Modeling global scale Sediment Flux, a new component in the spatially distributed Framework for Aquatic Modeling of Earth System (FrAMES)

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Introduction

The Framework for Aquatic Modeling of Earth System (FrAMES) is a spatially and temporally explicit multi-scale (local through global) hydrological/biogeochemical modeling scheme (Wollheim et al., 2008). FrAMES is an ongoing interdisciplinary project, modeling varying aspects of river flux response to changing environmental conditions. Here we present a new component within this framework, a spatially explicit sediment flux model.

Methodology

We expend the BQART sediment flux model from point (river outlet) to distributed (pixel) scale by integrating it into the WBM_{plus} continental hydrology model (an integral part of the FrAMES scheme).

The BQART model

An analytical model describing the empirical relationship between basin geomorphology, climatology, geology, human characteristics and long-term sediment flux (Syvitski and Milliman, 2007; Fig. 1):

$$\overline{Q}_s = wB\overline{Q}^{0.31}A^{0.5}R\overline{T} \quad \text{(Eq. 1)}$$

where

w – **0.02** [-]

$\overline{Q}_s$ –long-term **Average Suspended Sediment** load [kg/s]

$\overline{Q}$ – long-term **Average Discharge** [m^3/s]

A – contributing **Area** [km^2]

R – maximum **Relief** [km]

$\overline{T}$ – long-term average **Temperature** [^{0}C]

$$B = IL(1-T_E)E_h \quad \text{(Eq. 2)}$$

$I = 1+0.09A_g$ (Ag is percentage of **Ice Cover**)

L – **Lithology** Factor

T_E –**Sediment Trapping** by reservoirs

E_h –**Anthropogenic** Factor: *f*(**Pop. density**, **GNP**)

Daily suspended Sediment load (Q_s) is predicted with the **Psi** model (Morehead et al., 2003; Fig. 1):

$$Q_s = \psi\overline{Q}_s\left(\frac{Q}{\overline{Q}}\right)^C \quad \text{(Eq. 3)}$$

where

Q - **Daily Discharge** [m^3/s]

$$\sigma(\psi) = 0.763(0.99995)^{\overline{Q}}$$

C – yearly random variable with mean (C_m) and StdDev deviation (s):

$$C_m = 1.4-(0.025\overline{T})+(0.00013R)+0.145\ln(\overline{Q}_s) \quad \text{(Eq. 4)}$$

$$s = 0.17+(0.0000183\overline{Q}) \quad \text{(Eq. 5)}$$

The BQART/WBM model

WBM_{plus} is a spatially explicit model describing varying components of the global hydrological cycle (Wisser et al., 2010). BQART was integrated as a new component in the WBM_{plus} platform to allow spatially explicit calculations of sediment flux at a global scale (the **BQART/WBM** model).

As BQART is a basin-outlet model, BQART/WBM consider each pixel as a local outlet of its upstream contributing area.

The BQART/WBM model has two phases. The first phase generate the long-term average temperature and discharge values (illustrated in the '**Preprocess**' frame in Fig. 1) needed for calculating **Average long term Sediment Flux** ($\overline{Q}_s$; Eq. 1). The second phase calculate the **Daily Sediment Flux** (Q_s) values with the **Psi model** (Eq. 3).

BQART/WBM make use the **Daily Discharge** (Q) and **Reservoirs Capacity** (to determine T_E; Eq. 2) modules of WBM_{plus} (Fig. 1).

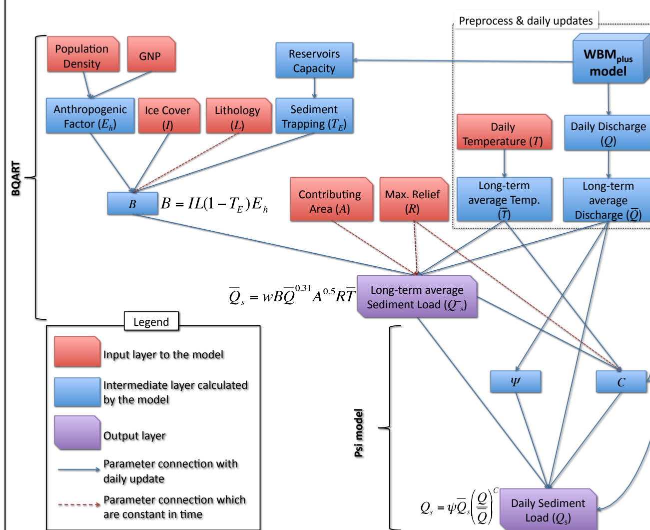

Figure 1. Flowchart of the sediment flux module in the BQART/WBM model.3

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Results

The BQART/WBM model is still in development and yet to be fully validated. We present two yearly-averaged (1976 and 2000) global-scale sediment flux maps from a daily 49 years test-run (1960-2009 at 30 minute spatial resolution).

Some notable differences between the two maps:

- Higher sediment flux in Africa's major rivers (Nile and Zaire/Congo) in 1976;
- Higher sediment flux in Northern Asia (Ob River) in 2000;
- Higher sediment flux in the Middle-East (Tigris-Euphrates system) in 1976;
- Higher sediment flux at the lower Colorado River in 1976;

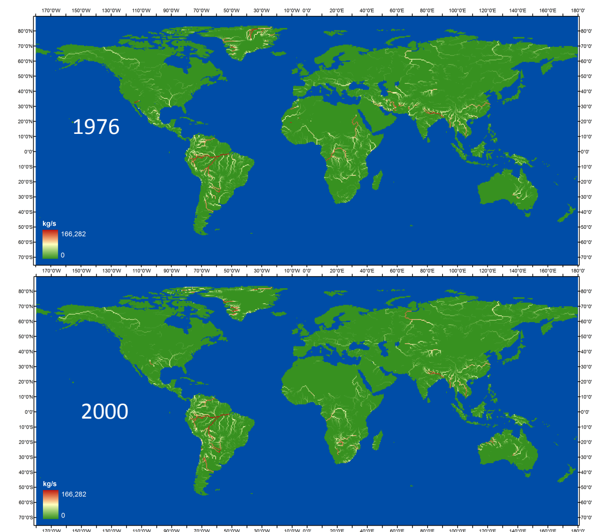

Figure 2. Two yearly-averaged sediment flux (kg/s) maps (30 minutes spatial resolution) from a daily time-step 49 years test run of BQART/WBM. Top map is for the year 1976 and the bottom map for the year 2000.

Applications and future development

Distributed sediment flux predictions are useful for a wide array of scientific and engineering applications (e.g. carbon cycle predictions and infrastructure design).

The BQART/WBM model will soon be applied with higher spatial resolution and will be used to test scenarios of future environmental changes (e.g. climate, land-use). In the next couple of years we intend to further develop the model by adding a bedload sediment transport component and introduce more physically-based equations to better account for the spatio-temporal variability of the sediment transport processes.

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