May long-term historical hydrological data be misleading for flood frequency analysis in current conditions of climate change?

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What has happened? – Historical flood

This flood became the most hazardous one in the region in 80 years history of observations.

- 25 people died
- 8 people are missing
- 3.7 thousand homes flooded
- 15 bridges destroyed
- 70 tons of crop washed away
- Economic damage from the flood in 2019 amounted up to half a billion Euro
Where has it happened? – the Iya River

- The South-Eastern part of Siberia, Russia;
- The northern slopes of the Eastern Sayan;
- The Iya River basin (14500 km²);
- Maximum height (2789 m);
- The climate is sharply continental
What did cause the flood?

- heavy rains as a result of climate change?
- melting of snow and glaciers in the mountains of the East Sayan?
- deforestation of river basins due to clearings and fires?

The aim of the study was to analyze the factors that led to the formation of a catastrophic flood in June 2019, as well as estimate the maximum discharge at the Iya River.
What did cause the flood? – heavy rains

- **Melting of snow and glaciers** in the mountains: **less than 10%** of the area was covered with snow. This **could not cause** flooding of such magnitude.

- **Deforestation**: the area of losing forest in the basin consists of **no more than 4%** of the total catchment area.

- From June 25 to 27, **from 170 to 250 mm** of precipitation fell. The main cause of the flood was a heavy rain.
Hydrograph model

Distributed deterministic model of hydrological processes

- **Parameters:** measured properties of soils and vegetation cover
- ✔ Applicable to catchments of all sizes
- ✔ Applicable on basins in the permafrost zone

- **Input:** temperature, humidity, precipitation
- **Output:** hydrographs in the last discharge section line, water balance characteristics, soil and snow conditions

- **Precipitation**: Rain, Snow
- **Interception**
- **Snow cover formation**
- **Heat energy**
- **Heat dynamics in snow**
- **Heat dynamics in soil**
- **Snow melt and water yield**
- **Infiltration and surface flow**
- **Initial surface losses**
- **Water dynamics in soil**
- **Evaporation**
- **Underground flow**
- **Transformation of underground flow**
- **Slope transformation of surface flow**
- **Channel transformation**
- **Runoff at basin outlet**
Model verification for 3 basins

3 basins:
a – the Kirej river, Ujgat
b – the Iya river, Arshan
c – the Iya river, Tulun.

<table>
<thead>
<tr>
<th>River</th>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>S (km²)</td>
<td>2950</td>
<td>5140</td>
<td>14500</td>
</tr>
<tr>
<td>H (m)</td>
<td>873</td>
<td>1483</td>
<td>979</td>
</tr>
<tr>
<td>Flow.obs.</td>
<td>374</td>
<td>540</td>
<td>326</td>
</tr>
<tr>
<td>Flow.sim.</td>
<td>402</td>
<td>528</td>
<td>338</td>
</tr>
<tr>
<td>Precip.</td>
<td>688</td>
<td>771</td>
<td>586</td>
</tr>
<tr>
<td>Evap.</td>
<td>286</td>
<td>243</td>
<td>247</td>
</tr>
<tr>
<td>NS (m/av)</td>
<td>0,66/0,57</td>
<td>0,69/0,62</td>
<td>0,72/0,67</td>
</tr>
</tbody>
</table>
For annual **maximum** water discharge;
The difference in values does not exceed 300 m$^3$s$^{-1}$ (8%).
Data for modelling catastrophic flood

The assessment of the maximum water discharge in June 2019 based on two types of input:

- Observed weather stations’ data (Arshan, Ikey, Tulun);
- ICON climate model data
Results

The results of flood modeling at the Iya River – Tulun in June 2019:

1, 2 – the amount of precipitation for the catchment - 3-hour precipitation according to the ICON weather model and daily precipitation based on data from weather stations;

3 – the observed flow hydrograph (based on extrapolation of the dependence of water flow on the level);

4, 5 – calculated 3-hour and averaged daily flow hydrograph according to the ICON weather model;

6 – calculated daily runoff hydrograph based on data from weather stations.
Results of modeling

- **Qmax. based on ICON**: 4780 m³s⁻¹ (daily) and 5260 m³s⁻¹ (3-hour)

- **Qmax. weather station data**: 6570 m³s⁻¹ (daily)

- The maximum discharge based on **ICON data is 1400 m³s⁻¹ lower than the observed**, however, its **formation coincides in the term**. According to **weather station data**, the maximum discharge **coincides in dimension**, but its formation is **delayed by 1 day**;

- We attempt to show the need to expand the meteorological and hydrological network. We also demonstrate the capabilities of the modern calculation methods and forecasts in case of insufficient observed data;

- We showed that the ensemble of input meteorological data from various sources could potentially be used to satisfactorily predict the magnitude and duration of the catastrophic flood in order **to minimize the consequences**;
Has this flood been observed before?

<table>
<thead>
<tr>
<th>Year</th>
<th>Water level, m</th>
<th>Discharge, m³/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>1937</td>
<td>8.5</td>
<td>1907</td>
</tr>
<tr>
<td>1980</td>
<td>9.0</td>
<td>2520</td>
</tr>
<tr>
<td>1984</td>
<td>11.0</td>
<td>4400</td>
</tr>
<tr>
<td>2019</td>
<td>13.8</td>
<td>6800 (preliminary assessment)</td>
</tr>
</tbody>
</table>

The level of protective dam is **12 m**.
Why?

The flood in the Tulun town.

https://pikabu.ru/story/masshtab_navodneniya_v_gorode_tulun_irkutskaya_oblast_6789293
Why was the maximum level of the dam 12 m?

Dam construction: 2006-2009

This series of discharge are not homogeneous;

Probability of the flood (1984) was underestimated as historical maximum;
What will be the new max level of the dam?

- This series of discharge also are not homogeneous;
- Will the probability of the flood (2019) be underestimated?
Conclusion

- The estimated discharge has exceeded previously observed one by about 50%.

- The results of the study have shown that recent flood damage was caused mainly by unprepared infrastructure.

- The safety dam which was built in the town of Tulun just ten years ago was 2 meters lower than maximum observed water level in 2019.

- This case and many other cases in Russia suggest that the flood frequency analysis of even long-term historical data may mislead design engineers to significantly underestimate the probability and magnitude of flash floods.
Thank you for attention!