BIG RIVERS OF THE WORLD: geomorphology, ecology and management

Lecture 18: The Lena River
Lecture 18: themes

- Geomorphology and Hydrology
- Considerations of permafrost
- Global warming/climate change
Geography

Costard and Gautier, 2007
The Lena: vital statistics

Length: 4300 km  
Peak Discharge: 189,000 m$^3$s$^{-1}$  
Mean Annual Water Discharge: 16,200 m$^3$s$^{-1}$  
Drainage Basin Area: 2.49 $\times$ 10$^6$ km$^2$  
Current Average annual suspended sediment discharge: 11 $\times$ 10$^6$ t
Characteristics

**It's cold!** — mean annual temperature at Yakutsk ...... -10.2°C; lowest temperatures.....-72°C

**Permafrost** — down to 1500m; average thickness 350m; average active layer ..0.5-2.5m

**Winter river ice** — 0.5 – 3m thick (S-N). In north, river ice for up to 240 days/year

**Ice jams** — very significant at thaw (log jams can also be influential)
Lena floods
Hydrology
Hydrology

(a) Adlan Tributary at Verhoyanski Perevoz

(b) Upper Lena at Tabaga
Permafrost is perennially frozen ground at a temperature under 0°C for more than 2 years continuously.

In Lena basin temperature and precipitation decrease following a southwest – northeast gradient.
Frozen Banks

Silts with cryoturbations
Cross bedded sands
Silts and fine sands
Medium sands and silts
Gravelly sands

Costard and Gautier, 2007
Frozen Banks
Frozen Banks
Geomorphological Features

• Alases – thermokarst lakes; may coalesce to produce alas valleys
• Pingos –
• ‘Beaded rivers’ –
• Lena delta – many thermokarst features; fault control on river
• Alases – thermokarst lakes; may coalesce to produce alas valleys
Geomorphological Features on delta

- Braided channels
Thermal Erosion

Costard and Gautier, 2007
Geomorphology

Costard and Gautier, 2007
Geomorphology
Geomorphology
Hydrological Change

- one major dam (Vilui) closed in 1967
- rock-filled dam, 75 m high and 600 m long
- area of 2100 km²
**Effects**

- Low flow increase
- High flow decrease

Ye et al., 2003
Effects of Global Warming

(a) Adlan Tributary at Verhoyanski Perevaz

(b) Upper Lena at Tabaga

Costard and Gautier, 2007

Ye et al., 2003
Effects of Global Warming

- Permafrost melting
- Increased Q
- More vegetation growth
- *Eventual* longer melting season? – reduced peak, more groundwater storage ...increased baseflow
- Less variability in Q

Table 2
Projections of future changes in annual runoff

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Climate scenario</th>
<th>River basin</th>
<th>Discharge change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Annual discharge</td>
</tr>
<tr>
<td>Miller and Russell (1992)</td>
<td>Canadian, GISS 2xCO₂</td>
<td>Yenisey, Lena, Ob, Kolyma</td>
<td>from +10 to +45</td>
</tr>
<tr>
<td>Georgievsky et al. (1996)</td>
<td>GFDL 2xCO₂ UKMO 2xCO₂</td>
<td>Inflow into the Barents Sea</td>
<td>+14–35</td>
</tr>
<tr>
<td>Amell (1999)</td>
<td>HadCM2</td>
<td>Yenisey</td>
<td>+6–14</td>
</tr>
<tr>
<td></td>
<td>HadCM3 6 scenarios by 2050.</td>
<td>Lena</td>
<td>+12–25</td>
</tr>
<tr>
<td>Miller and Russell (2000)</td>
<td>GISS CO₂: +0.5%/yr to 2100</td>
<td>Yenisey</td>
<td>+3–10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lena</td>
<td>+12–20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ob</td>
<td>+30–40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kolyma</td>
<td>+20–30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mackenzie</td>
<td>+19–29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yukon</td>
<td>+12–14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arctic total</td>
<td>+9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eurasian rivers</td>
<td>+23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N. American rivers</td>
<td>+8</td>
</tr>
<tr>
<td>Mokhov et al. (2003)</td>
<td>HadCM3</td>
<td>Yenisey</td>
<td>+24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lena</td>
<td>+4</td>
</tr>
<tr>
<td>Mokhov et al. (2003)</td>
<td>ECHAM4</td>
<td>Yenisey</td>
<td>+22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lena</td>
<td>+8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ob</td>
<td>+3</td>
</tr>
</tbody>
</table>

Anisimov et al., 2008
Lena Basin outlet

- Dual warming/impoundment response
- Increased peak Q
- Increased variability
Gordeev (2006):
• 30% increase in sediment flux carried is estimated for every 2 °C of warming
• 10% increase in sediment flux for every 20% increase in discharge
• The flow discharge of the six largest Eurasian arctic rivers (Yenisey, Lena, Ob, Pechora, Kolyma and Severnaya Dvina) would increase by 18–70% by 2100
• Which would mean that the sediment flux of the six arctic rivers would increase from 30 to 122% by 2100
Effects on channel pattern?

Single/multi channel threshold: $W = 90D_{50}^{0.42}$

Anisimov et al., 2008
The Lena River: Hydromorphodynamic Features in a Deep Permafrost Zone

François Costard1 and Emmanuel Gautier2

1CNRS-UMR IGE, CRNS-Université Paris-Est, 2, rue du Clos des Cygnes, 94334 Villejuif, France
2CNRS UMR IGE, Laboratoire de Géographie Physique et, Université Paris-Est, 2, rue du Clos des Cygnes, 94334 Villejuif, France

11. INTRODUCTION

With a maximum exceeding 450,000 km² in length and more than 150 tributaries tributaries, the Lena River is one of the major alluvial systems in the world. It occupies the 11th place among the longest rivers (Figure 11.1).

Due to its large basin (24.5 x 10^6 km²), the Lena River represents a very important contribution in the Laptev Sea, bringing annually 52.5 km³ of water (11% of the total freshwater input into the Arctic Ocean). The river flows southwest and north in Siberia, between the Yana and Lena Rivers. The two lastest streams are the longest ones with 2750 and 2650 km in length, respectively. Just before joining into the Laptev Sea, the Lena River develops large estuaries (with three main channels carrying 70% of the discharge), forming a large delta (90,000 km²) that supports an active delta.

11.2 DESCRIPTION OF THE LENA DEE NAGE BASIN

The Lena Basin occupies the eastern half of the Siberian Craton, with an Arctic continental shelf that is exposed in the Yana and Anabar Sinks. The drainage area of the Lena constitutes about 3% of the basin and spanning over 30° of latitude. Downstream of the Arctic Circle, the landscape is dominated by the Lena tundra. The Siberian tundra and basins still preserve a positive glacial history and the Lena Basin exhibits at least 25 species of mammals, 207 species of birds, 4 of fishes, and about 4600 insect species. Regarding the flora, 1301 species of vascular plants, 325 species of more than 550 species of herbs, and more than 510 species of mosses have been listed for the Lena River. Therefore, the Lena River plays a significant role in the Siberian landscape and ecosystems. It is expected to be affected by climate change, with potential impacts on the species distribution and on the ecosystem functions.

1. Introduction

Changes in Lena River streamflow hydrology: Human impacts versus natural variations

The Huang He River