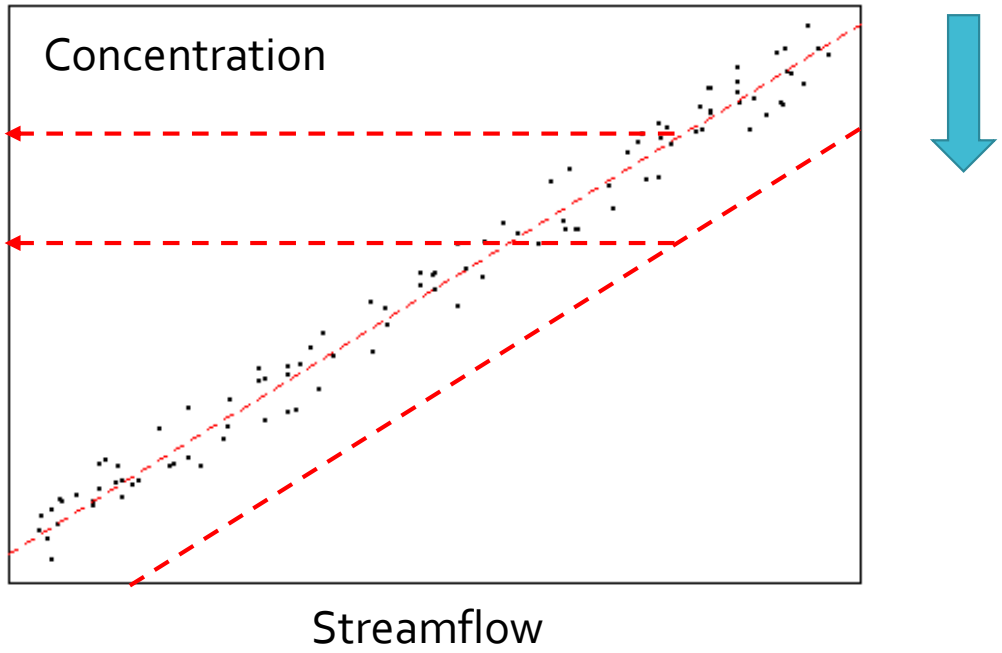
- Previous studied generally explained impacts of drought on sediments/nutrients concentrations as a result of reduced streamflow



Streamflow

In the context of previous literature…

- Previous studied generally explained impacts of drought on sediments/nutrients concentrations as a result of reduced streamflow
- This model identified something different – change of relationships between sediments and its controls including streamflow
- Analogue to the drought impacts on rainfall-runoff relationship



Summary & further studies

- This spatio-temporal model illustrates the use of data-driven models to interpret possible processes and improve predictions
- Monthly data – understanding limited by temporal resolution of variability we can capture, but the use of long-term dataset is still representative for important features of temporal variability
- We need to explore further on:

a) How do the relationships between water quality and its key spatial and temporal drivers (e.g. sediment & land use, sediment and streamflow) are changing (assumed static in our model)?

b) How can the model be adapted to include/explore long-term trends in water quality?

…