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Quantifying the hydroclimatological controls on diurnal ecological responses

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Why important?

Understanding system processes

- Reveals the interconnection between biogeochemical processes
- System response
- Wider implications
- Improved model representation
- Interpretation of WQ data

Diurnal dynamics in upland Wales

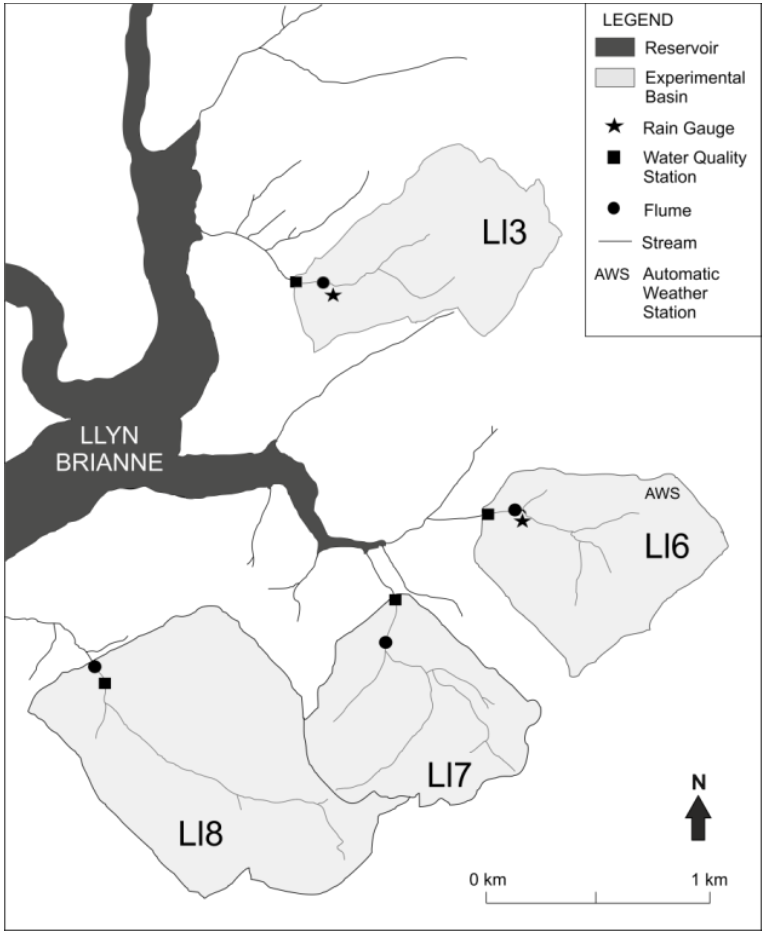
We focus on four experimental catchments in upland mid-Wales

High resolution datasets (15 minute interval)

Diurnal cycles in:

- Water temperature (°C)
- Photosynthetically Active Radiation (PAR)
- **pH**
- **Dissolved Organic Carbon (DOC)**
- **nitrate (NO_3-N)**

Llyn Brianne water supply reservoir



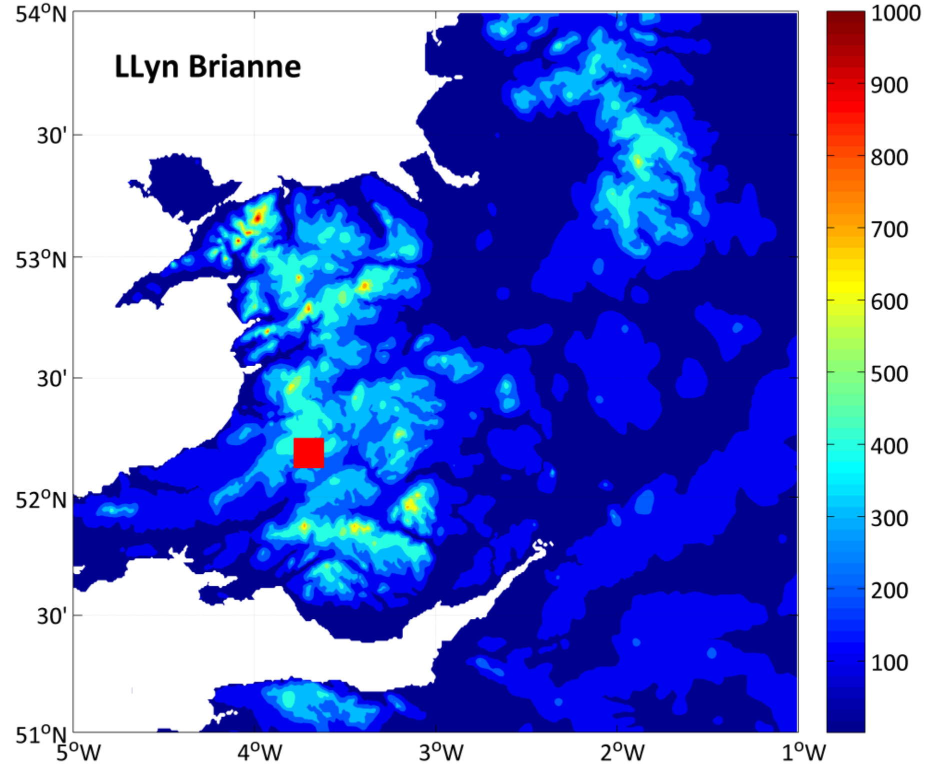
Location of each watershed and their associated instrumentation

Significance and wider implications

Critical region for water provision in the UK

***Microcosm of upland UK**: ~28% of Wales above 300m elevation, height of our gauging stations*

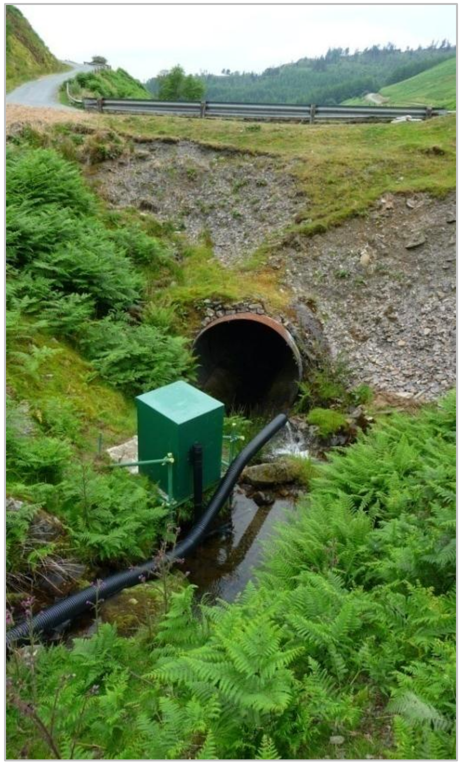
*Extrapolate further to **upland temperate regions***



Location of Llyn Brianne reservoir (masl)

Llyn Brianne: Instrumentation & monitoring

- 15 min sampling from December 2012 to July 2014
- Encompassing 2^{nd}-3^{rd} order headwater streams
- Moorland (LI6 and LI7) and coniferous plantation (LI8 and LI3)
- Areas range from 0.69 km^2 to 1.21 km^2



Water quality station at LI7

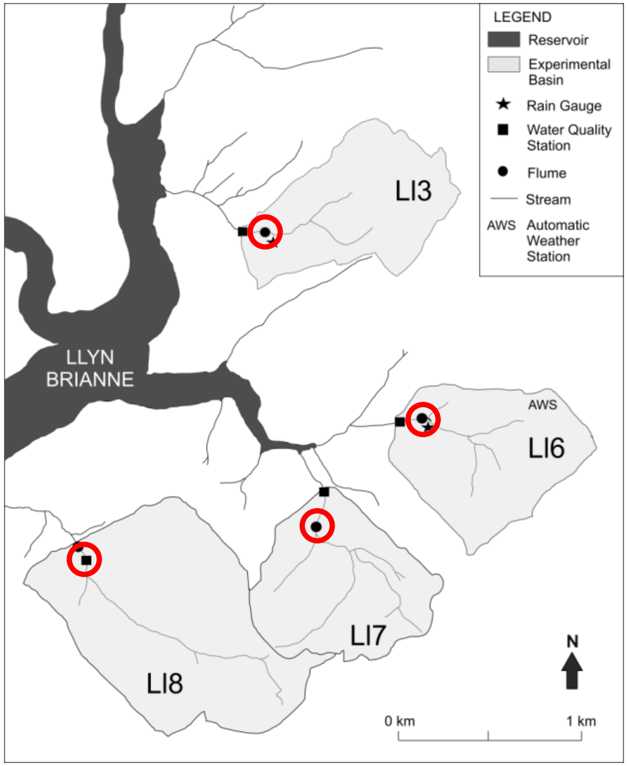
LI8 coniferous afforested catchment (1.21 km^2)

LI6 moorland catchment (0.69 km^2)

Instrumentation and high frequency monitoring

- Discharge (m^3/s): trapezoidal flume and 0-2.5 m H_2O pressure transmitter

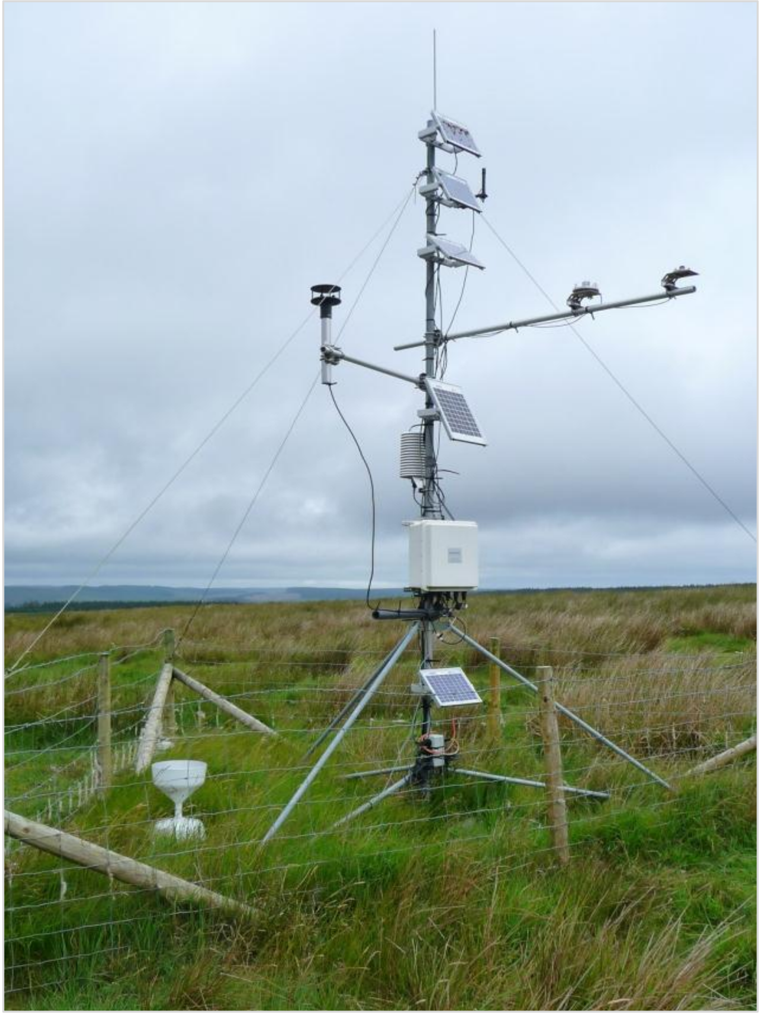
Trapezoidal flume at LI8



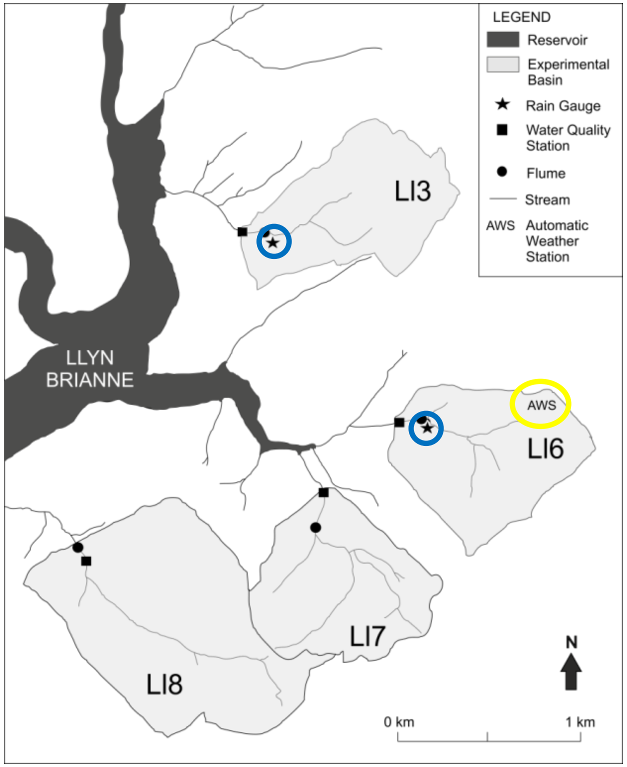
Location of each watershed and accompanying flume

Fibre glass trapezoidal flume at LI6

- Photosynthetically active solar radiation (μmol/m²/s)



Automatic weather station situated in LI6

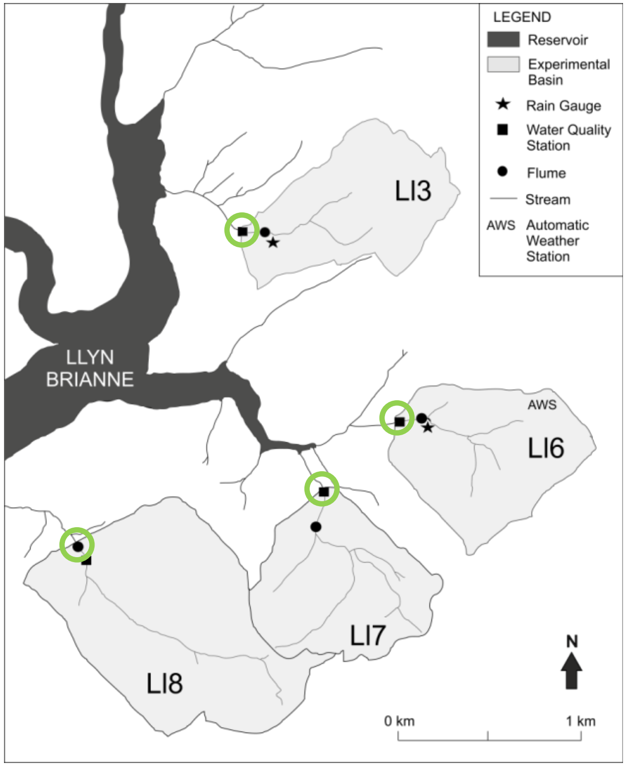


Location of each watershed, the automatic weather station and tipping bucket gauges

Tipping bucket rain gauge and flume at LI6

Instrumentation and high frequency monitoring

- Water temperature (°C): NTC 300 temperature sensor
- pH: digital differential pH sensor and SC200 controller
- NO_3-N (mg/l) and DOC (mg/l): s::can spectro::lyser™ UV/Visible spectrometer probe



Location of each watershed and accompanying water quality station

Water quality station at LI3

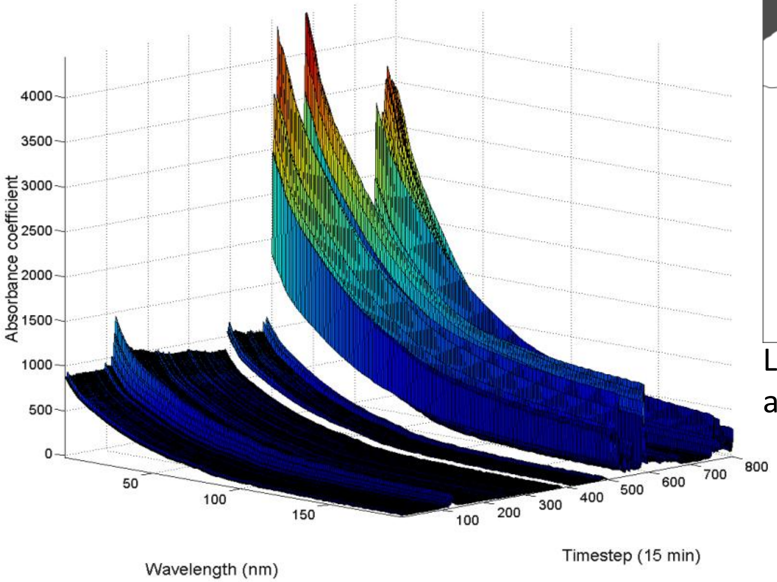
PVC pipe housing WQ sensors at LI8

SC200 controller

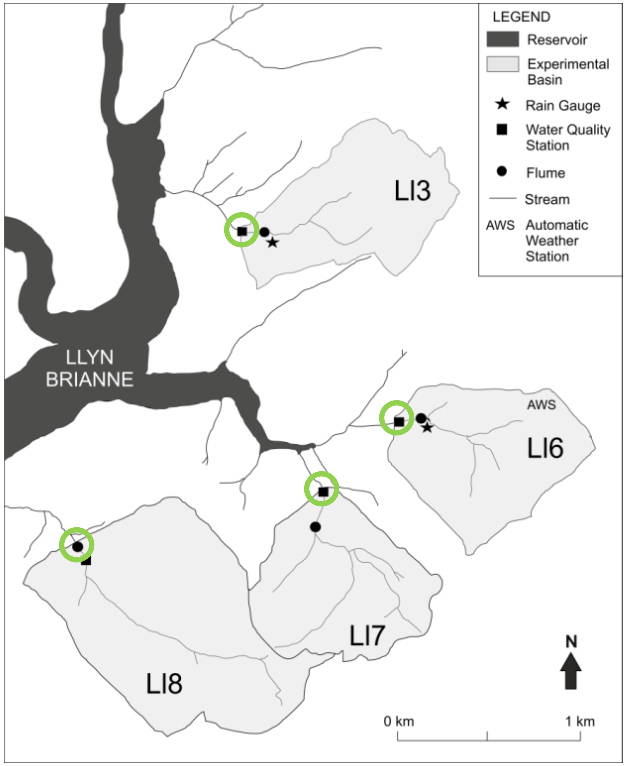
Instrumentation and high frequency monitoring

- Water temperature (°C): NTC 300 temperature sensor
- pH: digital differential pH sensor and SC200 controller
- NO_3-N (mg/l) and DOC (mg/l): s::can spectro::lyser™ UV/Visible spectrometer probe

PVC pipe housing WQ sensors at LI6



s::can measures absorbance across UV-Visible spectrum from 200 - 735 nm with a resolution of 2.5 nm



Location of each watershed and accompanying water quality station

s::can spectro::lyser

Instrumentation and high frequency monitoring

Identifying diurnal cycles: Data based mechanistic modelling

Unobserved Component - Dynamic Harmonic Regression (DHR) model

Time series decomposed into a trend, cyclical and white noise component

$$y_t = T_t + \boxed{C_t} + e_t \qquad e_t \sim N\left(0, \sigma^2\right)$$

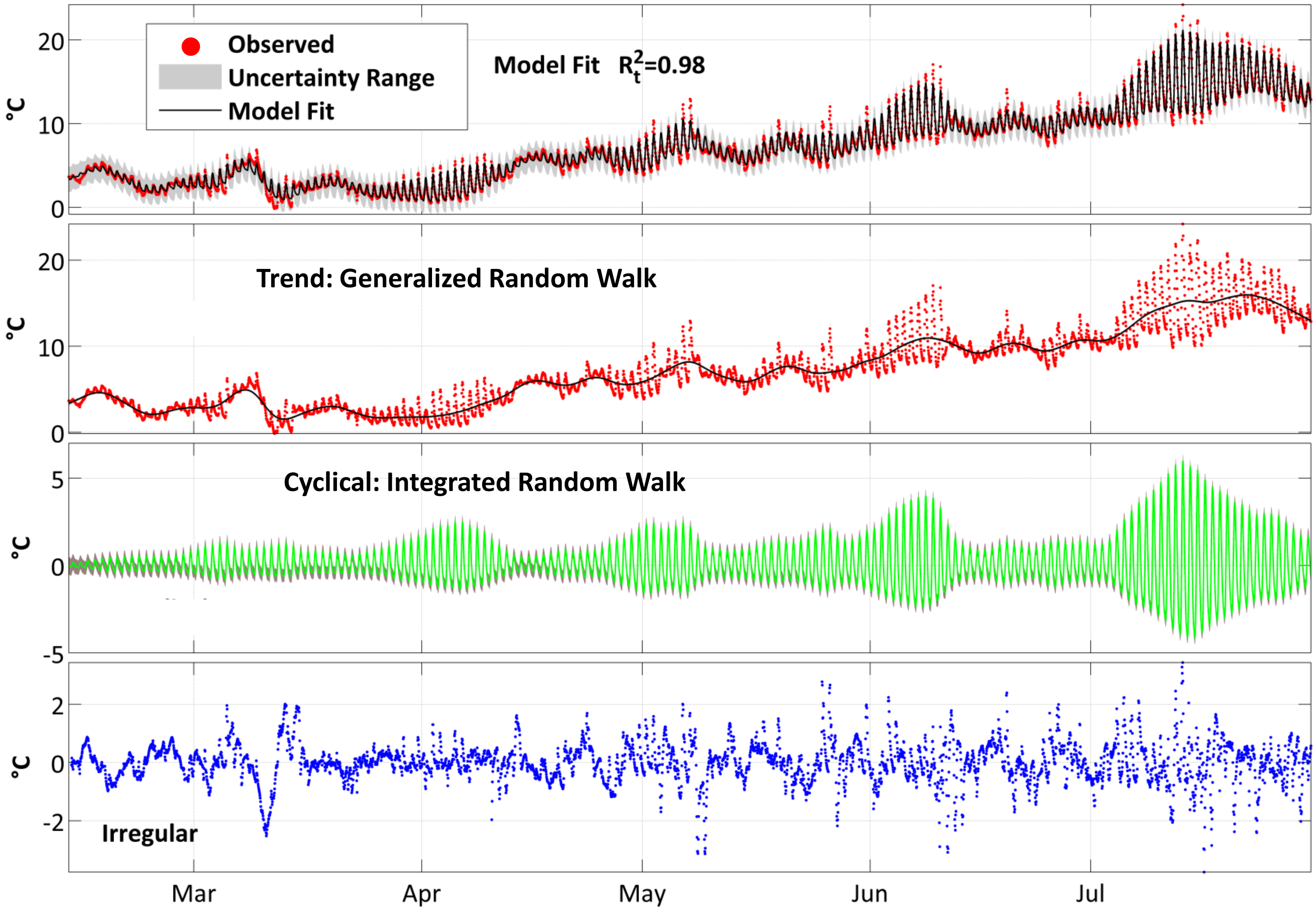
$$C_t = \sum_{t=1}^{S_s} \left\{ a_{i,t} \cos\left(\omega_i t\right) + b_{i,t} \sin\left(\omega_i t\right) \right\}$$

Young PC, *et al*., (1999) Dynamic harmonic regression. *Int. J. Forecast* 18: 369–394.

Taylor, *et al*. (2007) Environmental Time Series Analysis and Forecasting with the Captain Toolbox. *Environ. Modell. & Softw* 22: 797–814.

CAPTAIN TOOLBOX
Lancaster University

e.g., DHR analysis of water temperature (°C) series



Primary interest in cyclical component

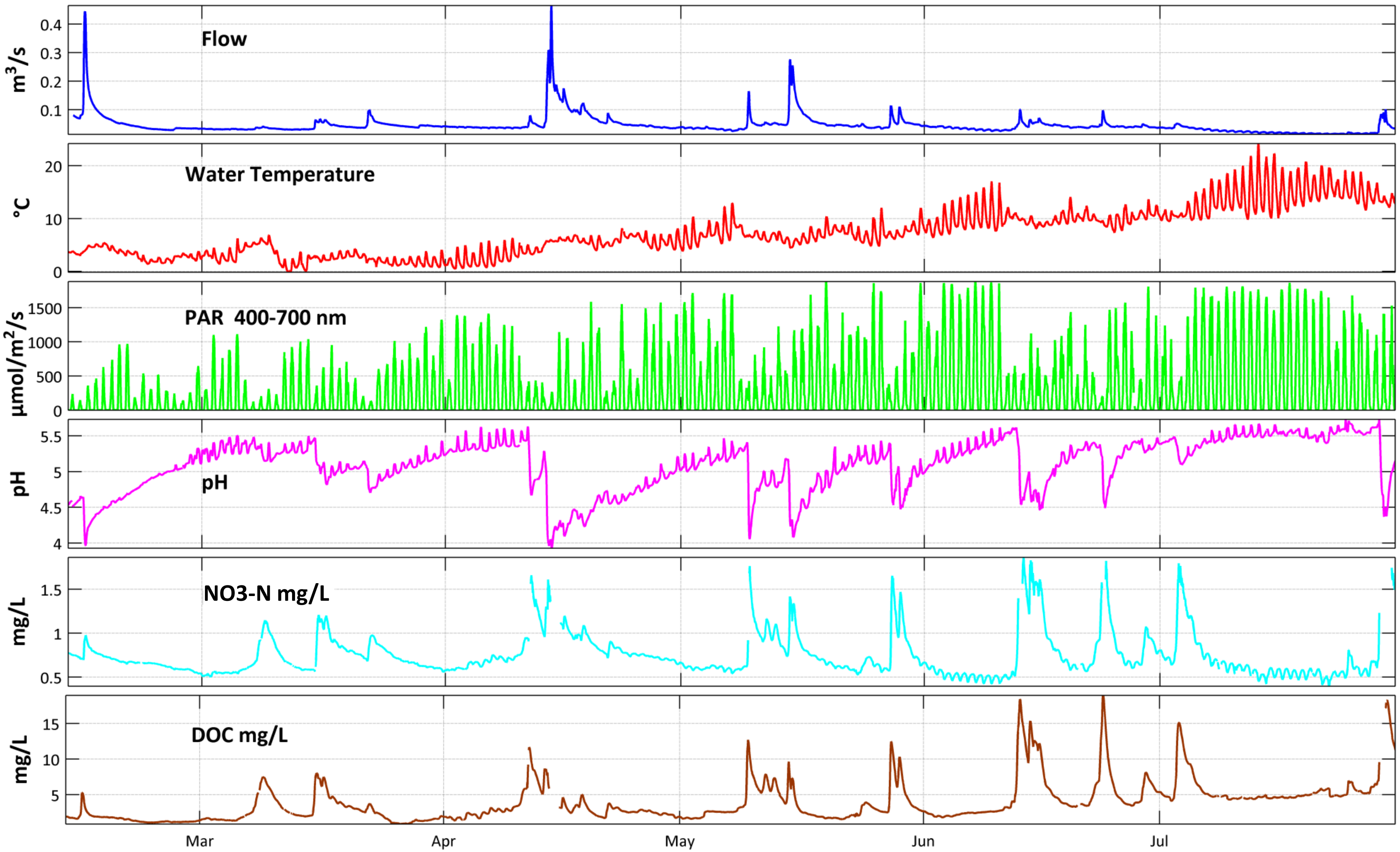
Noise Variance Ratio (NVR) estimated using steps ahead forecasting error criterion

NVR: 0.0011
0.6802
0.0700
0.0037

Spectral analysis and diurnal signal extraction

Diurnal cycles in observed data

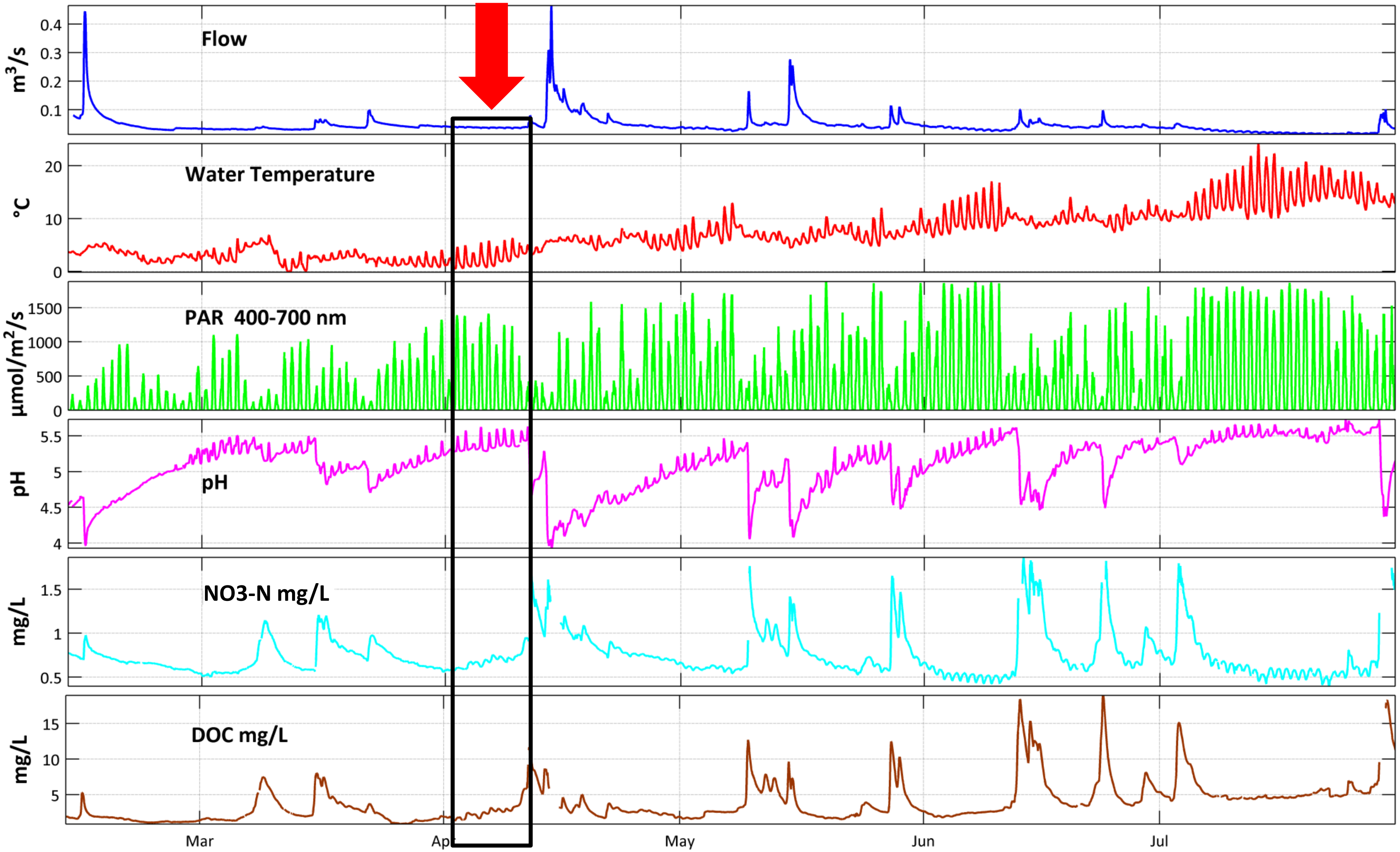
Observed high resolution time series



Data from LI8 for the period 12/02/2013 to 31/07/2013

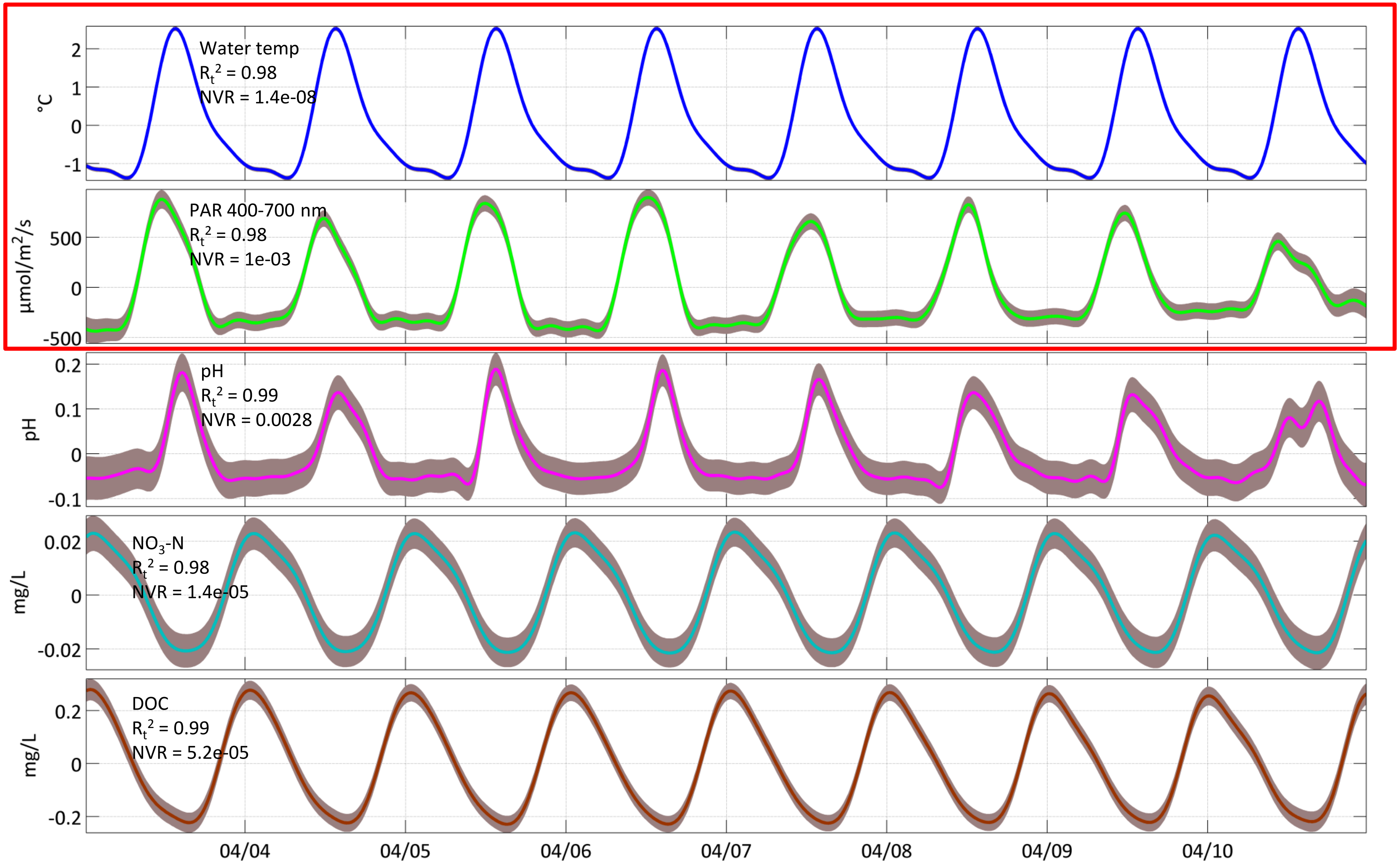
Observed diurnal cycles

Observed high resolution time series



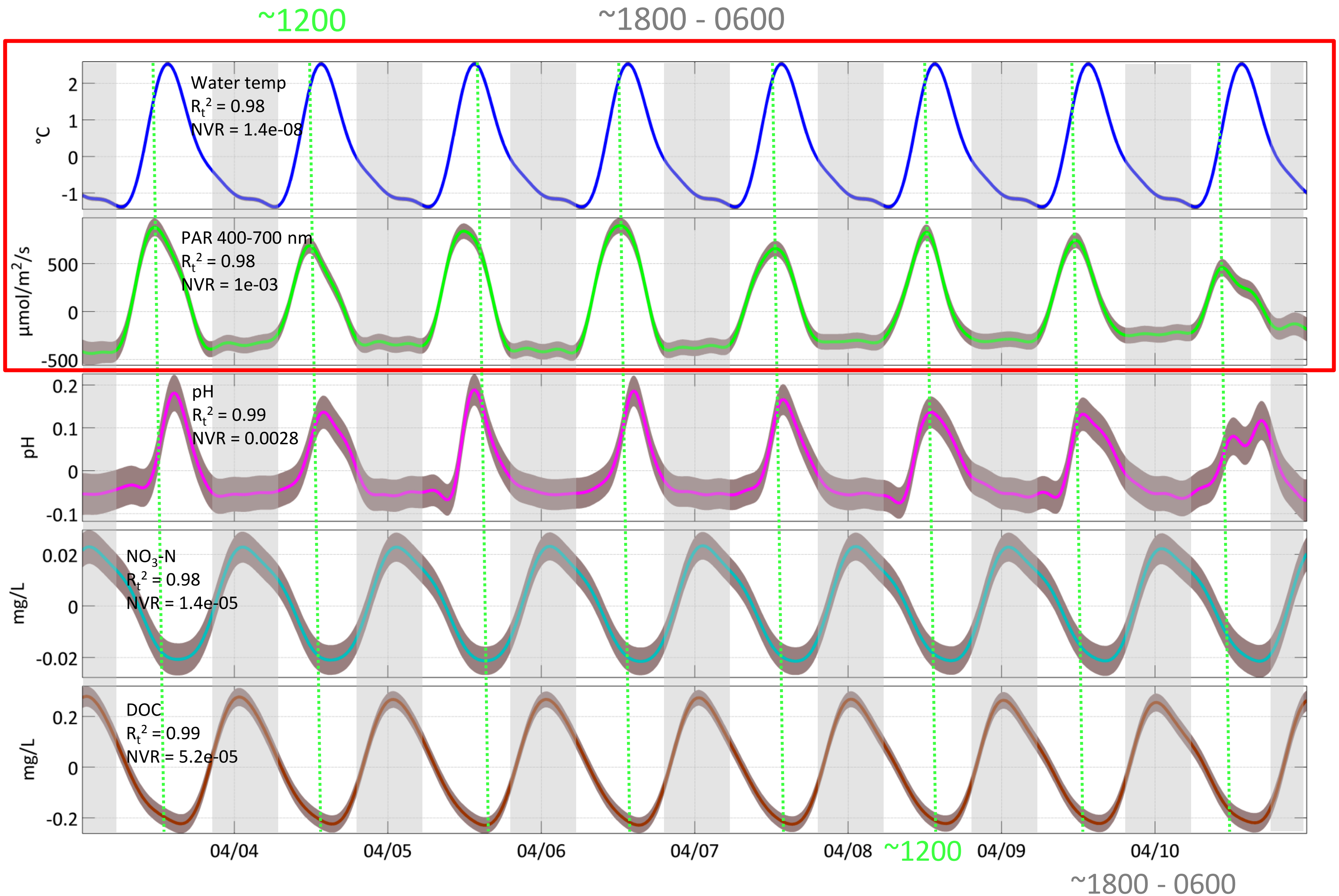
Data from LI8 for the period 12/02/2013 to 31/07/2013

Observed diurnal cycles



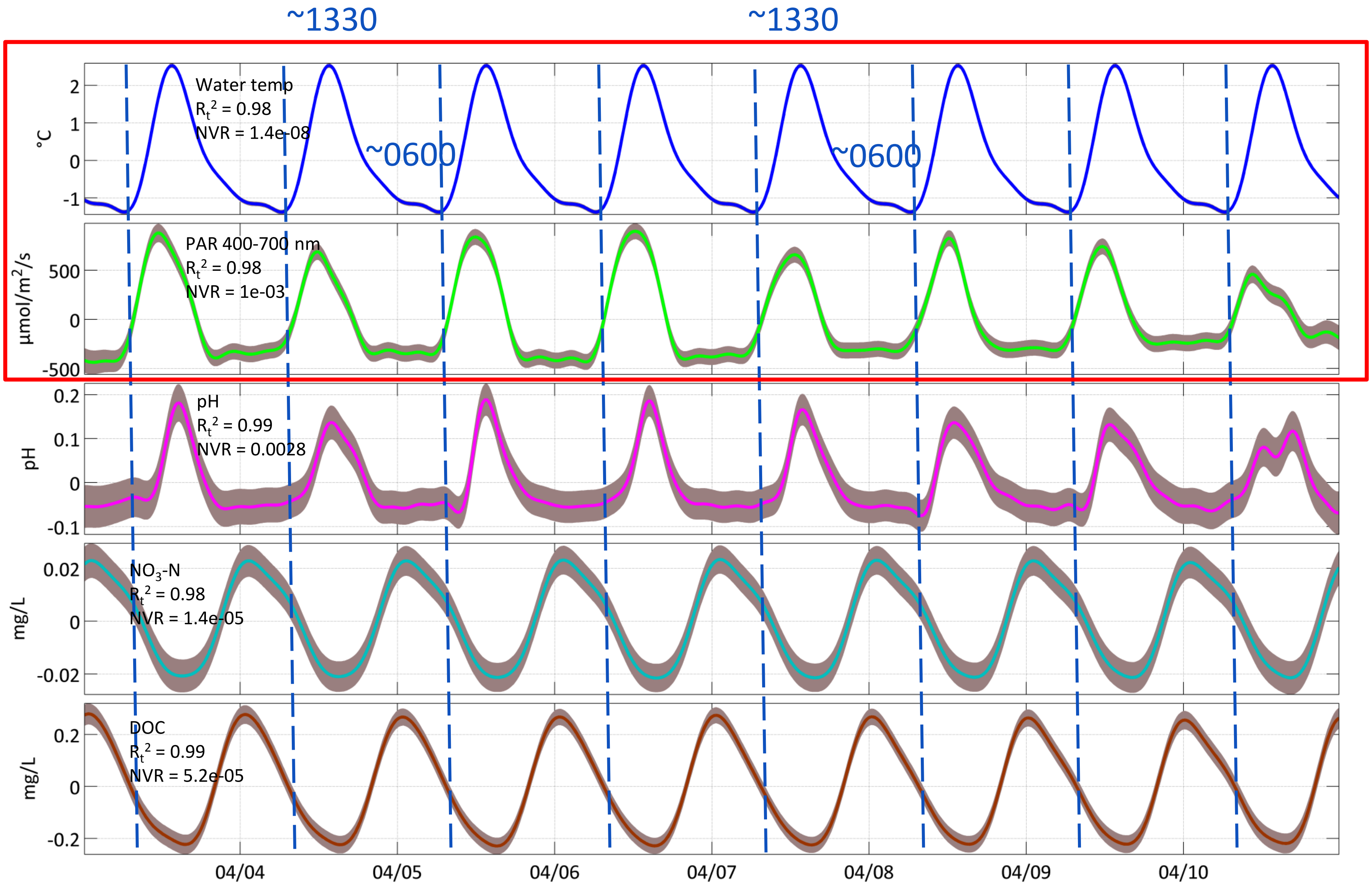
Extracted diurnal signal from LI8 for the period 03/04/2013 to 11/04/2013

Observed diurnal cycles: DHR



Extracted diurnal signal from LI8 for the period 03/04/2013 to 11/04/2013

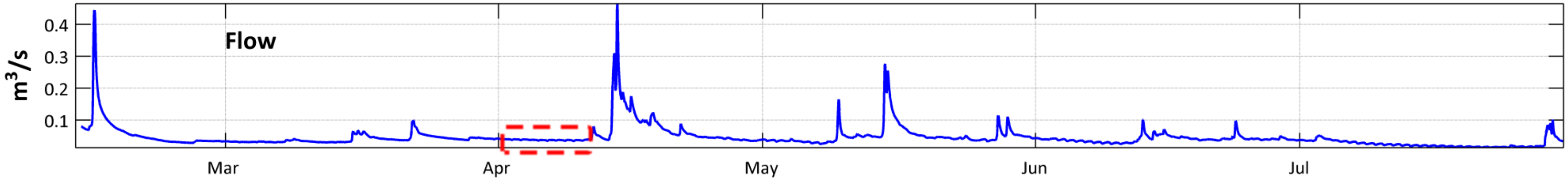
Observed diurnal cycles: DHR



Extracted diurnal signal from LI8 for the period 03/04/2013 to 11/04/2013

Observed diurnal cycles: DHR

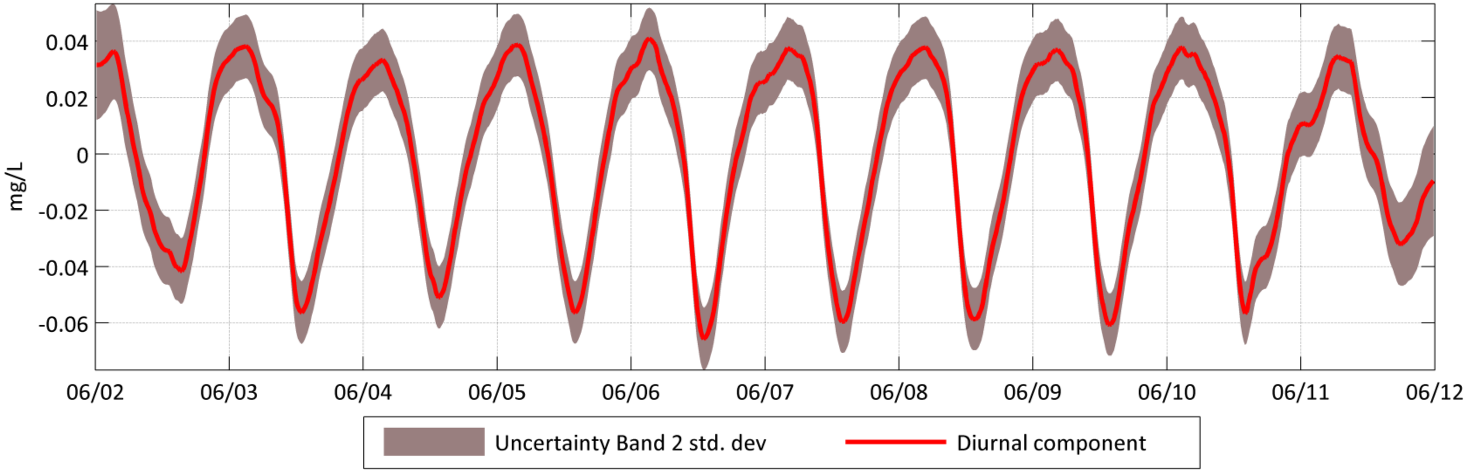
Necessity of high frequency sampling



Cross correlation (r)					
	Water temp	PAR	pH	DOC	NO_3-N
Water temp		0.85	0.77	-0.70	-0.85
PAR	0.85		0.73	-0.68	-0.75
pH	0.77	0.73		-0.72	-0.72
DOC	-0.70	-0.68	-0.72		0.76
NO3-N	-0.85	-0.75	-0.72	0.76	
Temporal offset (hrs)					
Water temp		2.25	0.50	1.75	0.50
PAR	-2.25		-1.50	-1.00	-1.75
pH	-0.50	1.50		1.25	-0.75
DOC	-1.75	1.00	-1.25		-1.00
NO_3-N	-0.50	1.75	0.75	1.00	

Sub-hourly* data is essential for quantifying the *high frequency dynamics* associated with *diurnal cycles

Total diurnal NO_3-N component extracted from 7 hourly and 15 minute samples

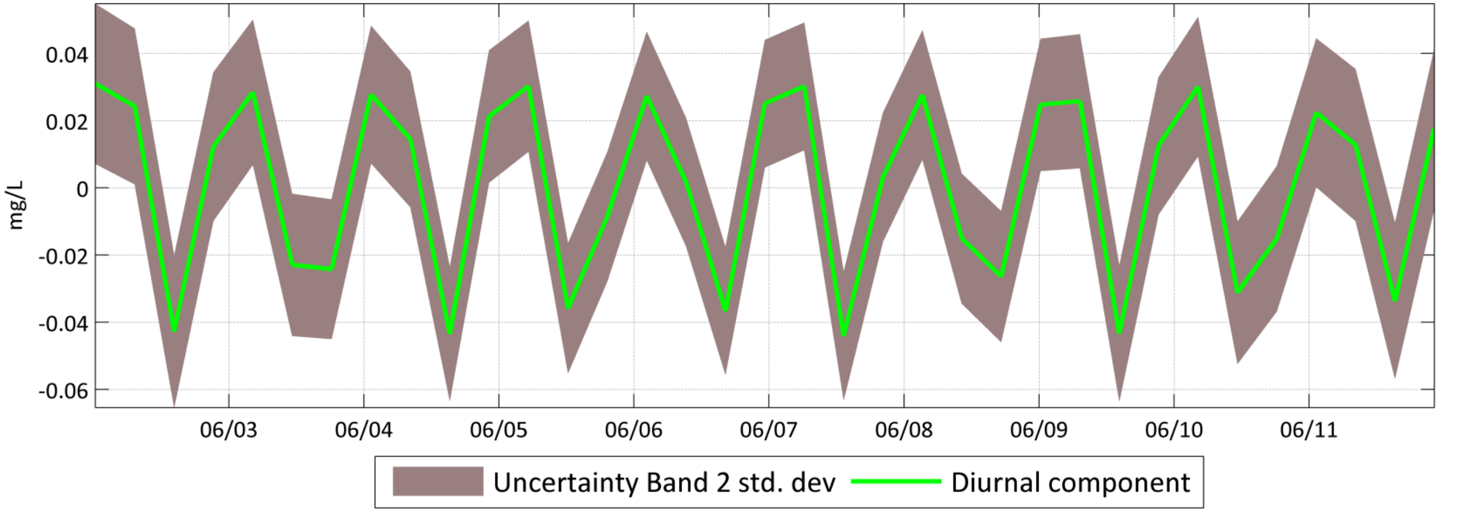


15 minute samples

NVR estimated using ML
Periodic 96./1:3
$R_t^2 = 0.994$

NVR

0.0000
0.0668
0.0062
0.0438



7 hourly samples

NVR estimated using Forecasting Criterion ('f8')
Periodic 3.4./1:3
$R_t^2 = 0.923$

NVR

0.71

DHR analysis of NO_3-N series from LI8 for the period 02/06/2013 to 12/06/2013

The importance of high frequency sampling

Thank you