

The suspended sediment load in the North Caucasus mountains primarily decreased at an average rate of **−1.2% per year** throughout the entire XXth century. After **1988–1994**, the rate increased significantly to **−12%.**

Insights into spatial and temporal changes in suspended sediment yield in the Caucasus Mountains during the Anthropocene

ANATOLII TSYPLENKOV^{1,2} tsyplenkova@landcareresearch.co.nz
VALENTIN GOLOSOV^{2,3,4}

¹ Manaaki Whenua Landcare Research, Palmerston North, New Zealand
² Lomonosov Moscow State University, Faculty of Geography, Moscow, Russia
³ Institute of Geography of the Russian Academy of Sciences, Laboratory of Geomorphology, Moscow, Russia
⁴ Kazan Federal University, Kazan, Russia

Regional suspended sediment yield dynamics

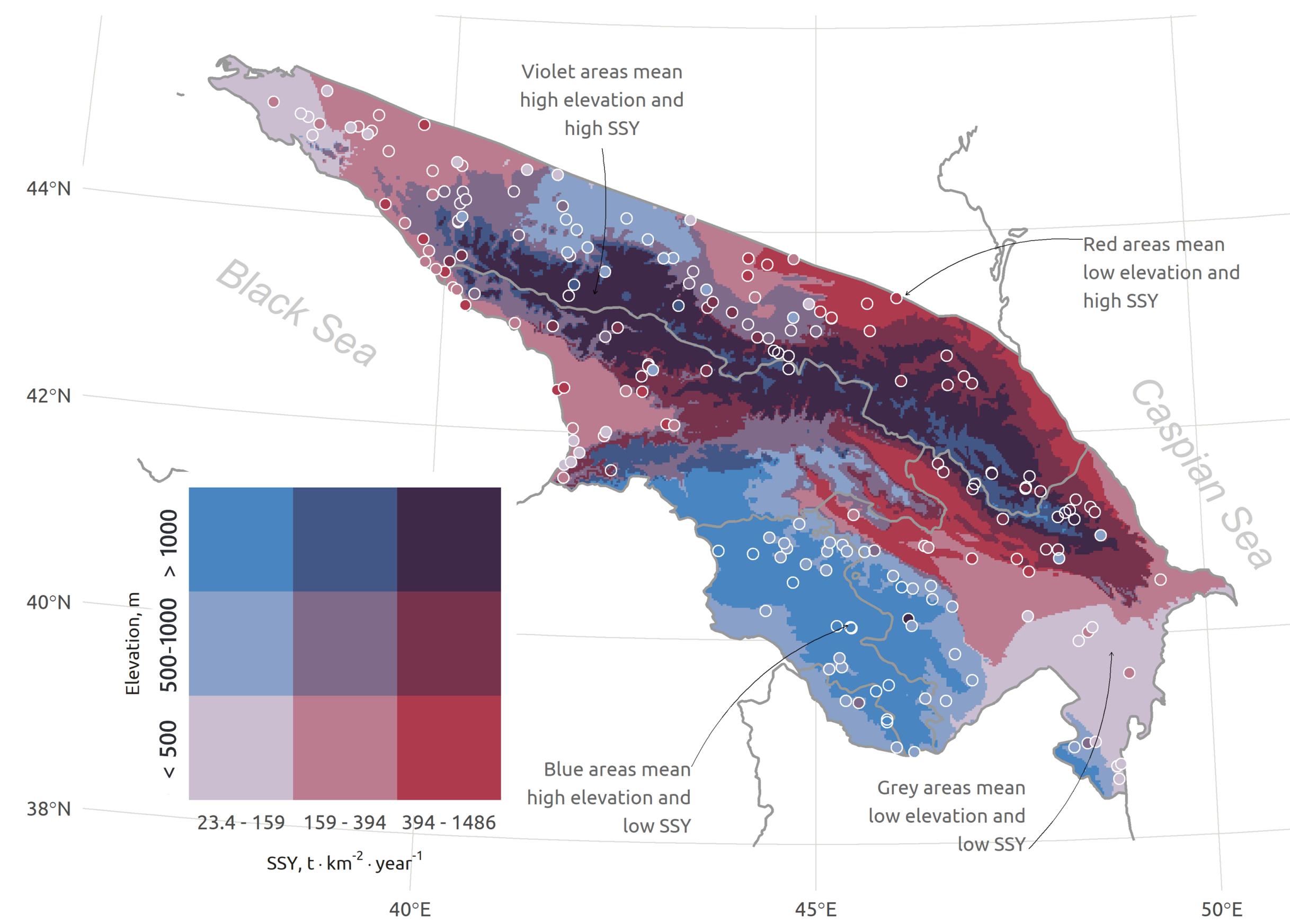


Figure 1. Spatial patterns of estimated SSY for the Caucasus Region based on mean interannual values

How did suspended sediment load change during the Anthropocene?

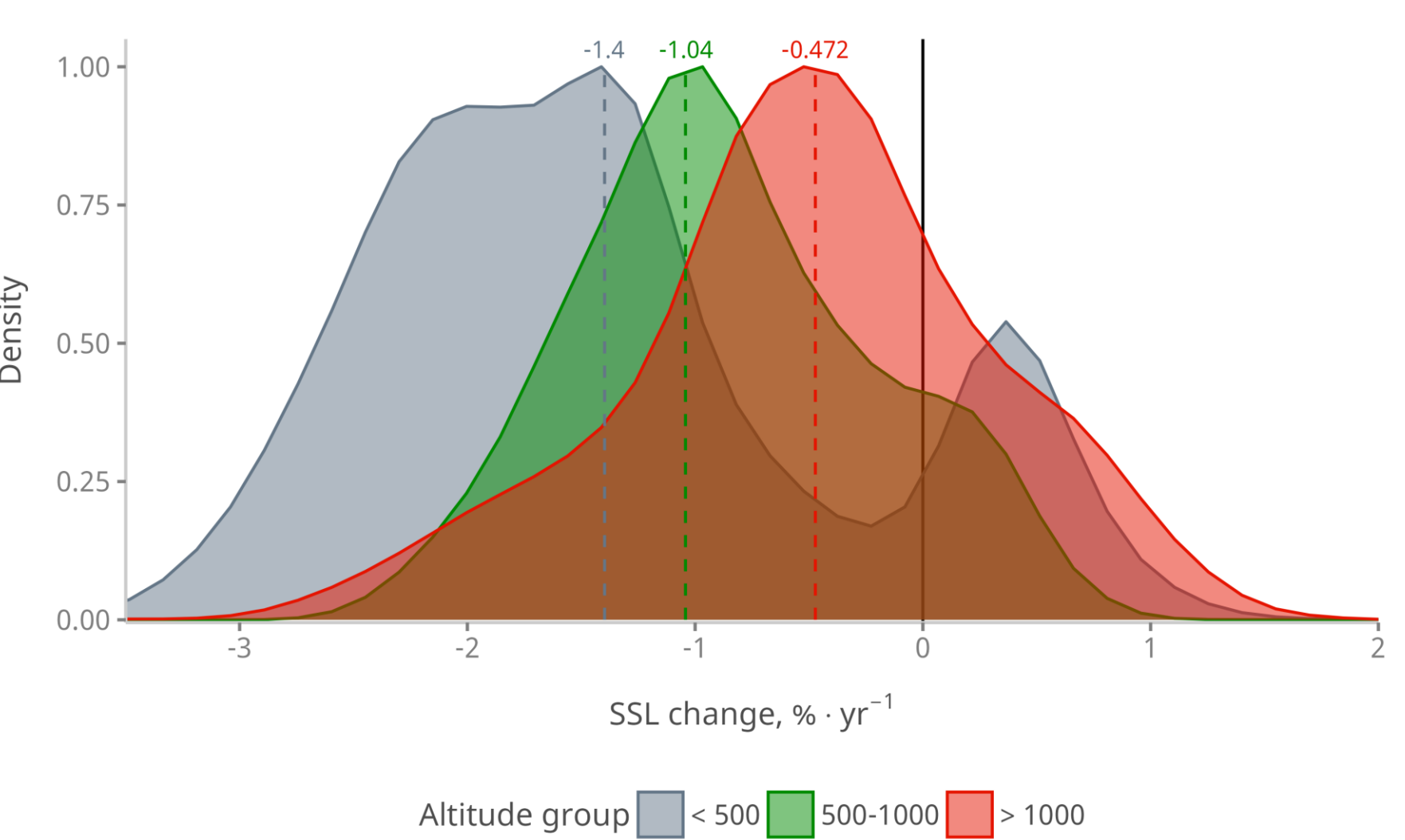


Figure 2. Density plots of trend magnitudes for SSL (%·year⁻¹)

When and why did these changes happen?

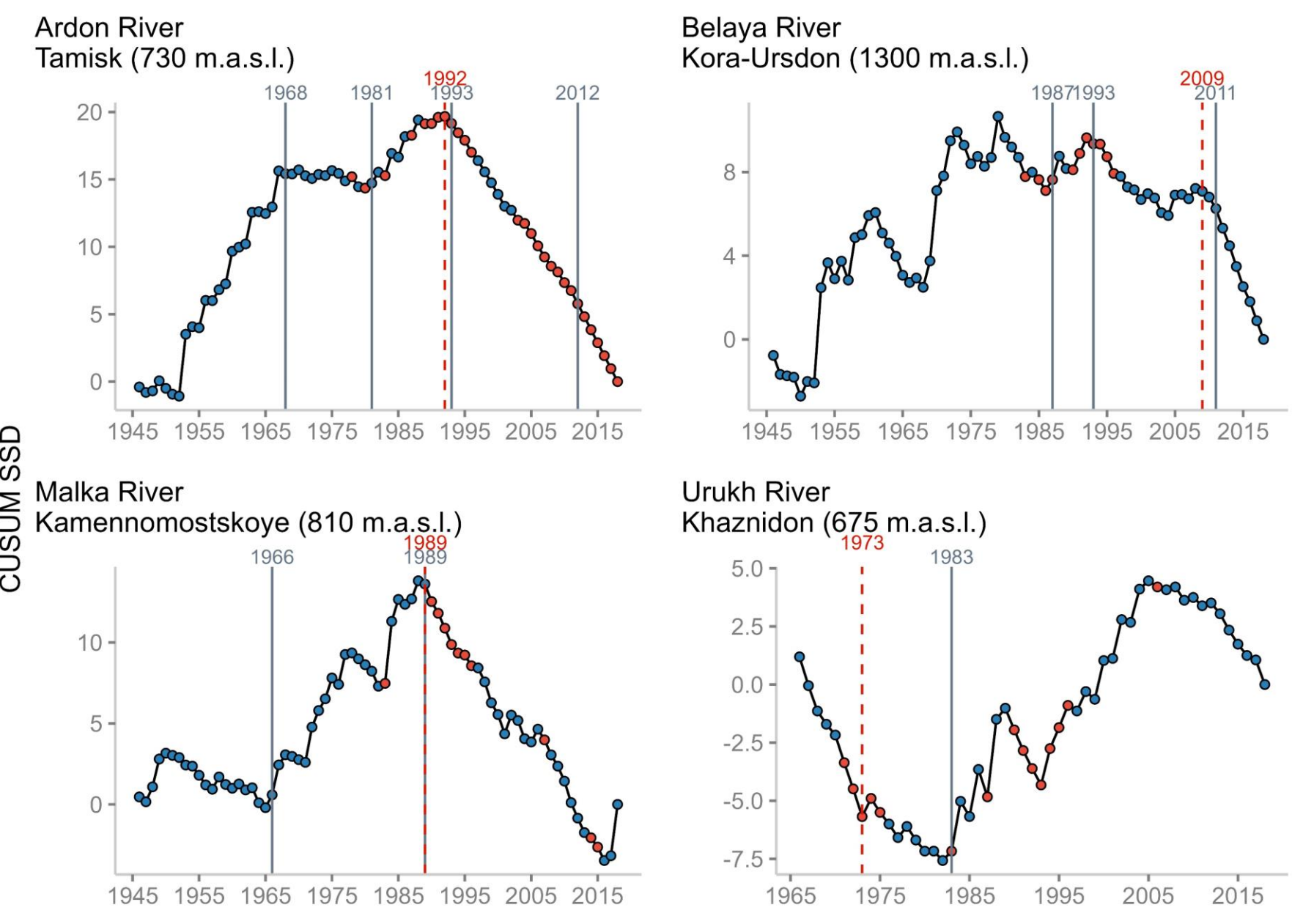


Figure 3. Cumulative sum (CUSUM) charts for the mean annual SSD

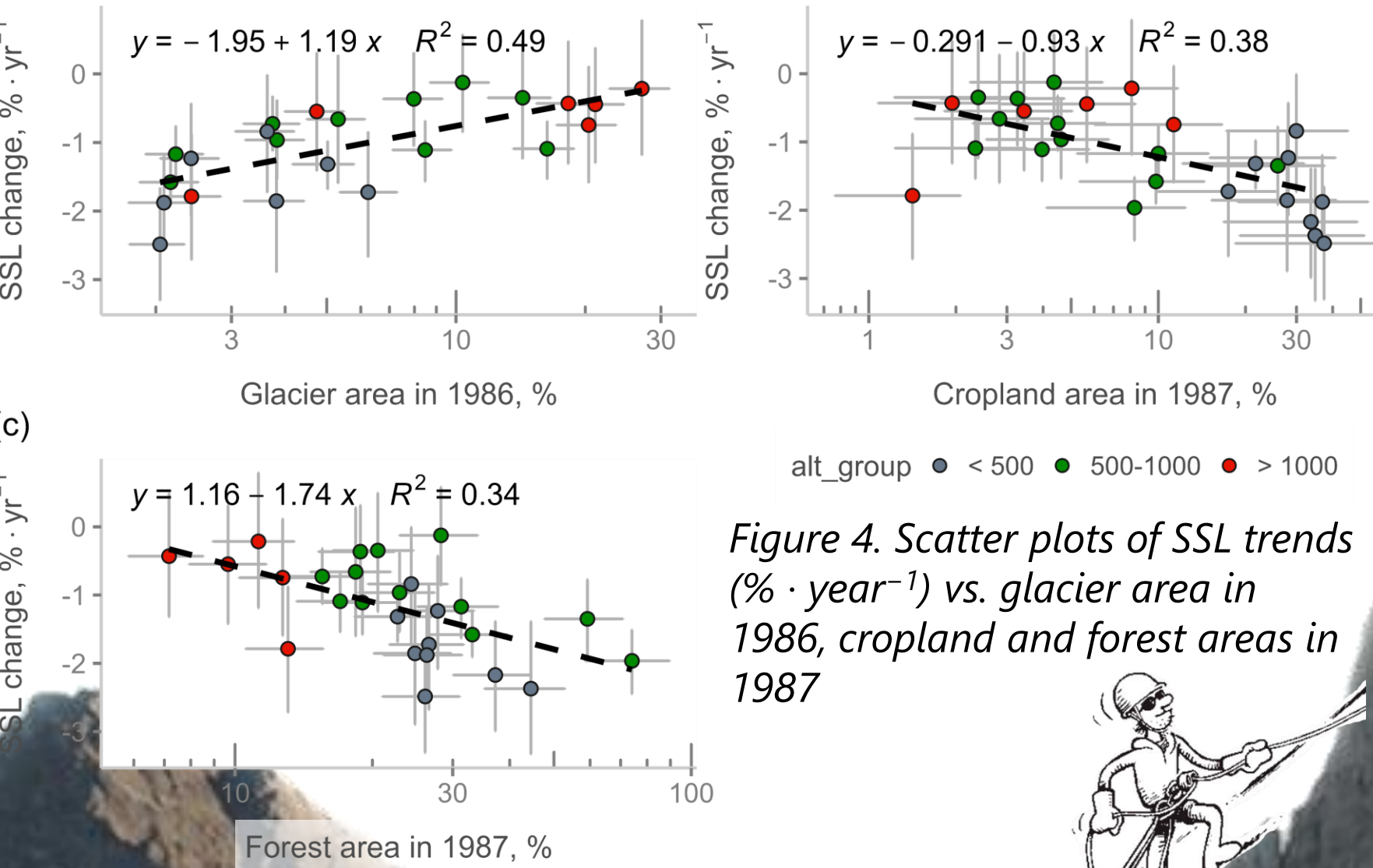
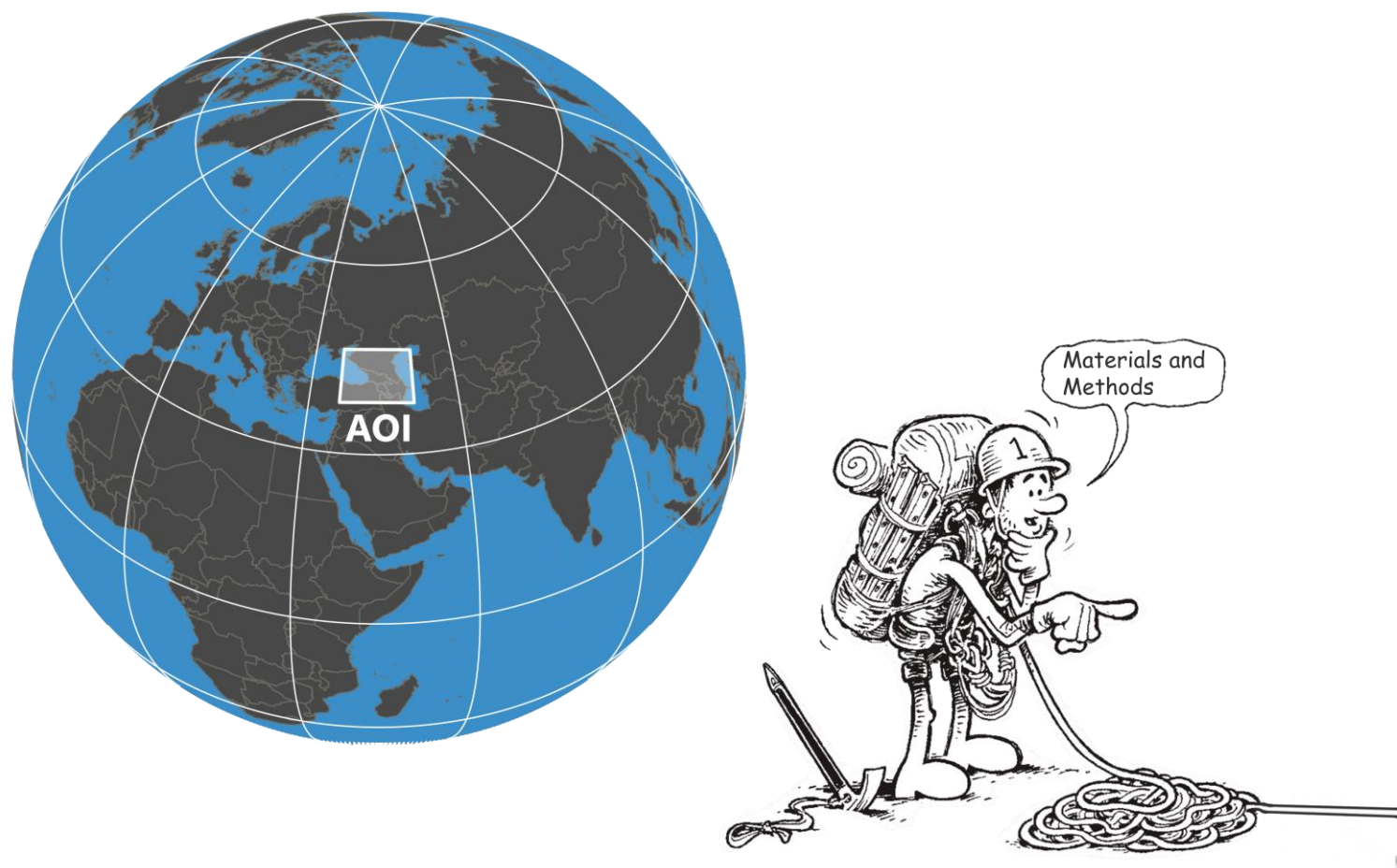


Figure 4. Scatter plots of SSL trends (%·year⁻¹) vs. glacier area in 1986, cropland and forest areas in 1987



Additional information

Suspended Sediment Yield (SSY) and Load (SSL)

$$SSY = \frac{\sum \frac{\bar{Q} \cdot \overline{SSC} \cdot 31.5 \cdot 10^3}{A}}{n} \quad (\text{eq. A})$$

where SSY is the mean annual suspended sediment yield, t·km⁻²·year⁻¹; \bar{Q} is the mean annual water discharge, m³·s⁻¹; \overline{SSC} is the mean annual suspended sediment concentration, g·m⁻³; A is the catchment area, km²; n is the measuring period length in years.

$$SSL = 31.5 \cdot 10^3 \cdot \overline{SSD} = 31.5 \cdot 10^3 \cdot \bar{Q} \cdot \overline{SSC}$$

where SSL is the mean annual suspended sediment load, t·year⁻¹; \overline{SSD} is the mean annual suspended sediment discharge, kg·sec⁻¹.

Uncertainties and Limitations

We considered two main sources of SSL measuring errors and using Monte-Carlo simulations estimated 95% credible intervals. In the equation below, U_{ME} reflected the correction associated with measuring errors, U_{FF} represented the correction associated with the unmeasured finer fraction.

$$SSL_{cor} = SSL \cdot \frac{U_{ME}}{1 - U_{FF}} \quad (\text{eq. C})$$

U_{ME} reflects the integrated effect of errors on individual runoff discharge measurements, suspended sediment concentration measurements, and uncertainties due to intra-daily variation in runoff and sediment concentrations not captured by the measurements. Previous studies reported that these errors are commonly 20%–30% (Harmel et al., 2006; Steegen & Govers, 2001; Vanmaercke et al., 2015). U_{ME} was sampled from a normal distribution with mean of 1 and standard deviation of 0.30.

At Russian gauging stations, suspended sediment concentration is measured by the gravimetric method using paper filters with pore sizes ranging from 2 to 3 μm (so-called «blue tape», deashed filters, «TY 6-09-1678-86» specification) according to Handbook for hydrological measurements at these gauging stations (PD 52.08.104-2002). However, in world practice a membrane filter with pore size of 0.45 μm is typically used for SSC measurement.

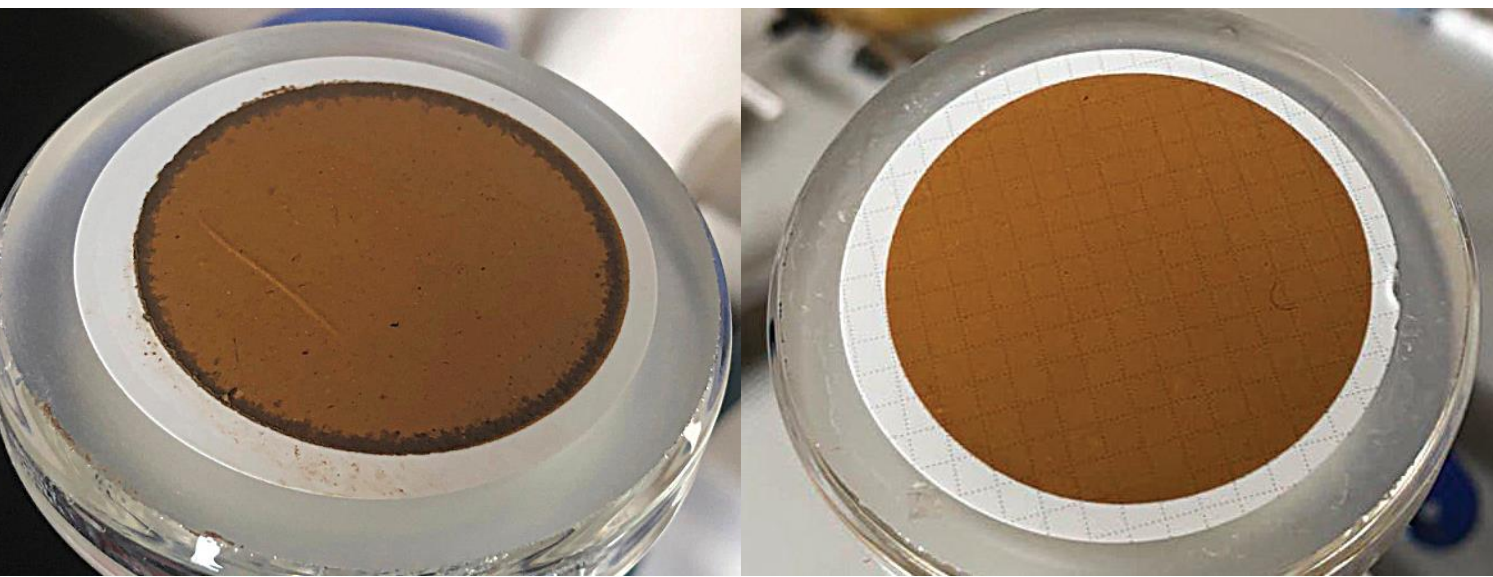


Figure A. Membrane filter with pore size of 0.45 μm (left) and paper filter with pore size of 2 μm (right). Photo by Sergey Chalov.

We performed a brief exploratory data analysis of particle size distribution from Williams and Rosgen (1989) to estimate how pore size impacts total measured suspended sediment concentration. We found that out of 216 samples, the mean percent by weight finer than 3 μm was 24.7%, with a corresponding standard deviation of 9.5%. The proportion of the finer fraction can vary from 8% to 43% (i.e., the 2.5% and 97.5% quantile) depending on the season and river. Hence, U_{FF} was simulated as a random number from a normal distribution with a mean of 0.247 and a standard deviation equal to 0.095. Evidently, U_{FF} values were restricted to values between 0.08 and 0.43.

Equation C was used to simulate respectively 1000 alternative SSL for every year and every gauging station. From these values, we calculated 95% credible intervals (CI) on every SSL value. See example below (Fig. B).

These simulations were further used to estimate trend uncertainties (in %·year⁻¹) as well as SSY errors.

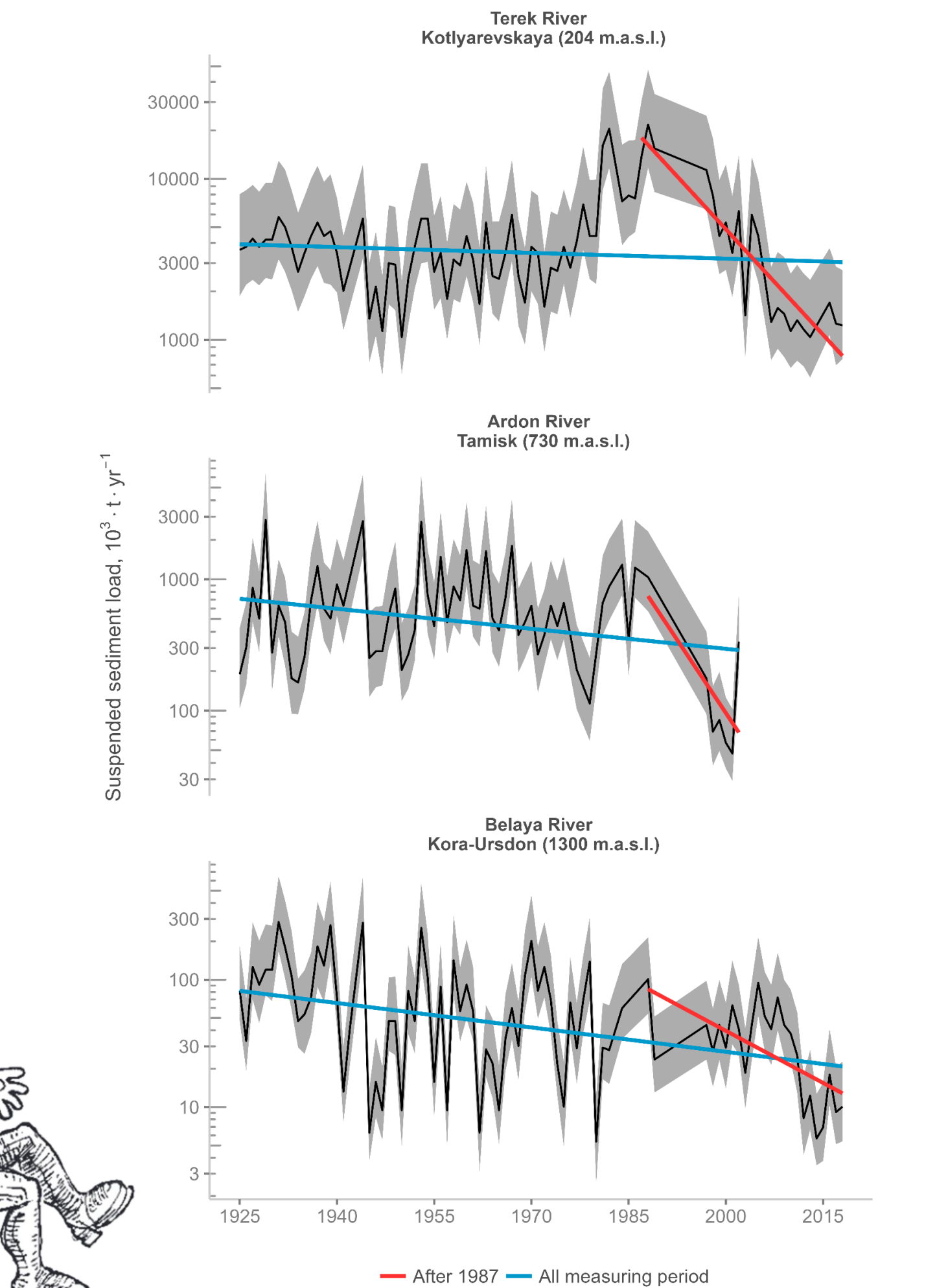


Figure B. Suspended sediment load time series for several gauging stations in the Terek basin. The black line displays the time series with the uncertainty envelope.

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