Riverine Water, Sediment And Nutrient Flux Predictions: The Spatially And Temporally Explicit *WBMsed* Model

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Introduction

- Quantifying global riverine discharge (**water**, **sediment** and **nutrients**) is an important scientific undertaking for a multitude of reasons (e.g. water security, env. sustainability, climate change).

- Unfortunately only a small fraction of global rivers are monitored on a frequent and long-term basis.

- *It was estimated that sediment fluxes to the oceans are monitored for less than 10% of the Earth's rivers and intra-basin measurements are even scarcer.*

Introduction

- Freshwater ecosystems are experiencing rapid transformations in response to population growth and economic development.
- Predicted impacts of climate change introduce major concerns for water security and eco-sustainability.
- Continental and global scale analysis of climatic and anthropogenic effects on freshwater systems is therefore warranted and timely.





Modeling Approach

- We developed the WBMsed model (Water Balance Model sediment) – a global scale spatially and temporally explicit riverine sediment flux model.
- An implementation of the Framework for Aquatic Modeling in the Earth System (*FrAMES*; Wisser et al. 2010), a multidisciplinary hydrological/biogeochemical modeling scheme.

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WBMsed, a distributed global-scale riverine sediment flux model: Model description and validation

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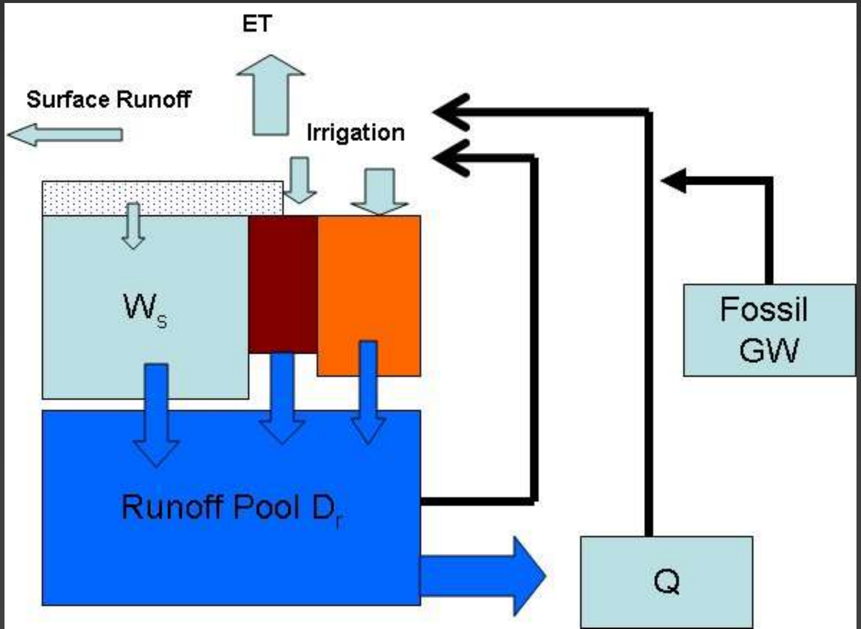
Modeling Approach: Water

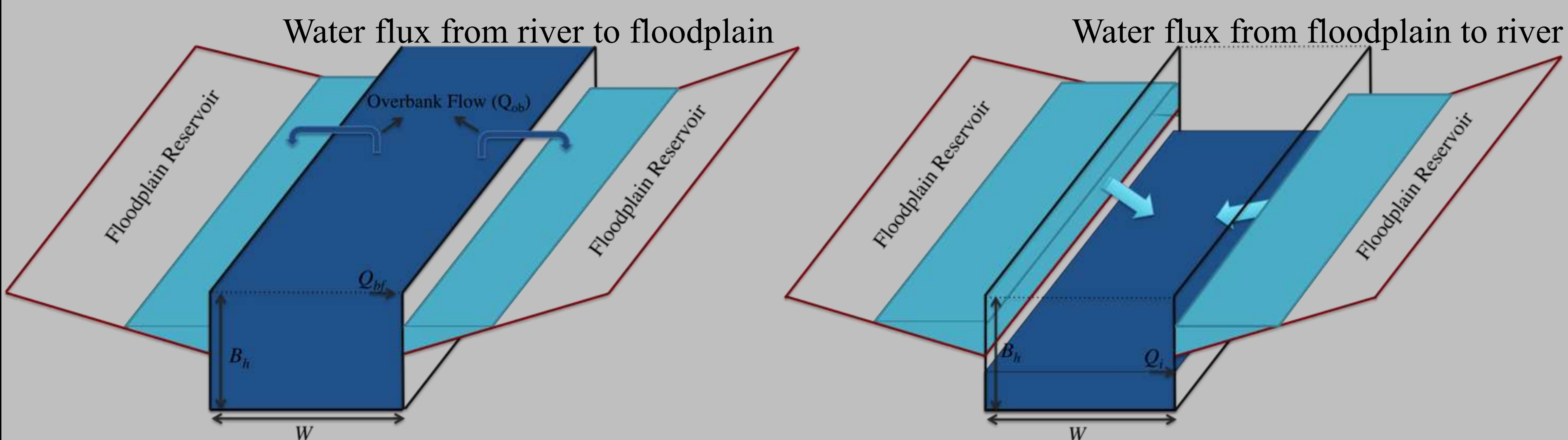
- The hydrological engine of WBMsed is a fully coupled water balance and transport model that simulates the vertical water exchange between the land surface and the atmosphere and the horizontal water transport along river networks.
- WBM (Vorosmarty et al., 1989) was probably the first hydrological model applied to a global domain.
- The main advantage of WBM is the high degree of flexibility in computation domains**, input data, hydrological modules** and configurations.



Modeling Approach: Water

The WBMsed v2.0 model introduced an improved water routing scheme that account for bankfull discharge and floodplain storage of flood waters

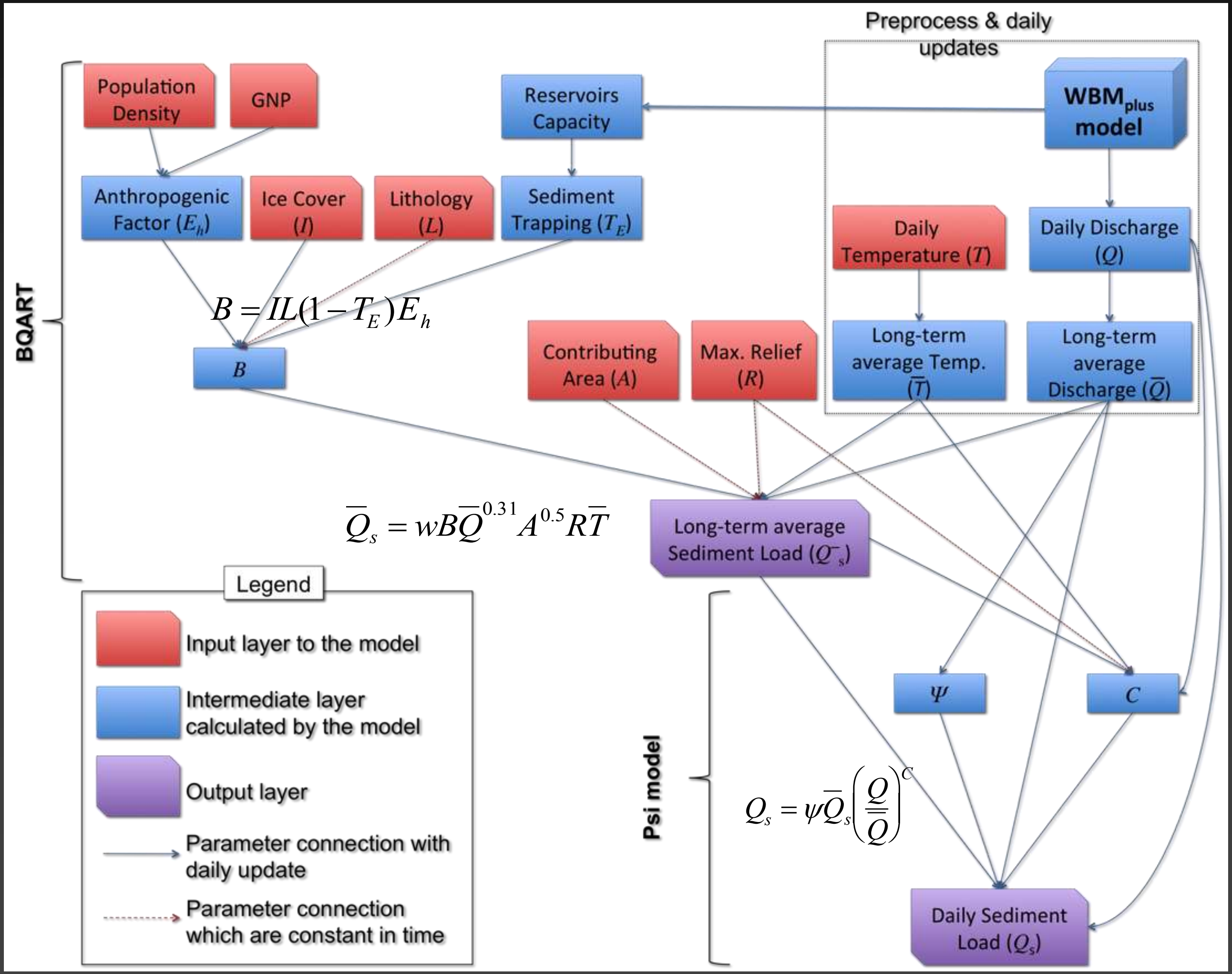
Fig. 1: Schematics of the floodplain reservoir component in *WBMsed v2.0*.



Cohen, S., A. J. Kettner, and J.P.M. Syvitski (2014), Global suspended sediment and water discharge dynamics between 1960 and 2010: Continental trends and intra-basin sensitivity, *Global and Planetary Change*, 115: 44-58.

Modeling Approach: Sediment

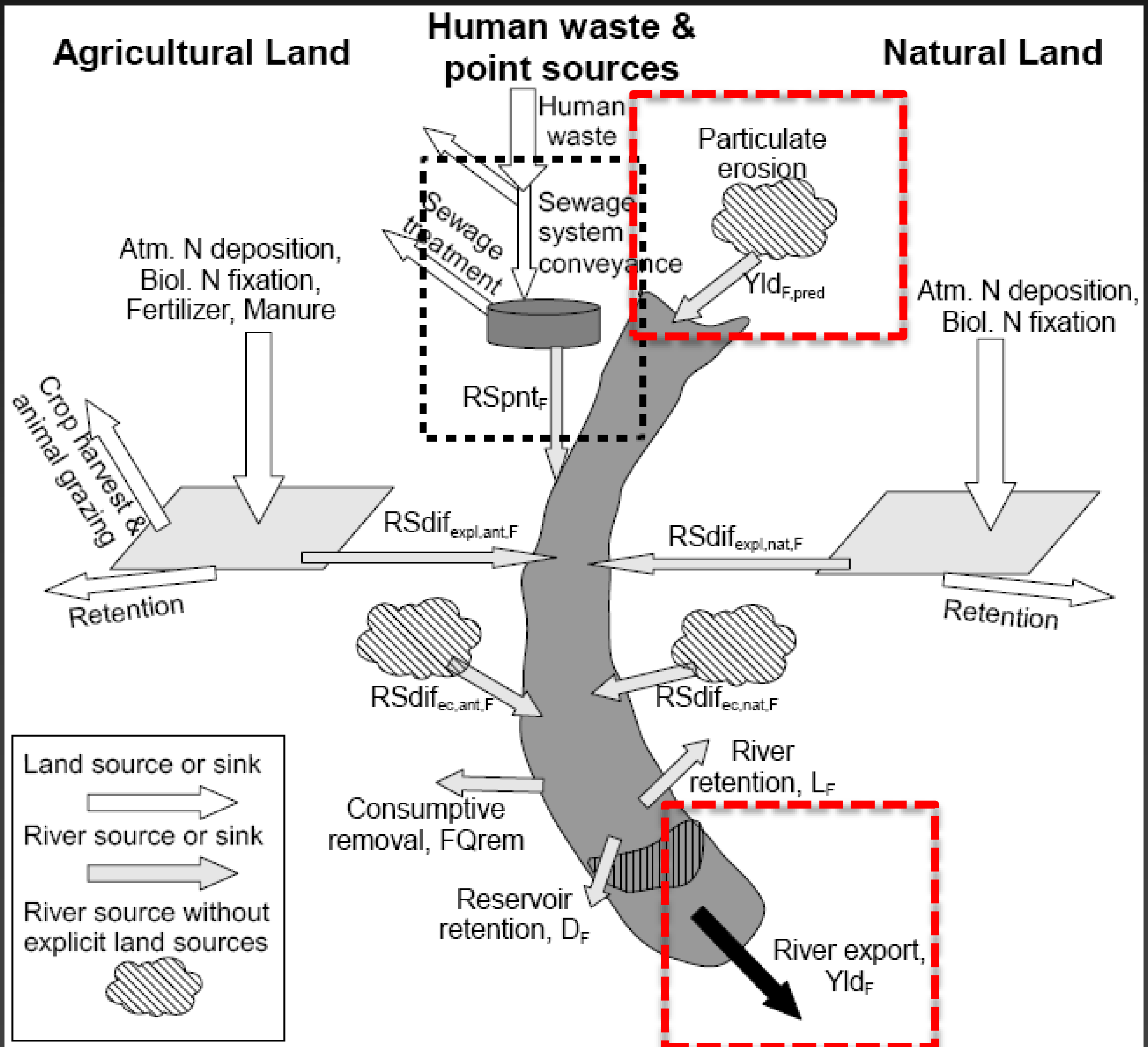
- WBMsed parameters:



Cohen et al., 2013

Modeling Approach: Nutrients

- The *WBMsedNEWS* model simulates flux of particulate Nitrogen, Phosphorus and Organic Carbon as a function of daily suspended sediment concentration.

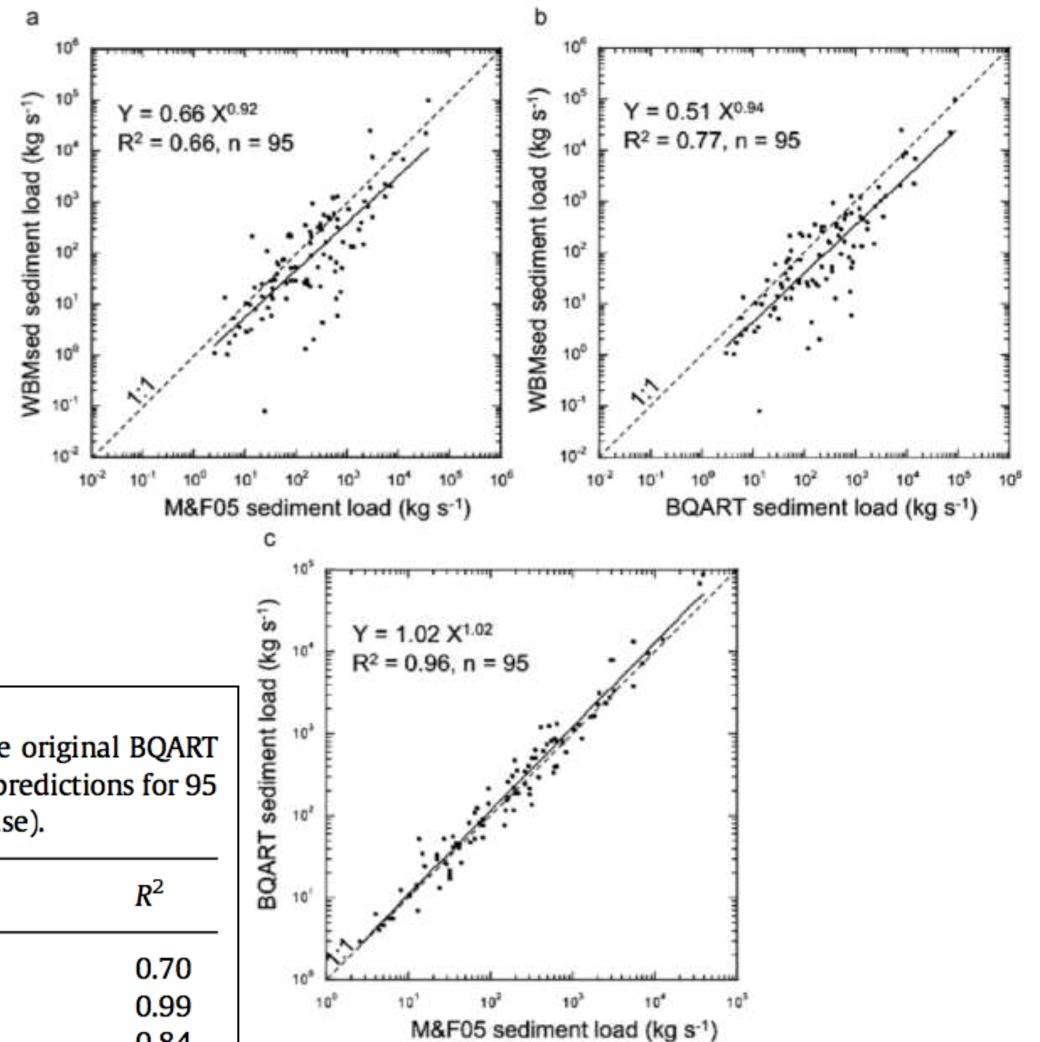


Mayorga et al. 2010, Env. Model. Soft.

Model Validation and Uncertainty

- Long-term average

$$\overline{Q}_s = wB\overline{Q}^{0.31}A^{0.5}R\overline{T}$$



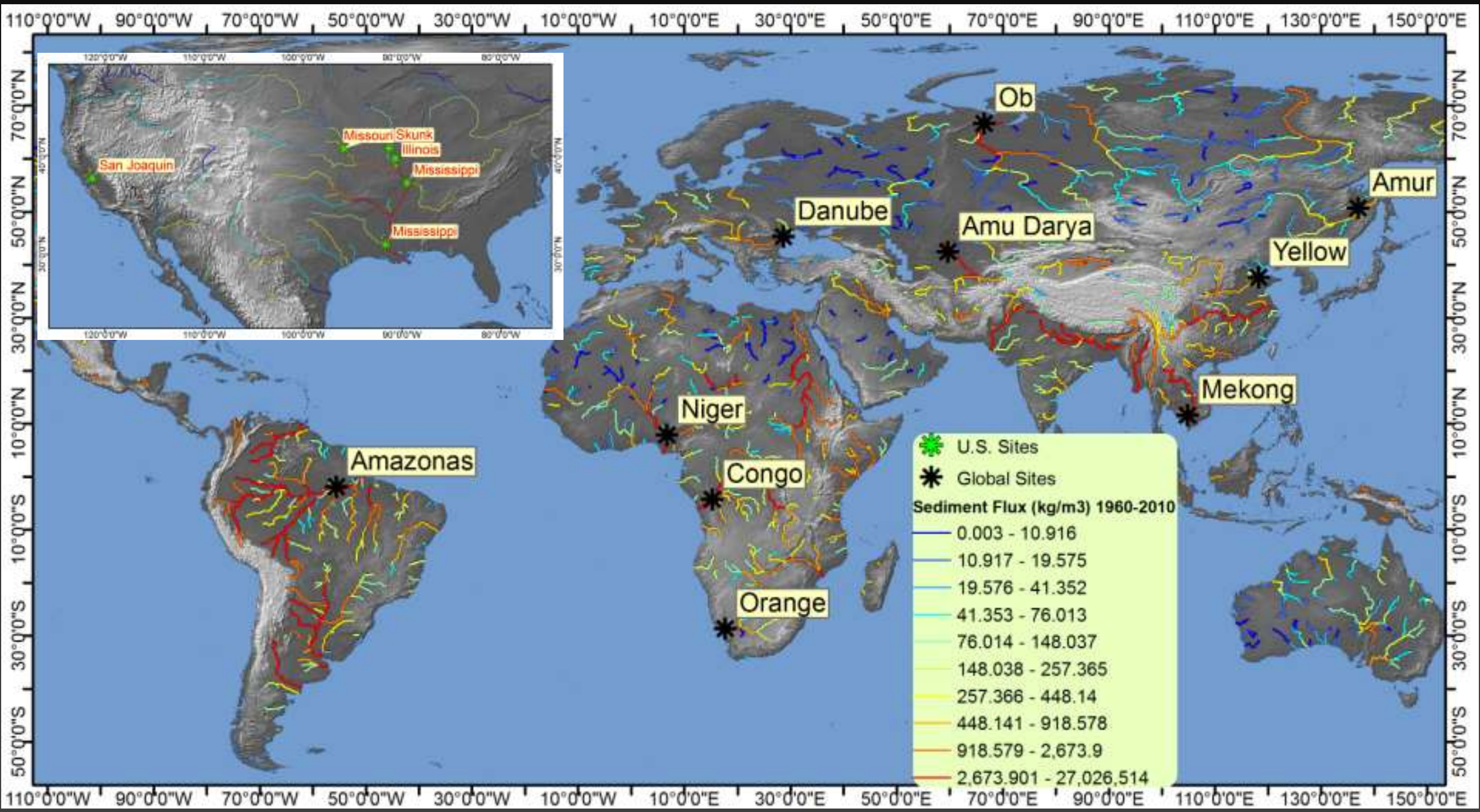
8–2007) average sediment load for 95 rivers at the river mouth (M&F05 subset) for (a) WBMsed-predicted and M&F05-observed; lculated; and (c) BQART-calculated and M&F05-observed.

Table 1
Correlation between parameters of Eqs. (4a), (4b), and (5) with the original BQART model calculations (Syvitski and Milliman, 2007) and the WBMsed predictions for 95 rivers at the river mouth (subset of the M&F05 global river database).

Parameter	R^2
Q (discharge)	0.70
Area	0.99
Relief	0.84
Temperature	0.94
B	0.10
Lithology	0.22
T_e (trapping)	0.04
E_h (human)	0.11

Cohen et al. 2013, Computers & Geosciences

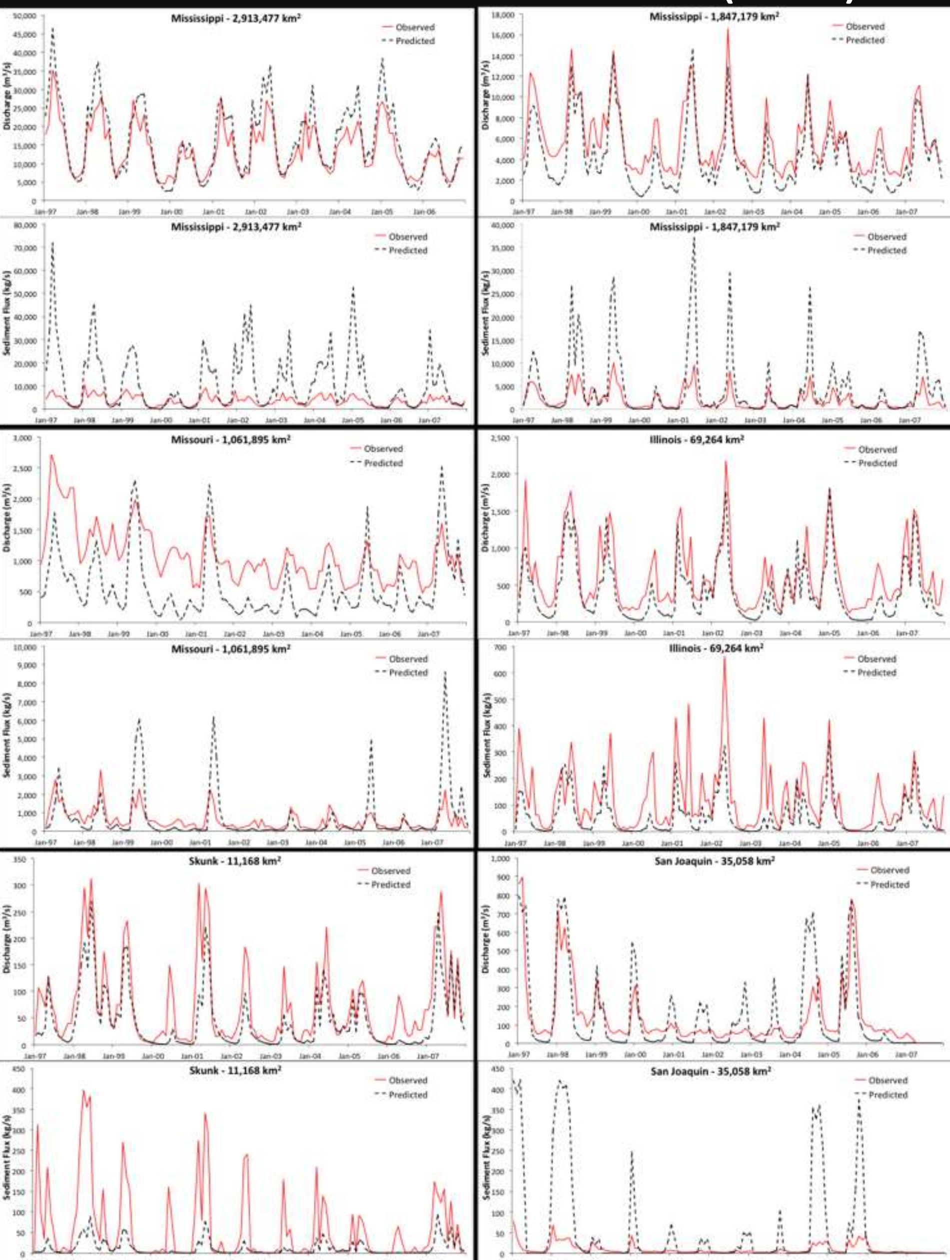
Model Validation: Water & Sediment



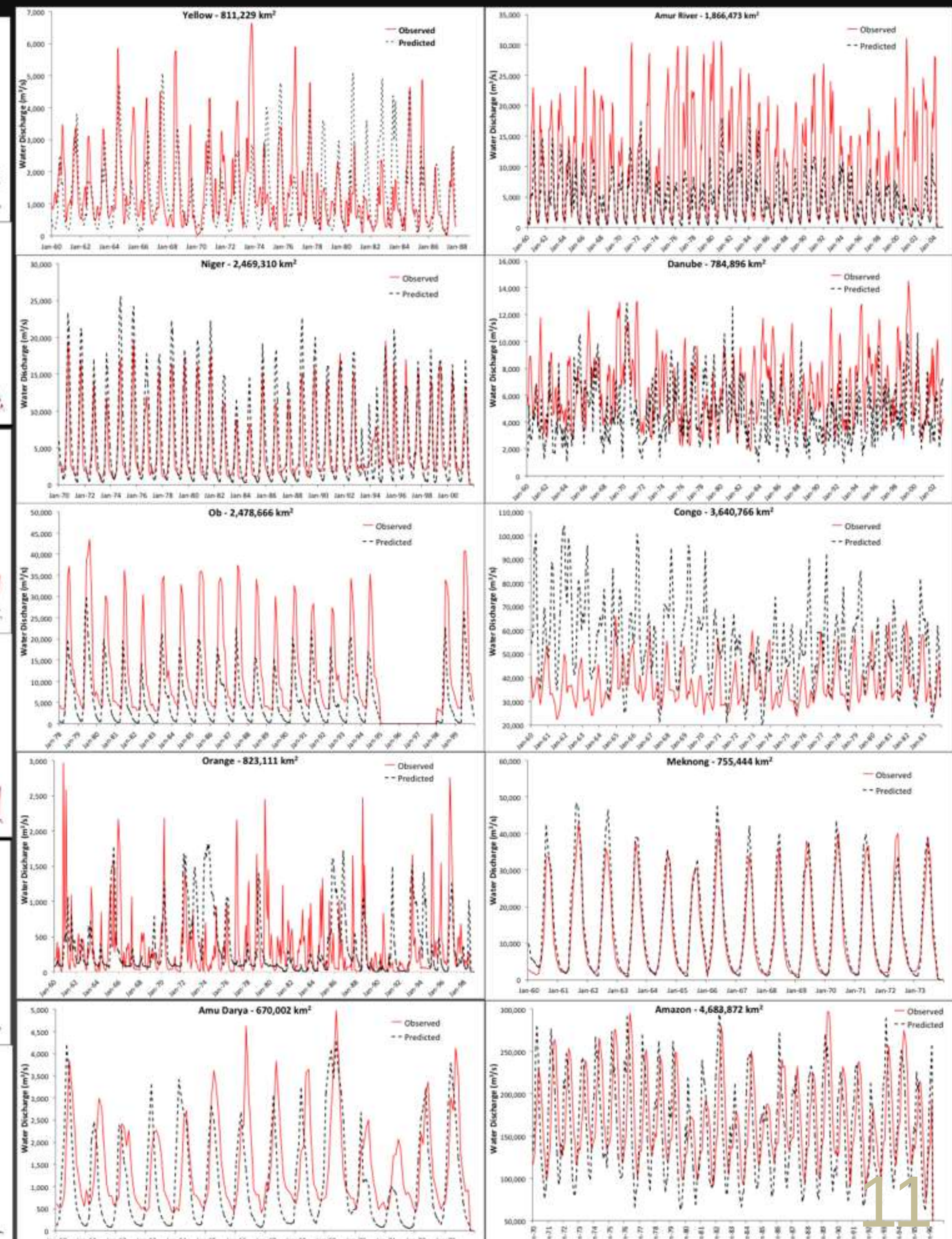
Cohen et al. 2014, Global Planetary Change

Model Validation: Water & Sediment

Water & Sediment (U.S.)

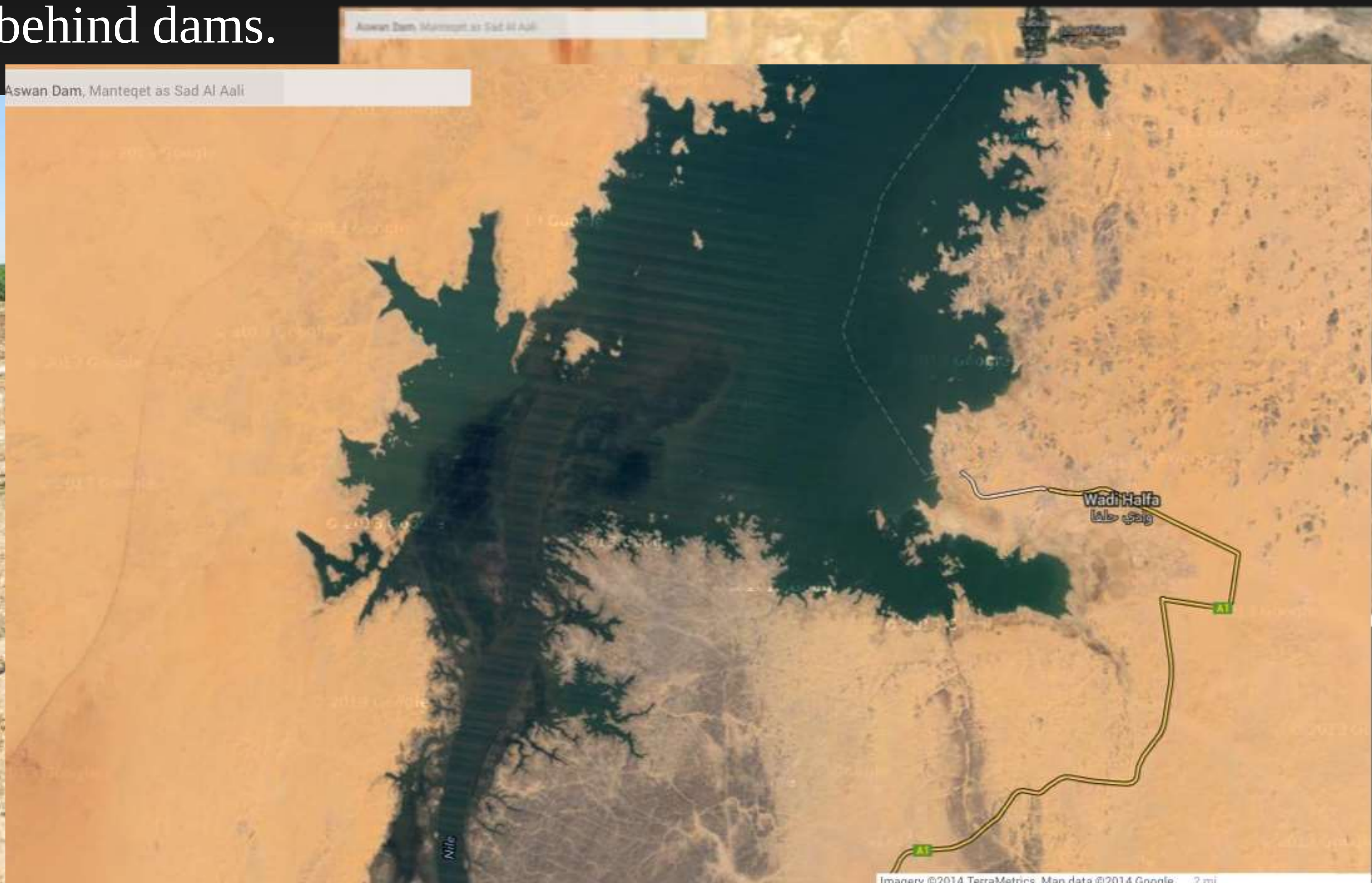


Water Discharge



Case Study 1: Anthropogenic impacts

- Humans are both ***increasing*** **sediment** flux by inducing soil erosion and ***decreasing*** fluxes by trapping sediment in reservoirs and behind dams.



Case Study 1: Anthropogenic impacts

Introduction:

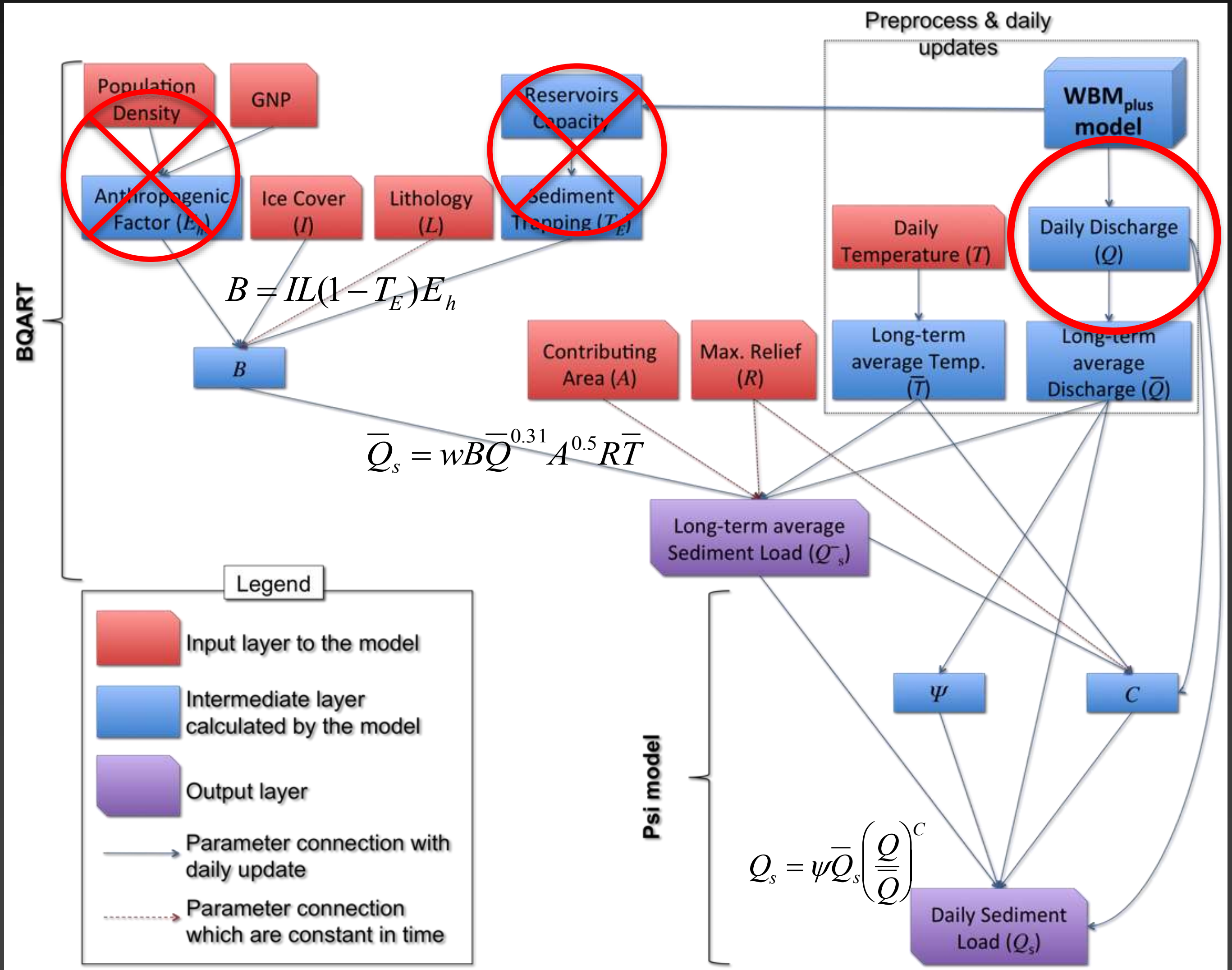
- Riverine **<u>water</u>** discharge has generally ***decreased*** due to water intake form surface and groundwater sources for domestic, industrial and agricultural activities and increased evaporation from manmade reservoirs.

- It was previously estimated that the discharge of global rivers has ***decreased*** by nearly **30%** for sediment and **3.5%** for water (Vörösmarty et al., 2003 and Döll et al., 2009 respectively).

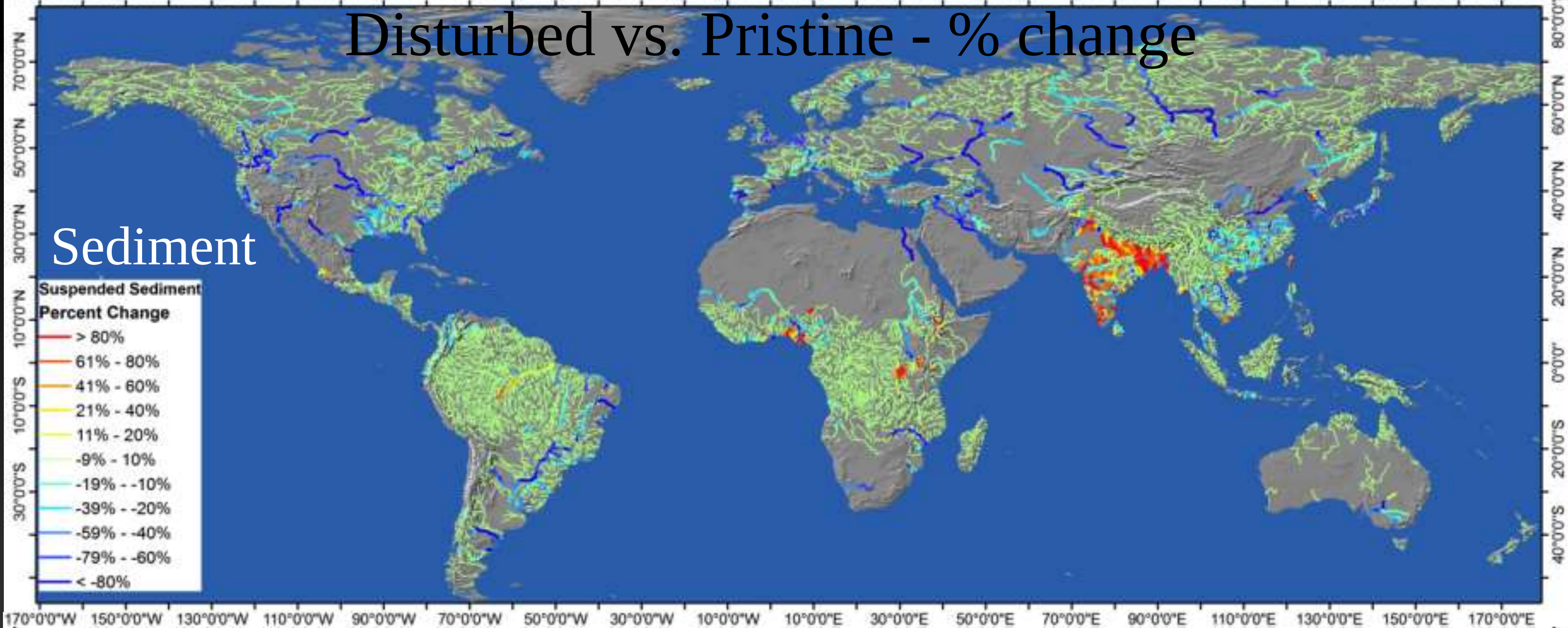
Case Study 1: Anthropogenic impacts

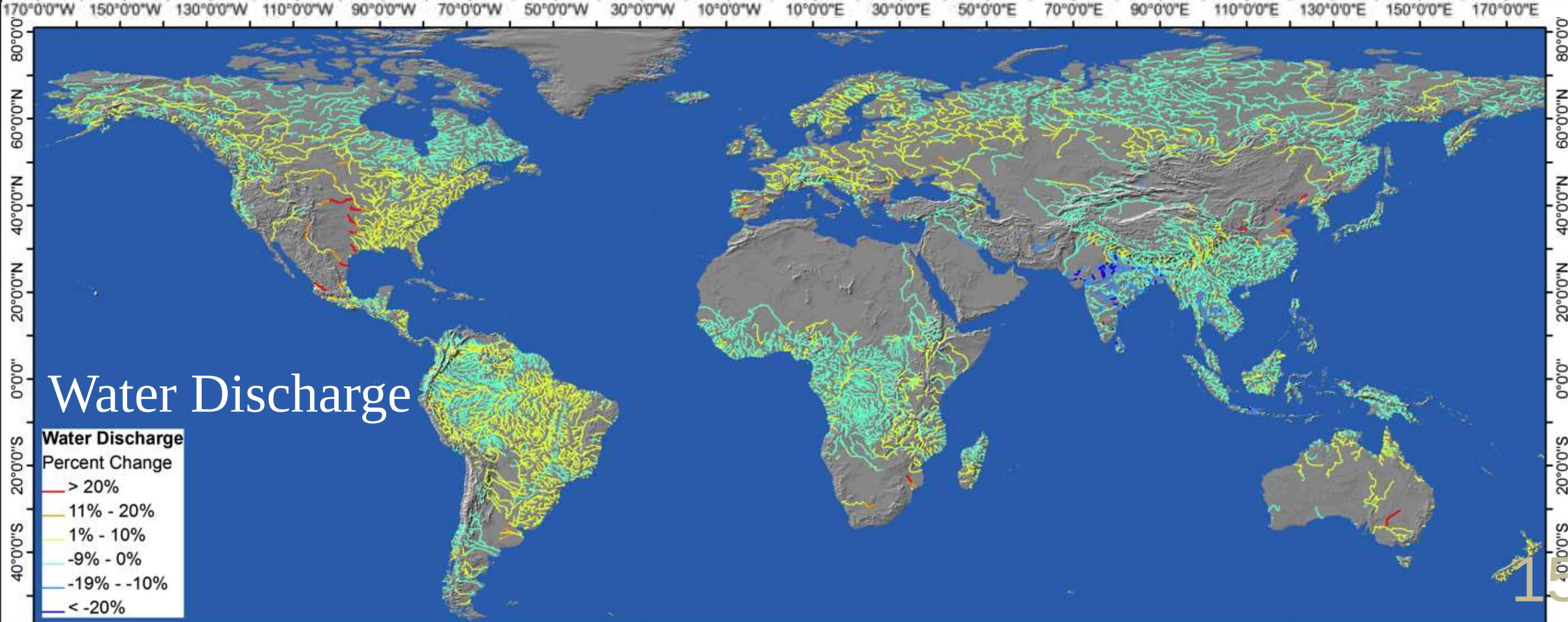
Methodology:

- Pristine vs. Disturbed

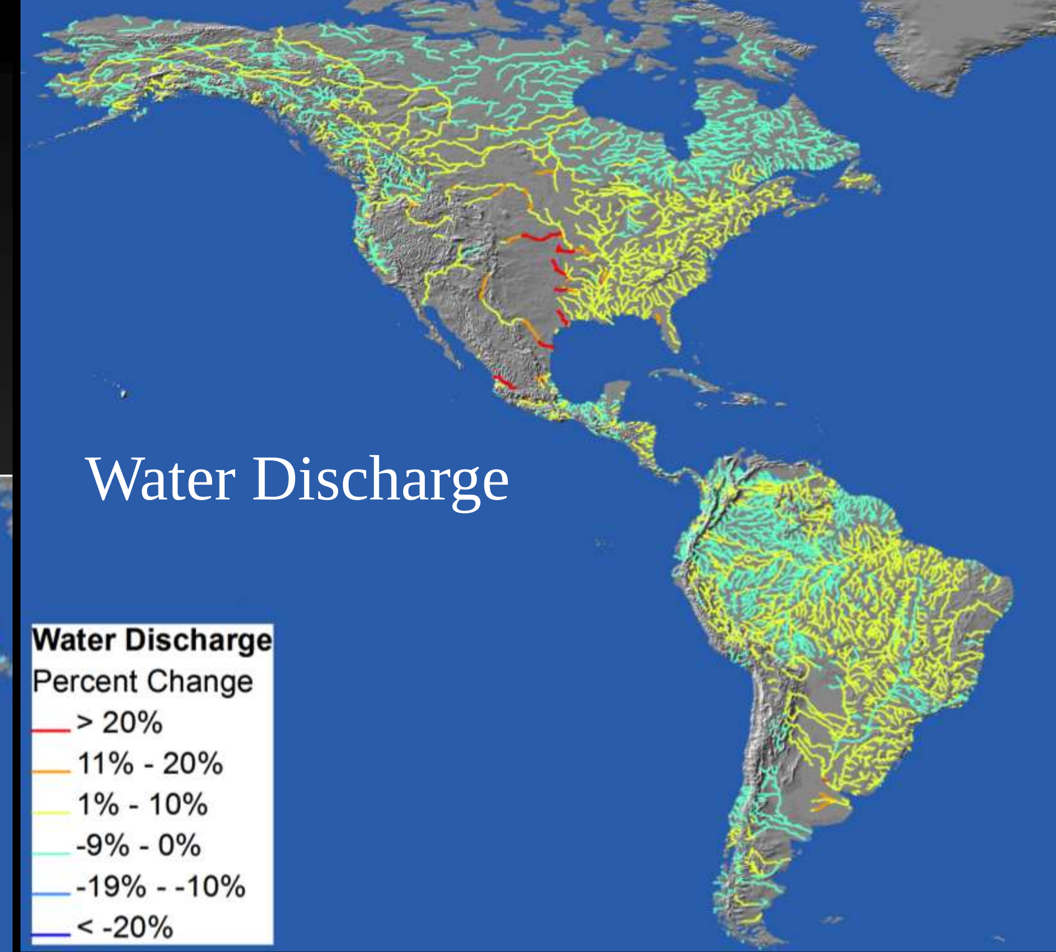


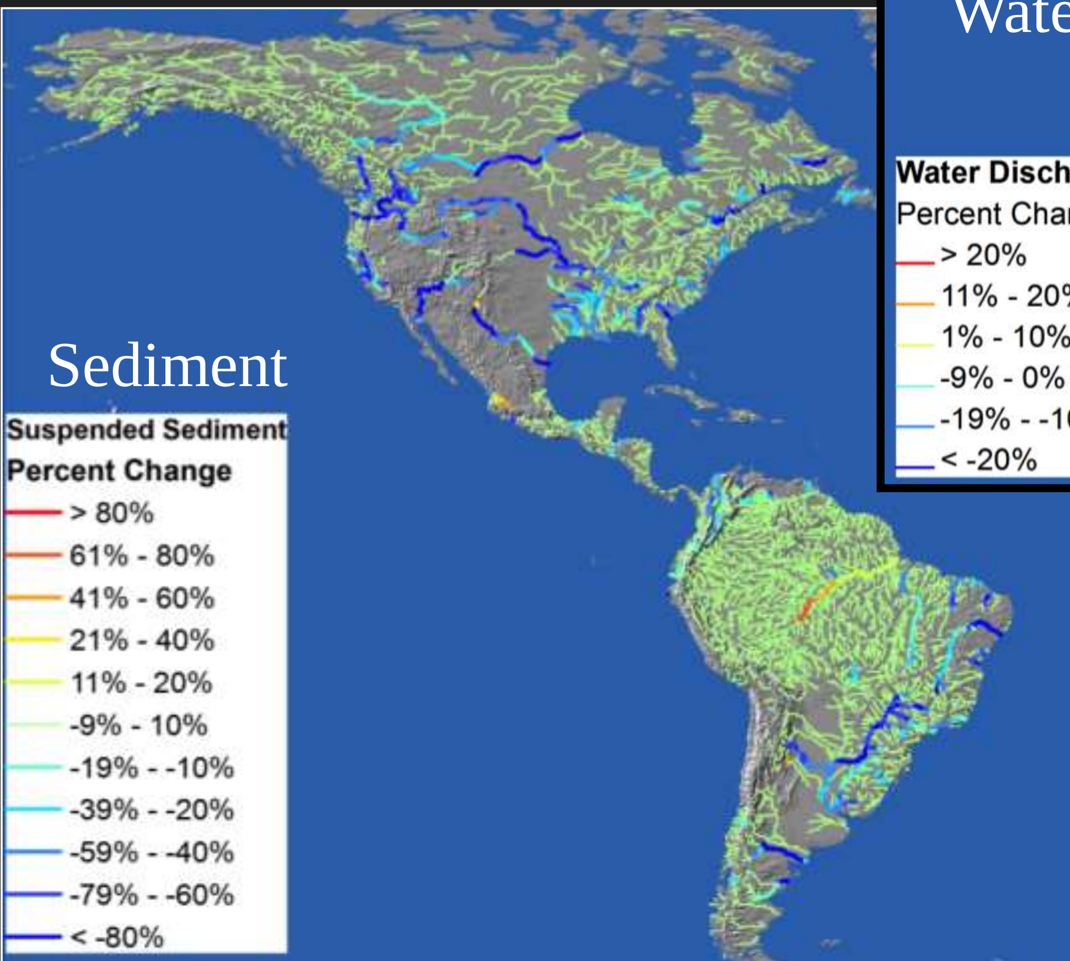
Disturbed vs. Pristine - % change





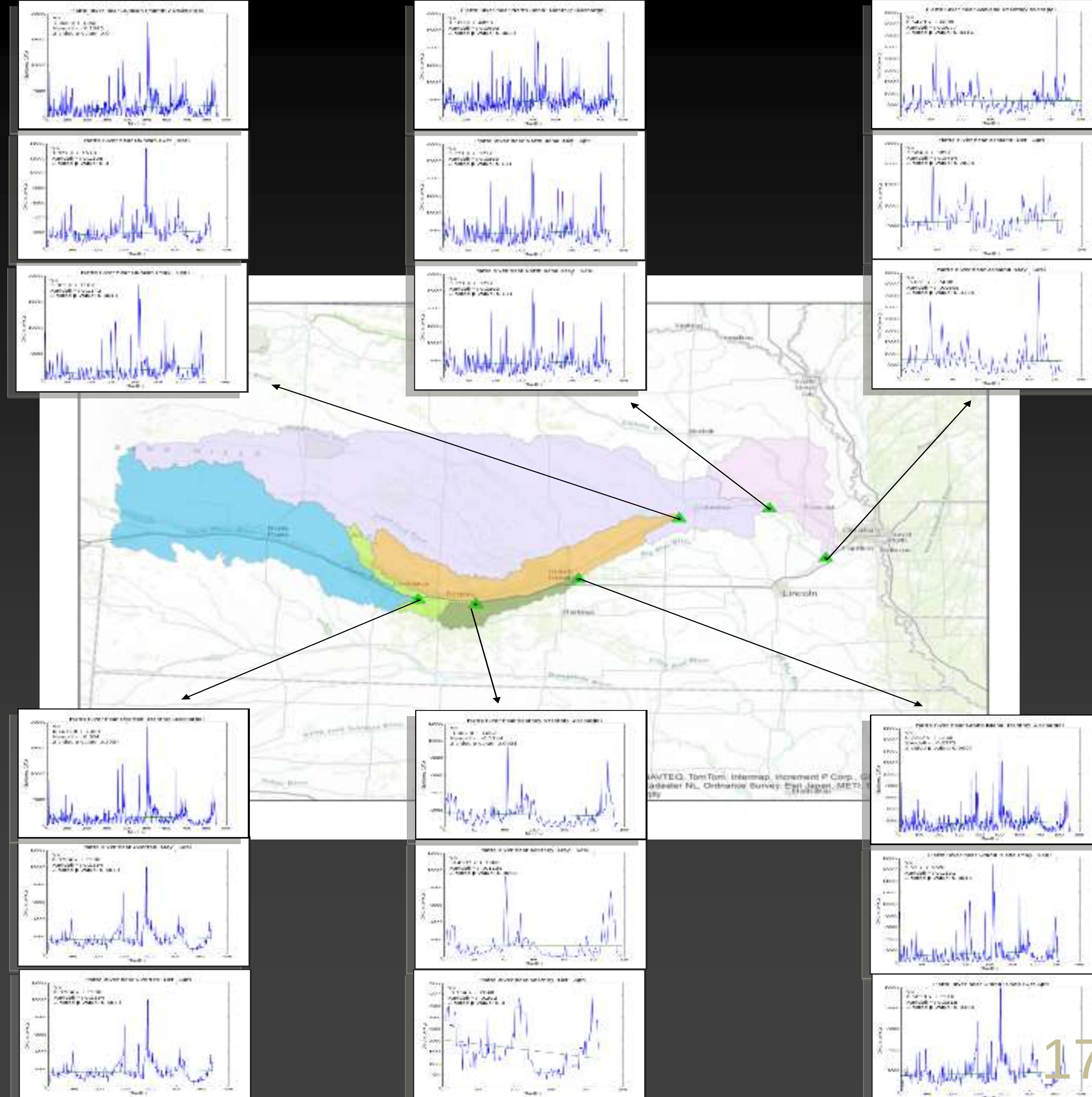
Disturbed vs. Pristine - % change





USGS Stream Gauges:
Platte River, Nebraska

Shawn Carter



Case Study 2: 50 yr Dynamics

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Global suspended sediment and water discharge dynamics between 1960 and 2010: Continental trends and intra-basin sensitivity

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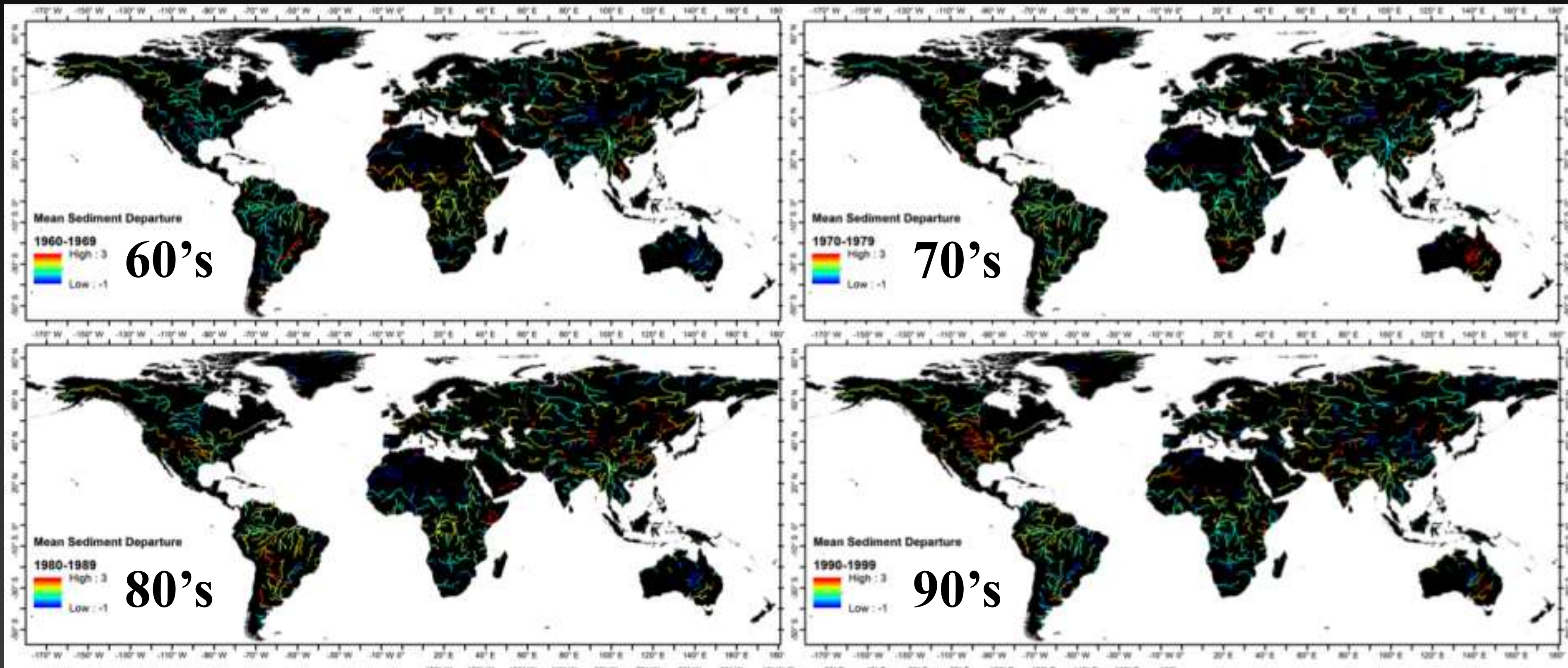
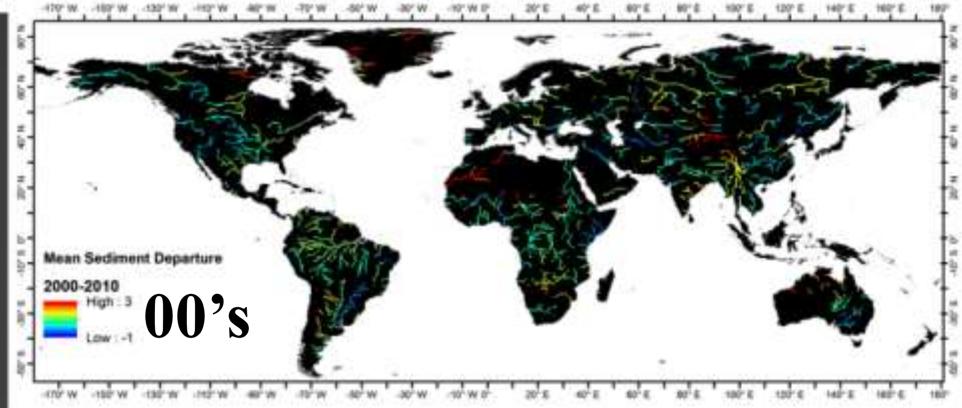
A B S T R A C T

Establishing a quantitative description of global riverine fluxes is one of the main goals of contemporary hydrology and geomorphology. Here we study changes in global riverine water discharge and suspended sediment flux over a 50-year period, 1960–2010, applying a new version of the WBMsed (WBMsed v.2.0) global hydrological water balance model. A new floodplain component is introduced to better represent water and sediment dynamics during periods of overbank discharge. Validated against data from 16 globally distributed stations, WBMsed v.2.0 simulation results show considerable improvement over the original model. Normalized departure from an annual mean is used to quantify spatial and temporal dynamics in both water discharge and sediment flux. Considerable intra-basin variability in both water and sediment discharge is observed for the first time in different regions of the world. Continental-scale analysis shows considerable variability in water and sediment discharge fluctuations both in time and between continents. A correlation analysis between predicted continental suspended sediment and water discharge shows strong correspondence in Australia and Africa (R^2 of 0.93 and 0.87 respectively), moderate correlation in North and South America (R^2 of 0.64 and 0.73 respectively) and weak correlation in Asia and Europe (R^2 of 0.35 and 0.24 respectively). We propose that yearly changes in intra-basin precipitation dynamics explain most of these differences in continental water discharge and suspended sediment correlation. The mechanism proposed and demonstrated here (for the Ganges, Danube and Amazon Rivers) is that regions with high relief and soft lithology will amplify the effect of higher than average precipitation by producing an increase in sediment yield that greatly exceeds increase in water discharge.

Case Study 2: 50 yr Dynamics

- Departure from mean

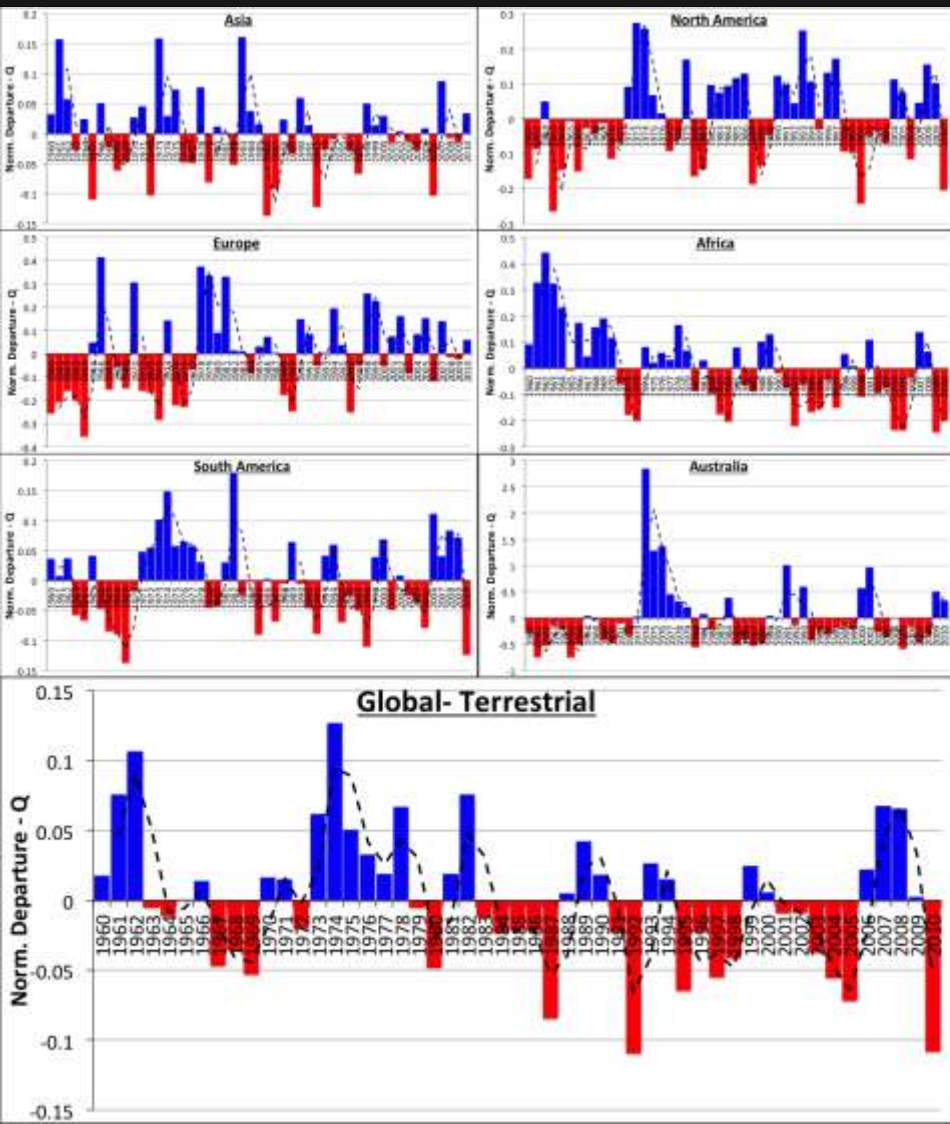




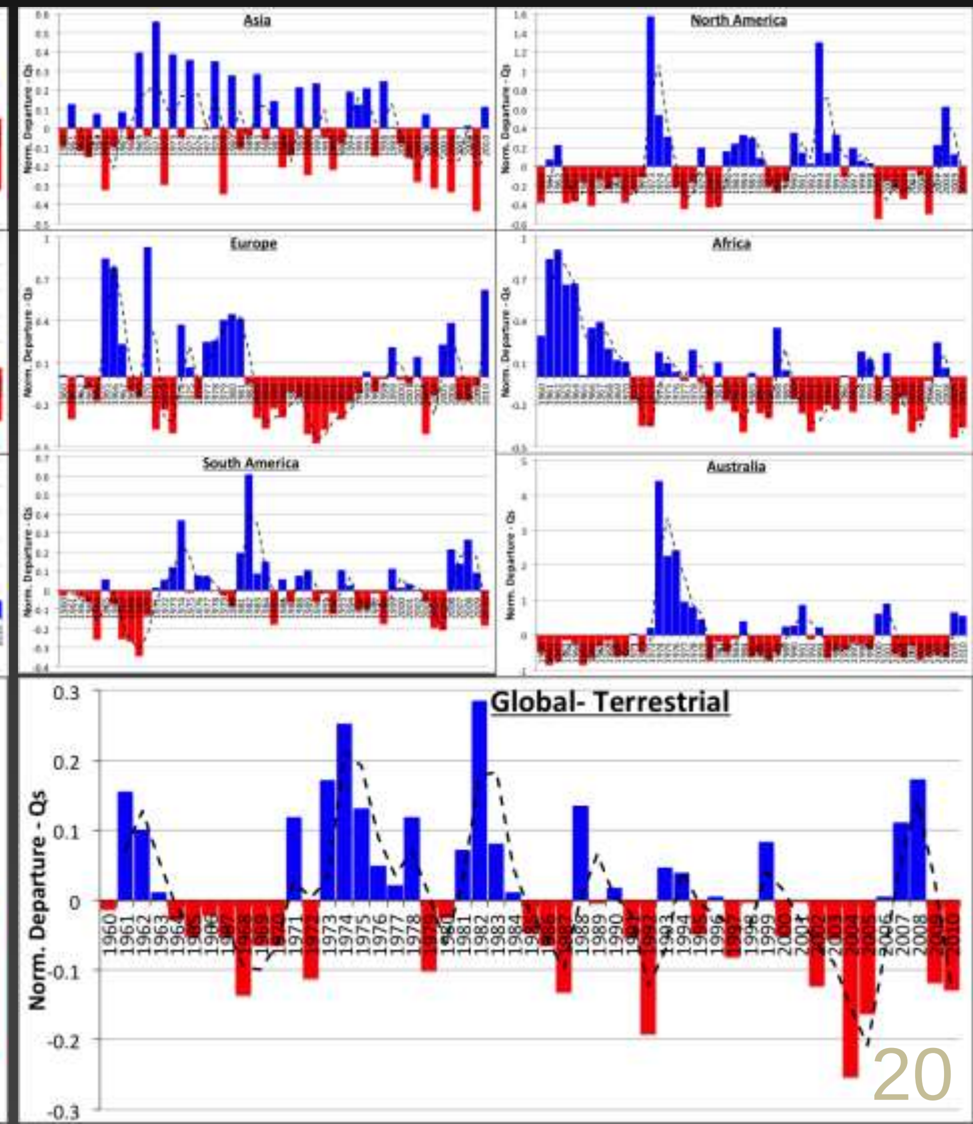
Case Study 2: 50 yr Dynamics

- Departure from mean

Water Discharge



Sediment Flux



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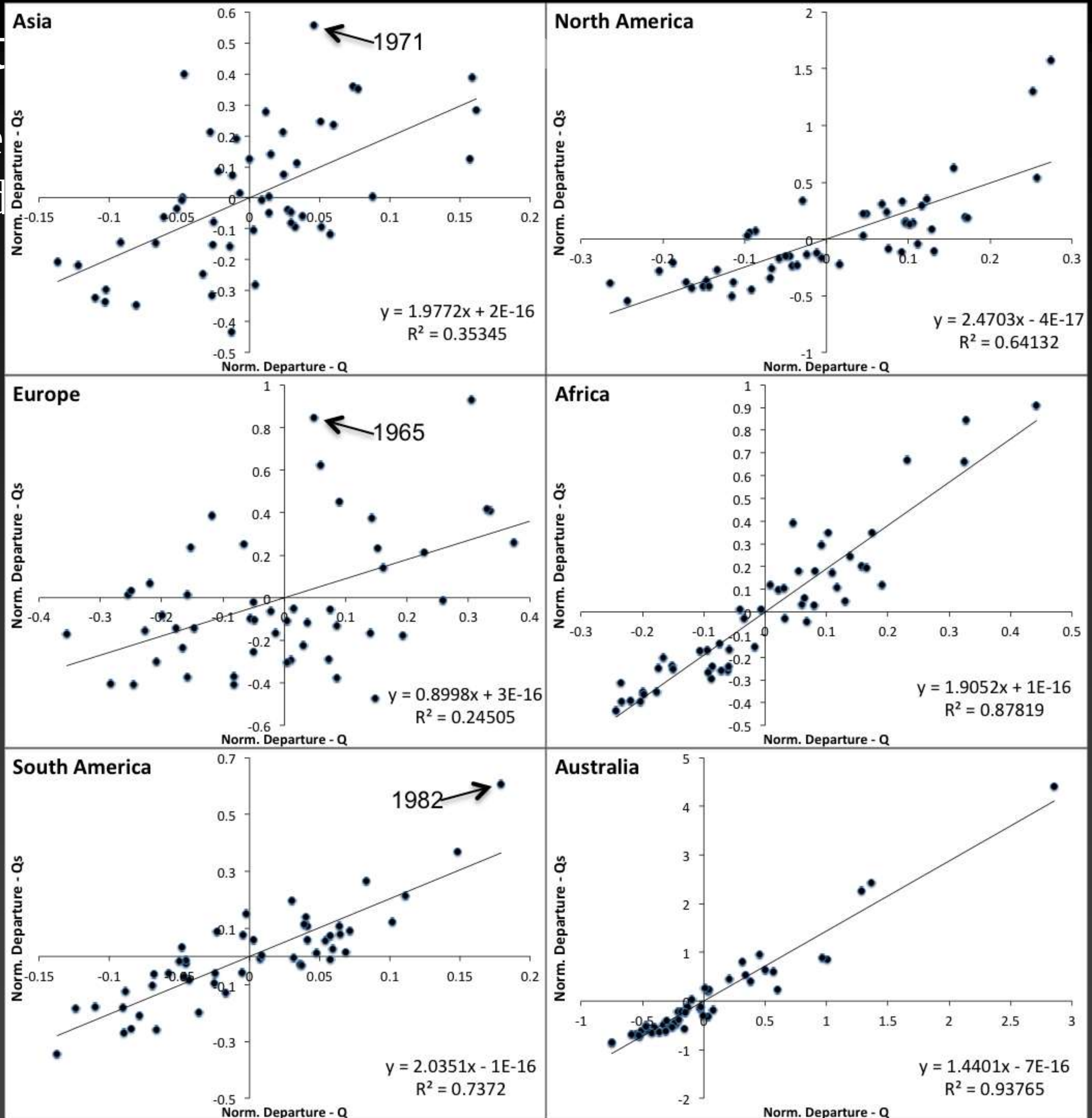
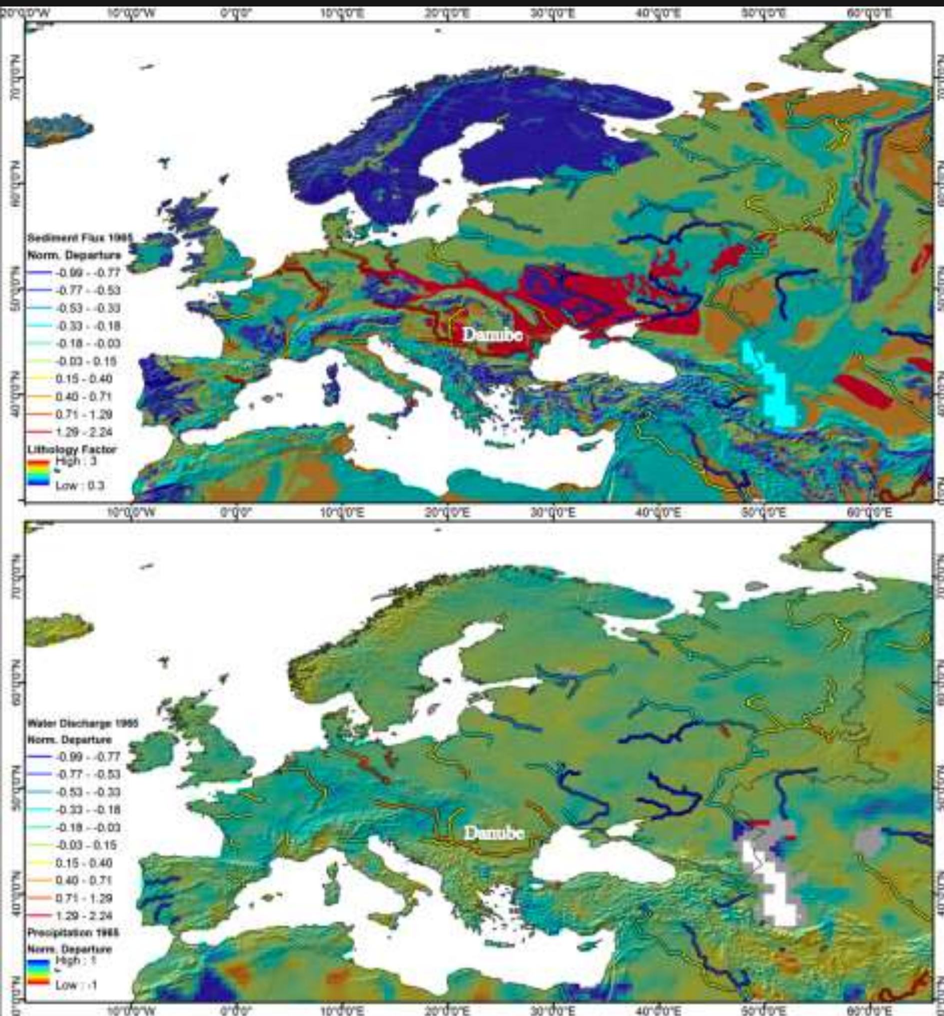
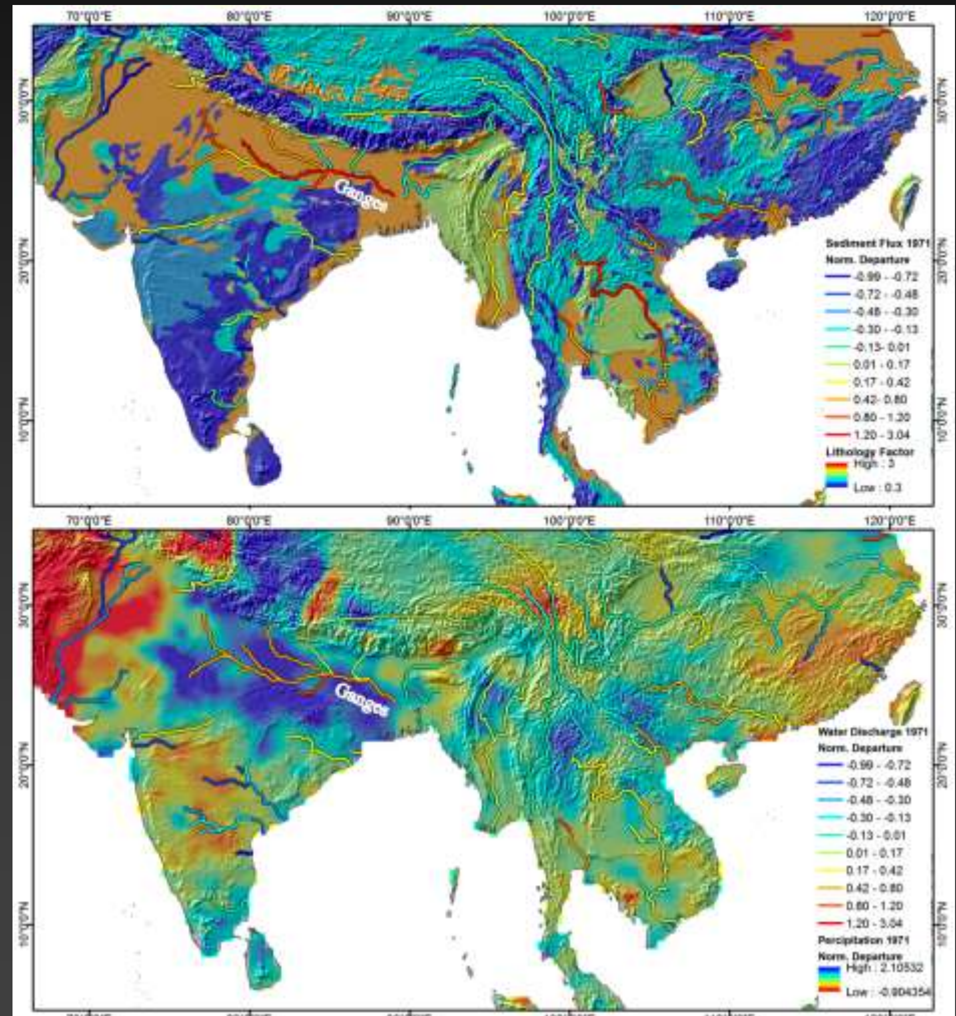


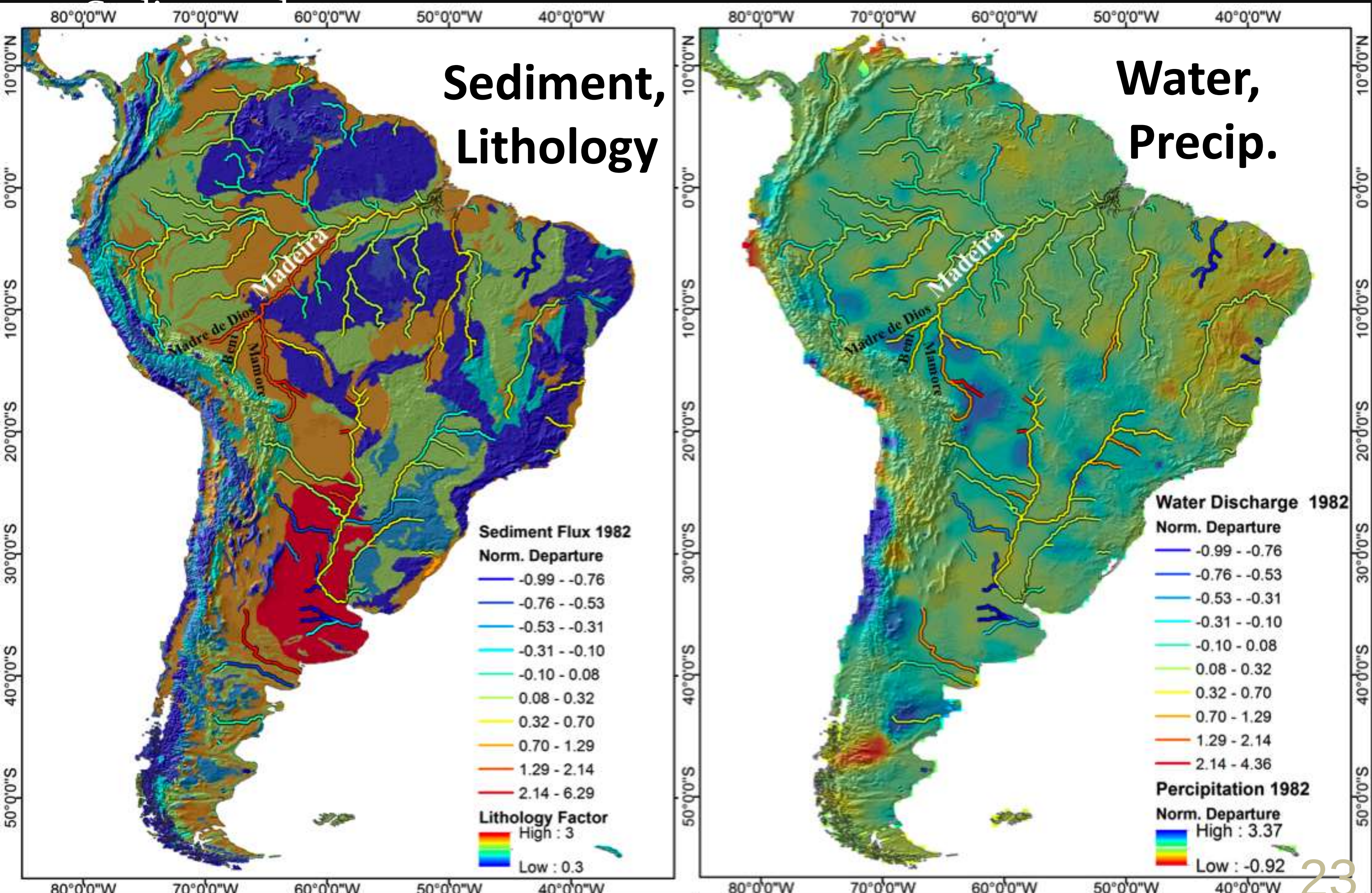
Case Study 2: 50 yr Dynamics

- Sediment, Water, Lithology, Precipitation





Case Study 2: 50 yr Dynamics



Case Study 2: 50 yr Dynamics

- Intra-basin patterns of precipitation can enhance or dampen sediment yield as a function of relief and lithology.

- Years with above average precipitation in high relief and soft lithology regions will yield a sediment flux that significantly exceeds increases in water discharge.

- As future climate change is expected to significantly change precipitation, land-use and vegetation patterns, our results suggests that sediment, nutrients and water discharge dynamics may be altered in nontrivial ways.