**Supporting information**

**Coupling global models for hydrology and nutrient loading to simulate nitrogen and phosphorus retention in surface water. Model description and analysis of performance**

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**Description of the measurement data**

**Rhine**

Measurements once per two weeks from 1 January 1970 to present at station Lobith at the Dutch-German border (light blue line, Figure 2, main text). The discharge is available from 1989 onwards. The average yearly concentration is weighted with discharge (dark blue line in Figure 2, main text) ([Ministry of Infrastructure and Environment, 2013](#_ENREF_4)).

**Meuse**

Measurements once per two weeks from 1 January 1970 to 2012 (light blue line, Figure 2, main text) at station Eijsden at the Dutch-Belgian border. The average yearly concentration is weighted with discharge (dark blue line in Figure 2, main text) ([Ministry of Infrastructure and Environment, 2013](#_ENREF_4)).

**Mississippi**

Measurements with varying frequency (within one station it may vary between 3 and 28 observations per year) for 1970-2015 at USGS stations listed in Table 4, main text (Mississippi River at Clinton, IA., Ohio river at dam 53 near Grand Chain, ILL., Mississippi river below Alton, Ill., Red river near Alexandria, LA., Mississippi river at Thebes, ILL., Mississippi river below Grafton, ILL., Ohio river at Cannelton dam, KY., Missouri river at Omaha, NE., Missouri river at Hermann, MO., Arkansas river at David D. Terry L&D BL Little Rock, AR., Mississippi river near St. Francisville, LA.). Data from [United States Geological Survey (2013](#_ENREF_5)). The average yearly concentration is weighted with discharge (see e.g. dark blue line in Figure 2, main text).

**European rivers**

The full database for European rivers is from *European Environment Agency* ([2013](#_ENREF_1)) (<http://www.eea.europa.eu/data-and-maps/data/waterbase-rivers-9>; version 13, dd. 11 October 2013). We selected measurements data for total N and total P concentrations for stations in rivers with an upstream catchment area > 10,000 km2. Each entry in the database contains information on the measurement station (id, name, location, longitude, latitude and river name) and year, minimum, maximum, median and mean of the concentration. We used 1809 measurements for years prior to the year 2001.

The location of the station (longitude, latitude) and year is used to collect the simulated annual N and P concentrations from 0.5 by 0.5 degree grid cells of the model.

A first comparison is made and the residues of the difference between simulated and measured concentration re-examined. Some rivers could not be matched with the model schematization, others were removed as outliers based on Cooks distance, qqplot and linear regression. A total of 11 stations were thus removed (in the order they are given) from the dataset (Table SI6).

The location of the first and second river which has been excluded (SE\_\* and HU\_\*) do not match the model schematization. The Motala Ström drains lake Vättern into Baltic Sea, but in the hydrological schematization this river starts at this location without the water from lake Vättern. The same holds for the Csaszarviz, which is located next to the main stream of the Danube, but has no water import from other grid cells. Furthermore, 8 Spanish and one German rivers are outliers. The resulting database contains 1690 measurements, including 49 stations for N with 709 N concentration measurements and 76 stations with 981 measurements for P concentrations.

**Global rivers**

Data on total N discharge at the river mouth compiled by Meybeck and Ragu ([1995](#_ENREF_3)) contains relevant information only a limited number of rivers. We excluded data in cases where the literature source was not provided. The final set of data on annual mean total N concentration comprises 38 rivers. Although this is a limited number, the selected rivers represent a variety of basin sizes and climates and a broad range of population densities and agricultural activity. A major shortcoming of the total N discharge data is the absence of upstream data, which would allow us to test our model at various points in the course of a river. For the Amazon we use data on N and P discharge presented by Forsberg et al. ([1988](#_ENREF_2)).

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| Table SI1. Measurement stations from the EEA database that were removed based on Cooks distance, qqplot and lineair regression. | | | | |
| Id | rivername | nutrients | years | Number of measurements |
| SE\_RV\_SE649673-151838 | Motala Ström | N/P | 1970 - 2000 | 62 |
| HU\_RV\_04FV12 | Csaszarviz | N/P | 1987- 2000 | 28 |
| ES\_RV\_ES08120 | Tuejar | P | 1994 - 1996 | 3 |
| ES\_RV\_ES02046 | Adaja | P | 1994 | 1 |
| ES\_RV\_ES08067 | Canoles | P | 1994 | 1 |
| ES\_RV\_ES08202 | Turia | P | 1994 | 1 |
| ES\_RV\_ES01186 | Agϋera | P | 1995 - 1996 | 2 |
| ES\_RV\_ES01346 | Nalon | P | 1995 - 1996 | 2 |
| DE\_RV\_BE01 | Spree | N/P | 1994 - 2000 | 14 |
| ES\_RV\_ES08036 | Jucar | P | 1994, 1996 | 2 |
| ES\_RV\_ES08112 | Cabriel | P | 1994 - 1996 | 3 |

**Literature**

Waterbase rivers Version 13 (<http://www.eea.europa.eu/data-and-maps/data/waterbase-rivers-9)>, access: 13 October 2013, 2013.

Forsberg, B. R., Devol, A. H., Richey, J. E., Martinelli, L. A., and Dos Santos, H.: Factors controlling nutrient concentrations in Amazon floodplain lakes, Limnology & Oceanography, 33, 41-56, 1988.

Meybeck, M., and Ragu, A.: River discharges to oceans: An assessment of suspended solids, major ions and nutrients, United Nations Environment Programme (UNEP), 245, 1995.

Ministry of Infrastructure and Environment: [http://live.waterbase.nl/waterbase wns.cfm?taal=nl](http://live.waterbase.nl/waterbase_wns.cfm?taal=nl) (in Dutch). Accessed 1 March 2013. Ministry of Infrastructure and Environment (Rijkswaterstaat), The Hague, The Netherlands, 2013.

United States Geological Survey: Water Quality Samples for the Nation (<http://waterdata.usgs.gov/nwis/qwdata)>, U.S. Geological Survey, 2013.