Global trends and patterns of glacier lake outburst floods since 1900

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1 Background

Retreating glaciers have provided new space for glacier lakes to form and grow in past decades, posing hazards to mountain communities when they empty catastrophically. Such Glacier Lake Outburst Foods (GLOFs) often lead to millions of dollars of damages and fatalities in mountain regions worldwide. While there is growing evidence of an increase in the number and size of glacier lakes, estimates of a commensurate regional or local increase in GLOF hazard and risk remain controversial. Therefore, we compiled the largest available GLOF database to analyze changes in flood volume and peak discharge since the beginning of the 21st century.

Figure 1: Photograph of drained Summit Lake, Canada [2022-09-21]

2 Compiling a global database

769 literature and web sources

GLOF lake area change mapped from 839 optical satellite images

**Database
57 parameters
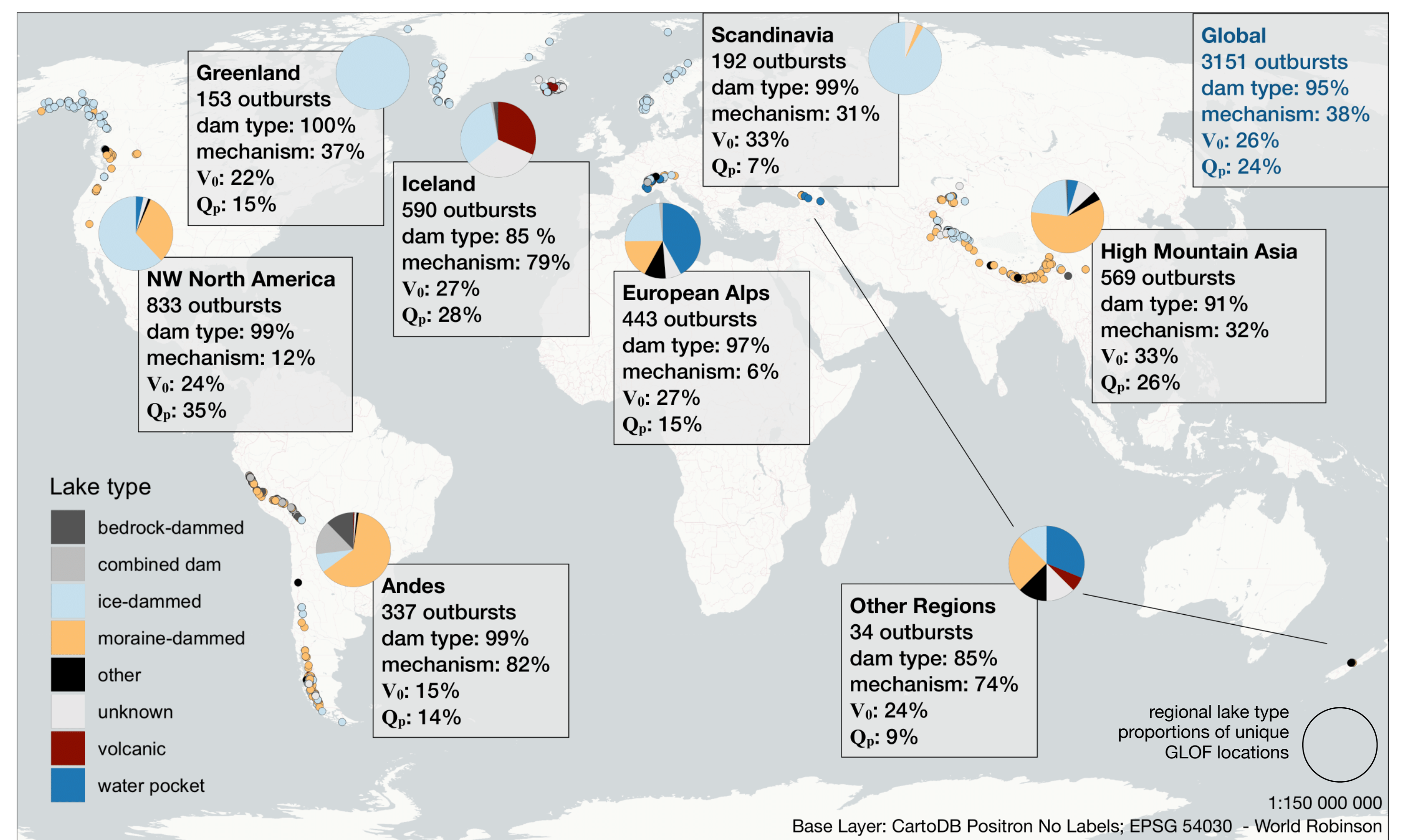3151 GLOFs**

Visit our interactive map interface!

Figure 2: GLOF locations and selected regional database contents: number of GLOFs, percentage of GLOFs with information on dam type, outburst mechanism, peak discharge (Q_p), and flood volume (V_0).

Greenland
153 outbursts
dam type: 100%
mechanism: 37%
V_0: 22%
Q_p: 15%

Iceland
590 outbursts
dam type: 85 %
mechanism: 79%
V_0: 27%
Q_p: 28%

Scandinavia
192 outbursts
dam type: 99%
mechanism: 31%
V_0: 33%
Q_p: 7%

Global
3151 outbursts
dam type: 95%
mechanism: 38%
V_0: 26%
Q_p: 24%

NW North America
833 outbursts
dam type: 99%
mechanism: 12%
V_0: 24%
Q_p: 35%

European Alps
443 outbursts
dam type: 97%
mechanism: 6%
V_0: 27%
Q_p: 15%

High Mountain Asia
569 outbursts
dam type: 91%
mechanism: 32%
V_0: 33%
Q_p: 26%

Andes
337 outbursts
dam type: 99%
mechanism: 82%
V_0: 15%
Q_p: 14%

Other Regions
34 outbursts
dam type: 85%
mechanism: 74%
V_0: 24%
Q_p: 9%

Lake type
- bedrock-dammed
- combined dam
- ice-dammed
- moraine-dammed
- other
- unknown
- volcanic
- water pocket

regional lake type proportions of unique GLOF locations

1:150 000 000
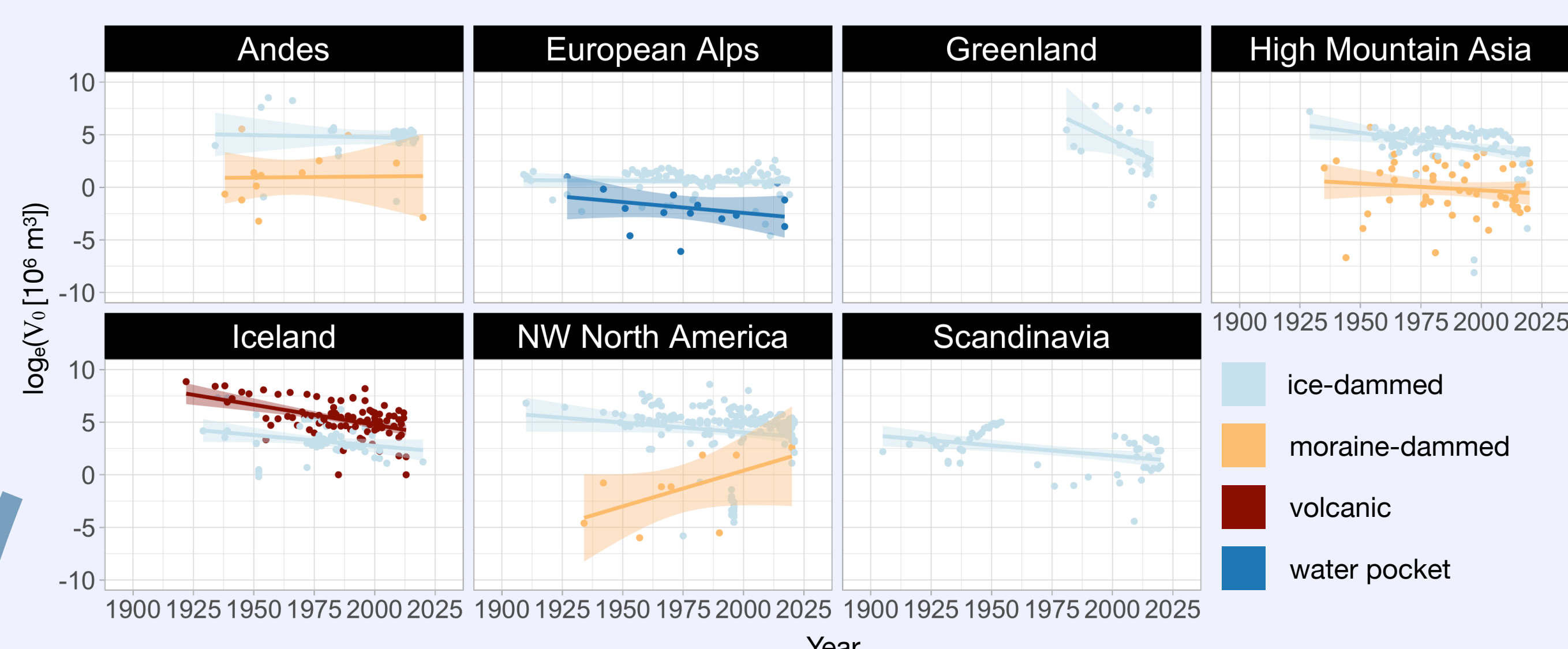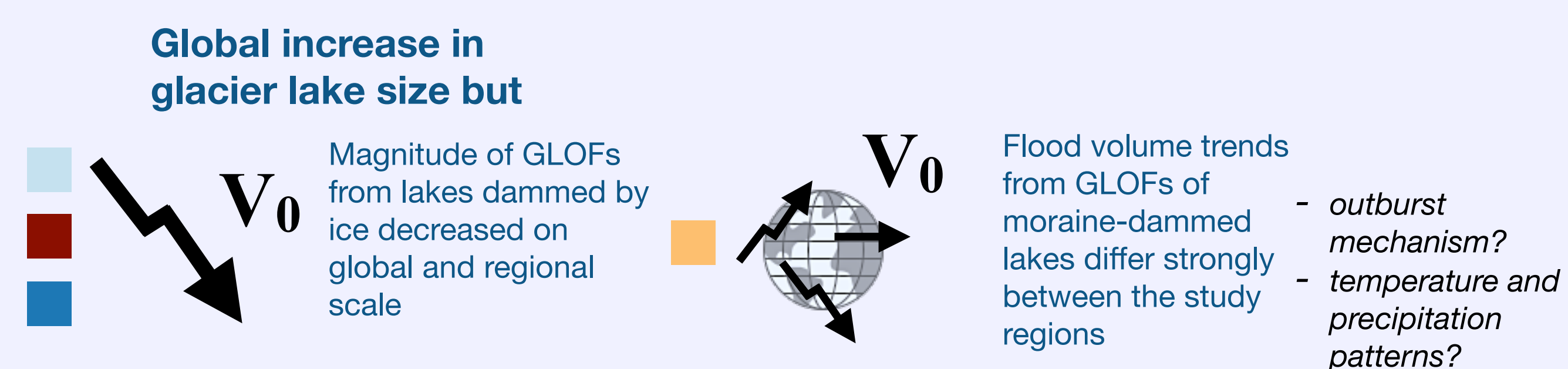Base Layer: CartoDB Positron No Labels; EPSG 54030 - World Robinson

3 Trends in flood volume

Figure 3: GLOF volume (V_0) on natural log scale with fitted linear regressions by lake type and region [1900-2022].

ice-dammed
moraine-dammed
volcanic
water pocket

Global increase in glacier lake size but

V_0 Magnitude of GLOFs from lakes dammed by ice decreased on global and regional scale

V_0 Flood volume trends from GLOFs of moraine-dammed lakes differ strongly between the study regions

- outburst mechanism?
- temperature and precipitation patterns?

Key findings

Limited evidence for connection between global lake size increase and GLOF magnitudes

Trends in flood volumes strongly depend on the type of dam that impounds glacial meltwater

Flood magnitudes of GLOFs from ice-dammed lakes only weakly correlate with glacier thinning

4 Impact of glacier decay on GLOF size

thinner glacier → smaller flood ?

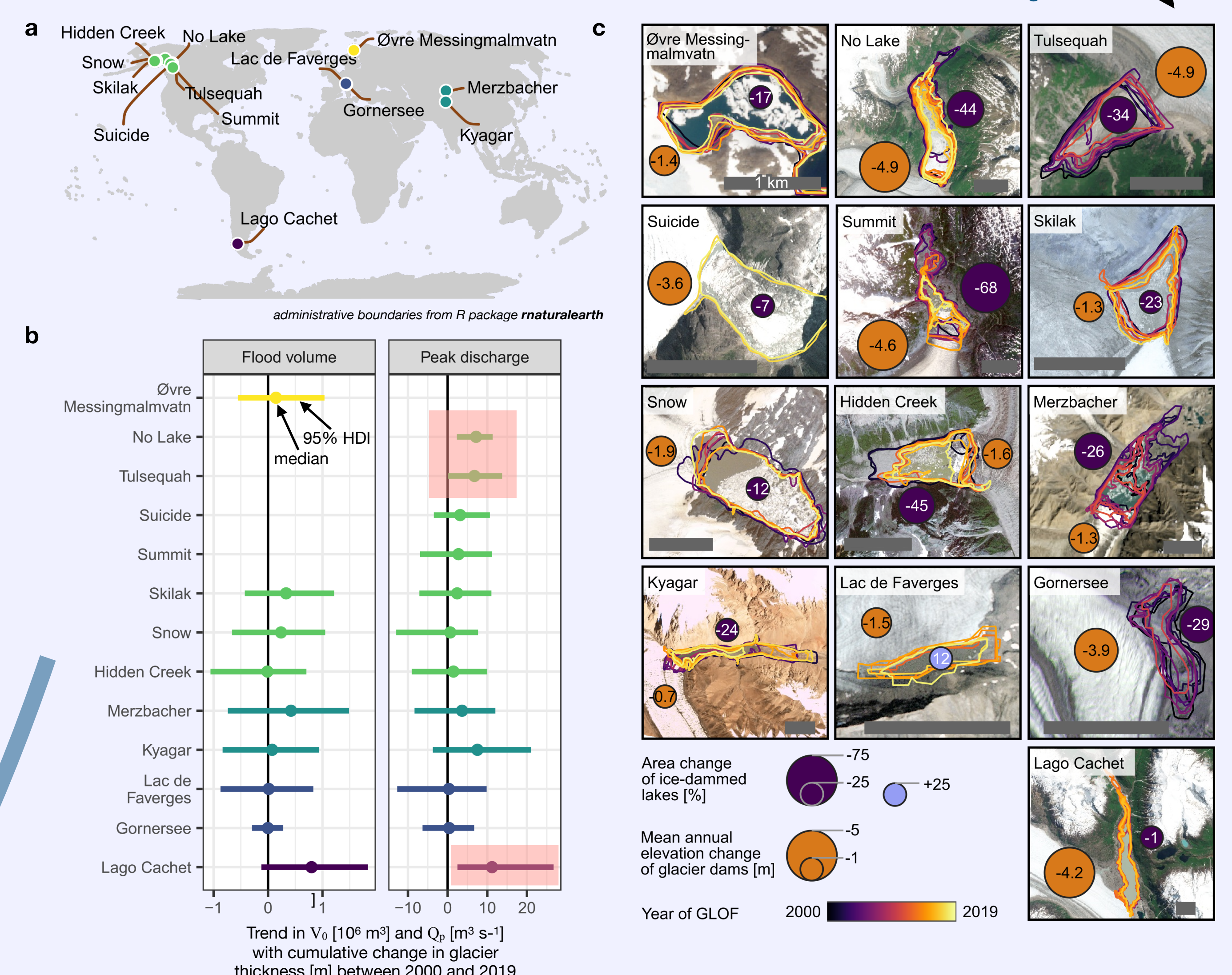the lake area of the majority of ice-dammed lakes with recurring GLOFs is decreasing

Figure 4: Trends in flood volume (V_0), peak discharge (Q_p), and lake area (A) with cumulative changes in glacier thickness [2000-2019]. a, Lake locations b, Posterior regression slopes (hierarchical quantile regression models). c, Local lake area and glacier elevation change.

administrative boundaries from R package rnaturalearth

Flood volume

Peak discharge

95% HDI median

Øvre Messingmalmvatn
No Lake
Tulsequah
Suicide
Summit
Skilak
Snow
Hidden Creek
Merzbacher
Kyagar
Lac de Faverges
Gornersee
Lago Cachet

Trend in V_0 [10^6 m³] and Q_p [m³ s⁻¹] with cumulative change in glacier thickness [m] between 2000 and 2019

Area change of ice-dammed lakes [%] -75 -25 +25

Mean annual elevation change of glacier dams [m] -5 -1

Year of GLOF 2000 2019

only 3/12 lakes show significant trends of an increase in peak discharge with higher cumulative change in glacier thickness

V_0
Q_p
general decrease in flood volume or peak discharge

thinning of the glacier dam

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