Management Implications for Bedload Models in the Grand Canyon of the Colorado River

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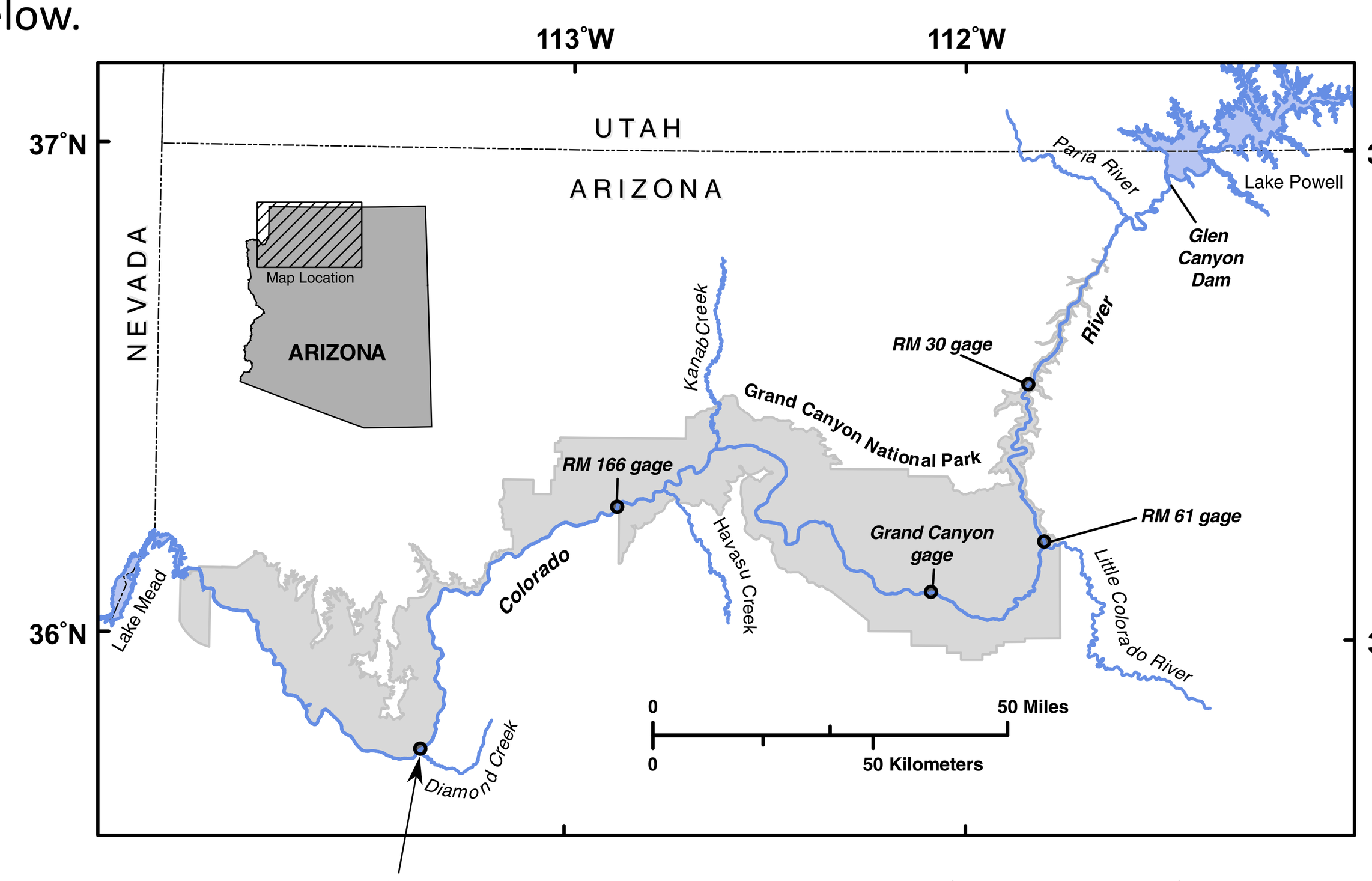
ABSTRACT

1 SETTING

Gage estimates of sediment flux are an imortant tool for quantifying large-scale geomorphic change. On the Colorado River, estimates of sediment flux are used to constrain sediment mass-balance in five discrete reaches. Acoustic sediment monitoring instruments provide reliable estimates of suspended sand but bedload is estimated as a constant 5% of suspended sand load. Here, we utilize a recently developed bedload model to test this assumption at one monitoring station shown below.


113°W
112°W
37°N
36°N
UTAH
ARIZONA
NEVADA
Map Location
ARIZONA
Lake Powell
Glen Canyon Dam
Paria River
River
RM 30 gage
Kanab Creek
Grand Canyon National Park
RM 166 gage
Grand Canyon gage
RM 61 gage
Colorado
Havasu Creek
Little Colorado River
Lake Mead
Diamond Creek
50 Miles
50 Kilometers

Diamond Creek sediment monitoring station (River Mile 225)

2 BEDLOAD MODEL

Independent Variables:

Unit water discharge	$Q\ [m^2/s]$
Reach slope	$S\ [-]$
Median diameter of bed material	$D_b\ [m]$

PHYSICS →

(Garcia, 2008; Wright & Parker, 2004)

Dependent Variables:

Unit bedload flux	$q_b\ [m^2/s]$
Suspended sand concentration	$C_s\ [-]$
Median diameter of suspended sand	$D_s\ [m]$

Power-law approximation for underlying physics:

$$q_b \propto Q^{\alpha_{11}} S^{\alpha_{12}} D_b^{\alpha_{13}}$$
$$C_s \propto Q^{\alpha_{21}} S^{\alpha_{22}} D_b^{\alpha_{23}}$$
$$D_s \propto Q^{\alpha_{31}} S^{\alpha_{32}} D_b^{\alpha_{33}}$$

Solve for q_b →

$$q_b = A e^{\beta_0} Q^{\beta_1} C_s^{\beta_2} D_s^{\beta_3}$$

where $A = q_{b0}/Q_0^{\beta_1} C_{s0}^{\beta_2} D_{s0}^{\beta_3}$

For more information on modeling, see "Statistical bedload modeling on the Colorado River in Grand Canyon National Park" (T3. Advances in River Science in the Intermountain West I, Thursday May 17 (tomorrow), 9:45 AM)

Works Cited:

Garcia, M. (2008), Chapter 2: Sediment Transport and Morphodynamics, in ASCE Manuals and Reports on Engineering Practice: Sedimentation Engineering: Process, Management, Modeling and Practice, pp. 21–163, Reston, VA.

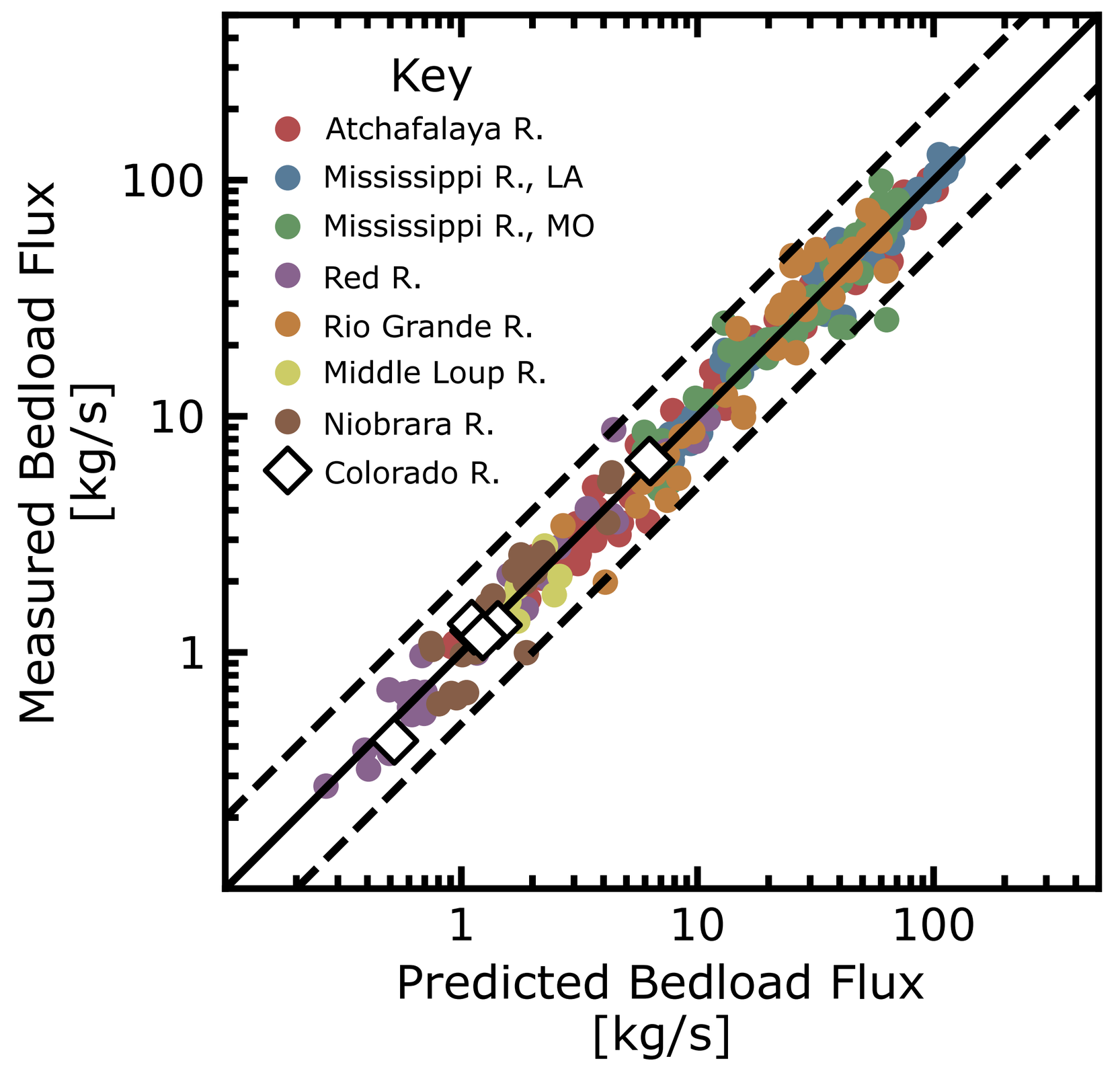
Gelman, A., Carlin, J. B., Stern, H. S., Dunson, D. B., Vehtari, A., & Rubin, D. B. (2014). Bayesian data analysis (Vol. 2). Boca Raton, FL: CRC press.

Toffaleti, F. B. (1968). A Procedure for Computation of the Total River Sand Discharge and Detailed Distribution, Bed to Surface (No. TR-5). Army Cor. of Eng. Comm. on Chan. Stab.

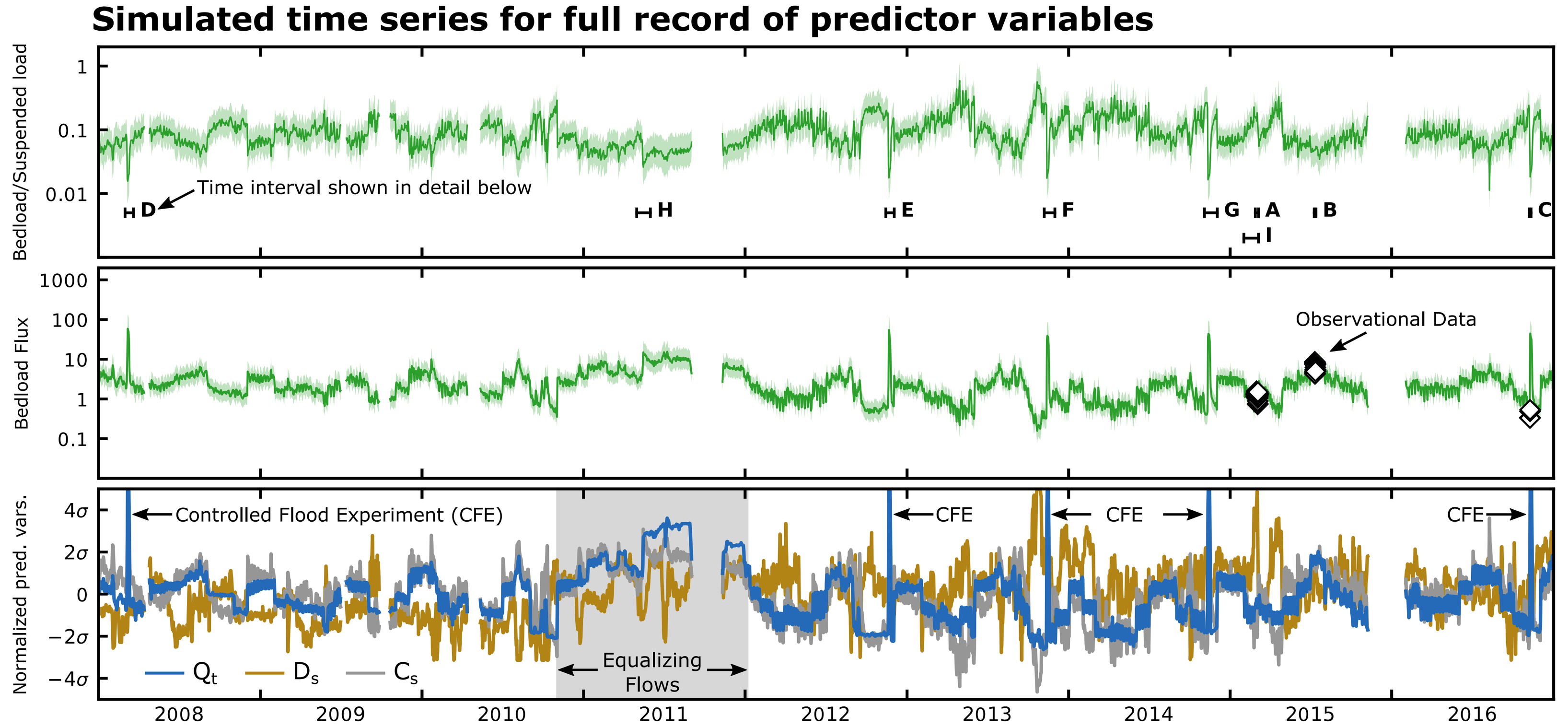
Wright, S., and G. Parker (2004), Flow Resistance and Suspended Load in Sand-Bed Rivers: Simplified Stratification Model, J. Hydraul. Eng., 130(8), 796–805.

3 PARAMETER ESTIMATION AND PREDICTION

Parameter estimation and prediction is performed using Bayesian hierarchical linear regression (Gelman et al., 2014). Data collected at our study site was supplemented by data from seven other sites on other rivers reported by Toffaleti (1968). Bedload flux and the ratio of bedload to suspended load were then simulated over the full record of predictor variables at our study site.

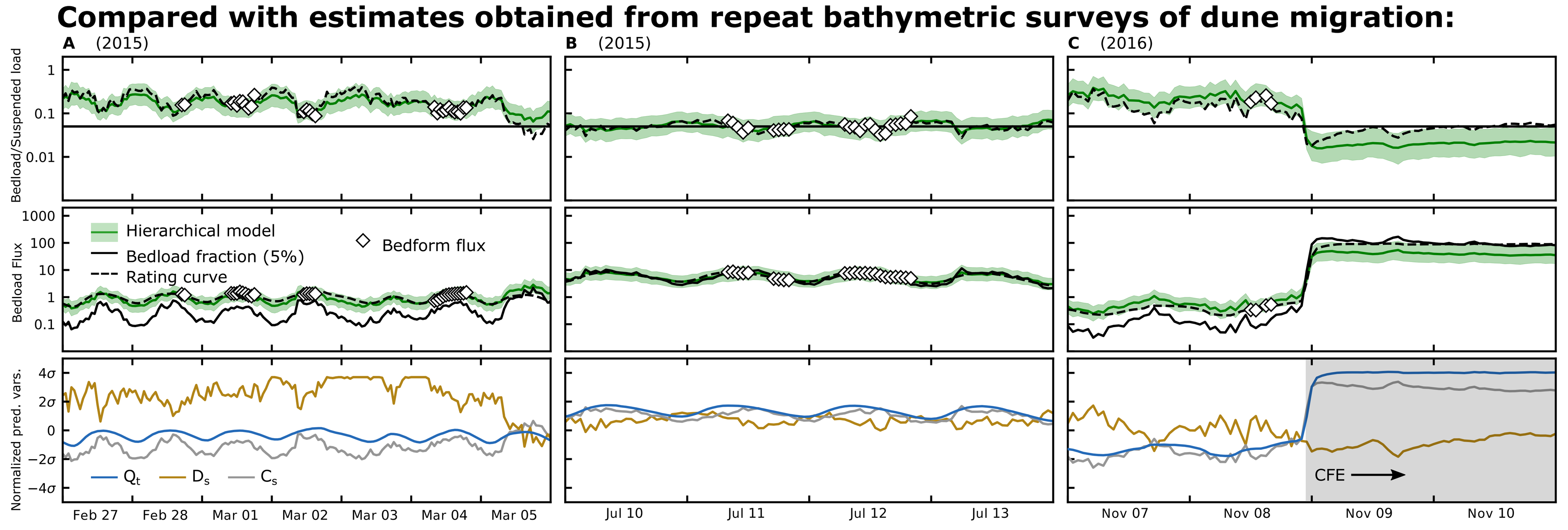


Simulated time series for full record of predictor variables

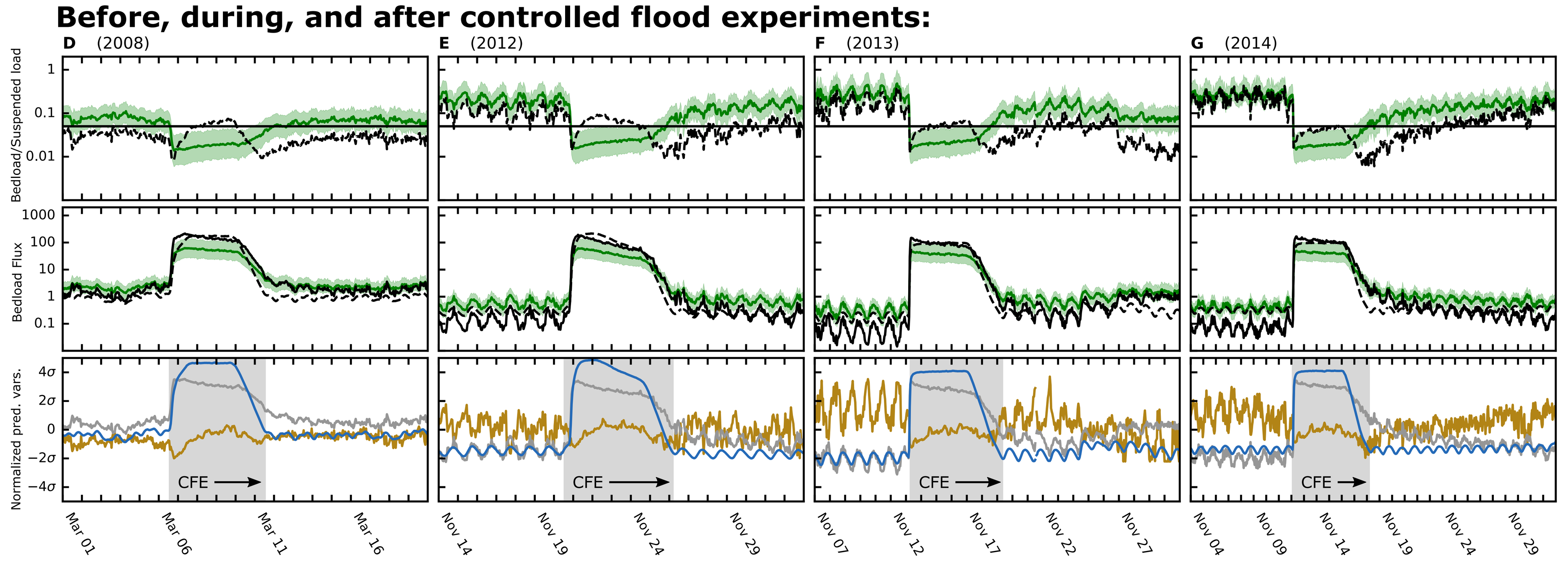


4 SIMULATED BEDLOAD TIME SERIES EXAMPLES

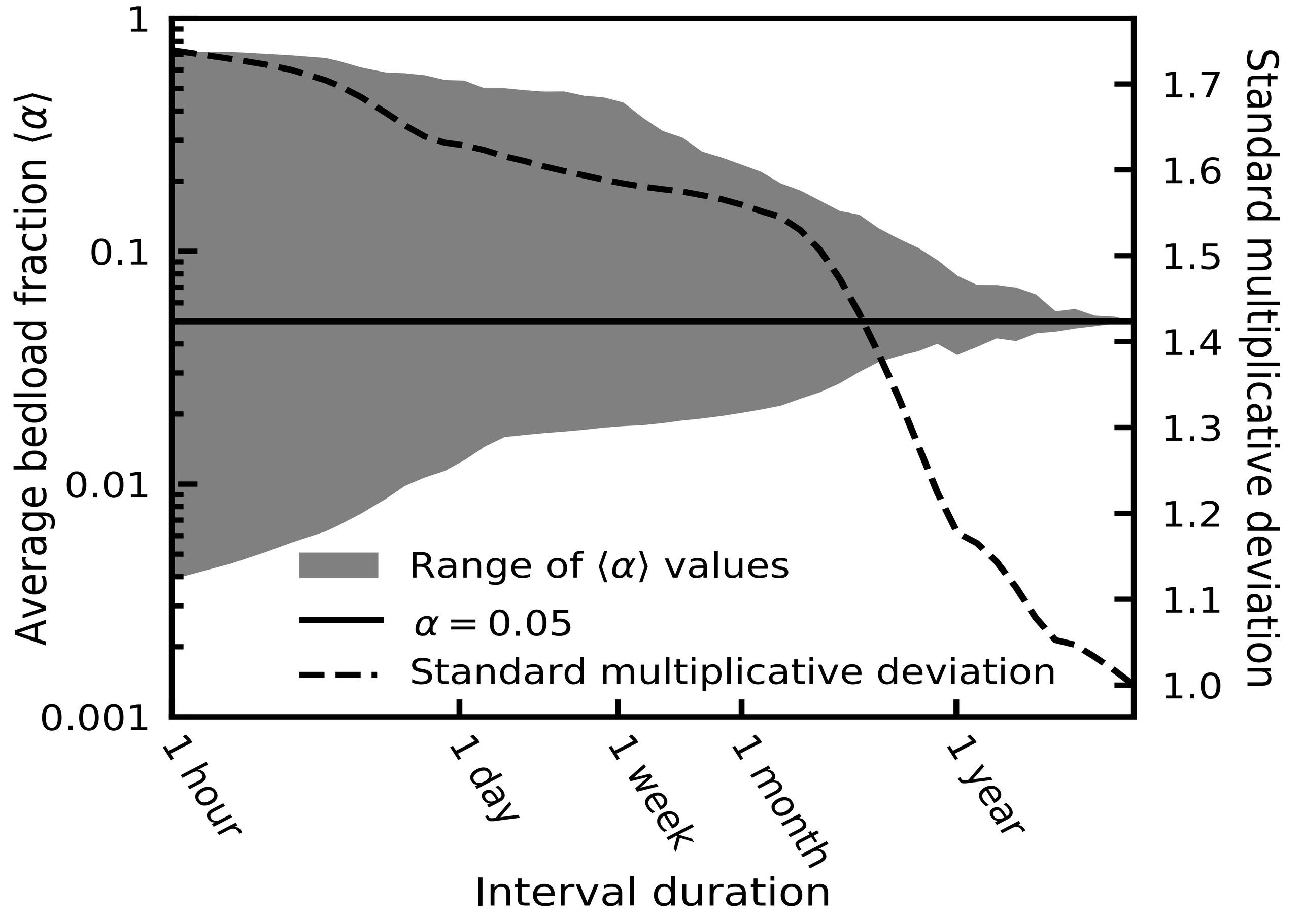
Compared with estimates obtained from repeat bathymetric surveys of dune migration:



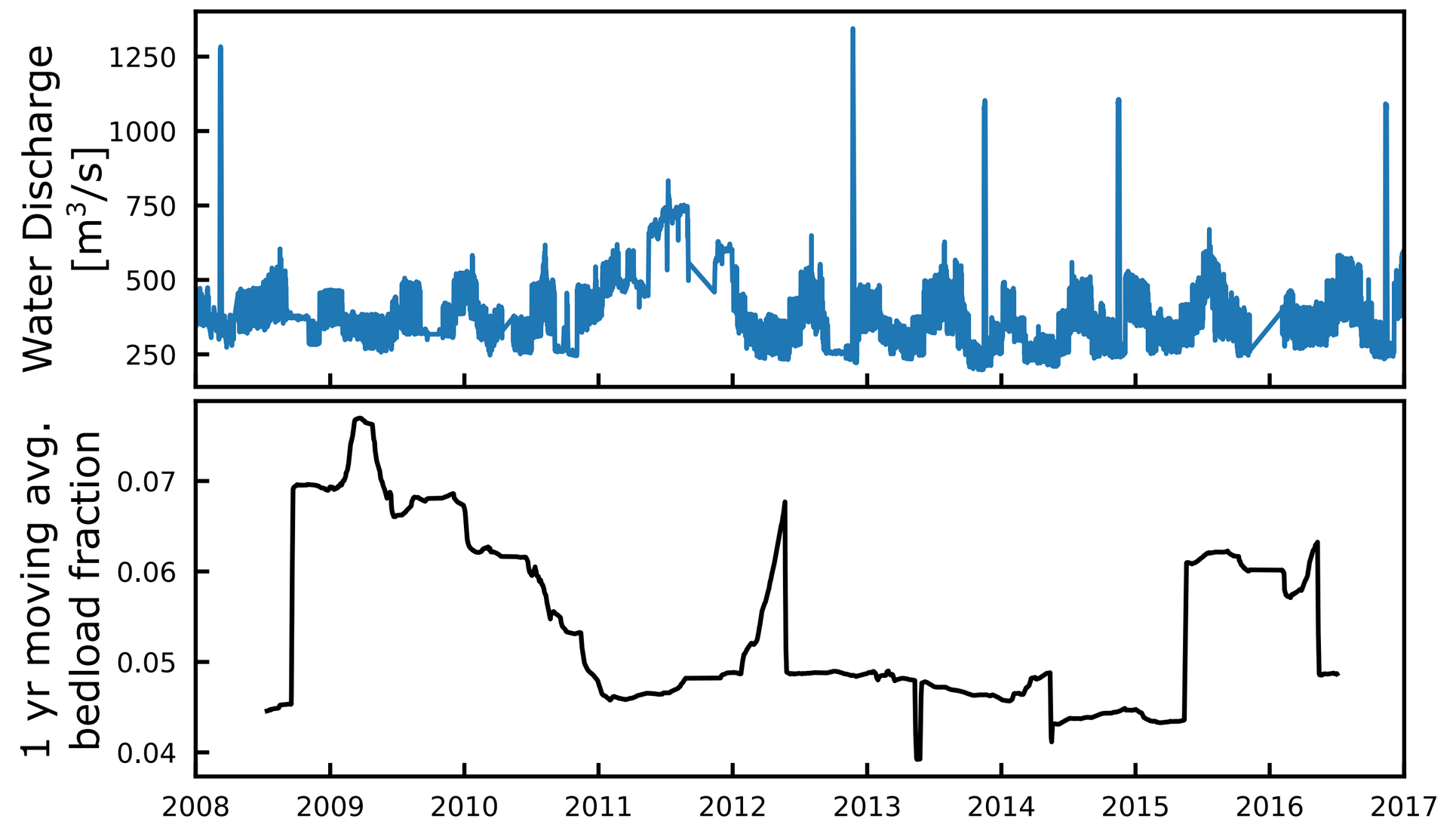
Before, during, and after controlled flood experiments:



5 TIMESCALE-DEPENDENT AVERAGING



6 CONCLUSIONS



1. Cumulative bedload flux over the full record is approximately 5% of cumulative suspended sand flux. However, future changes in sediment supply or water discharge could cause changes in the long-term average bedload fraction
2. Instantaneous bedload flux may range from less than 1% to as much as 75% of suspended sand flux.
3. High bedload fractions occur during fine sediment-depleted base flow conditions, while low bedload fractions occur during fine sediment-enriched flood conditions

During periods of gradual depletion of fine bed material