Future glacial lakes of the World

Risks & opportunities

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EGU 2020: Sharing Geoscience Online
Session CR3.1

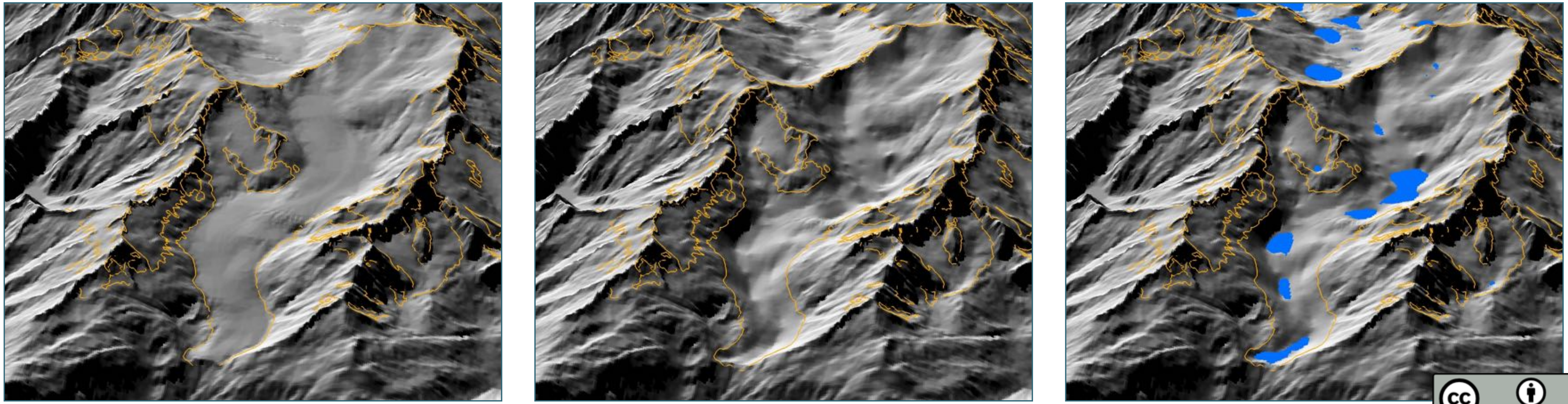
[CONCEPT]

Foto: Laguna Arteson, Peru
Área de Evaluación de Glaciares y Lagunas, Autoridad Nacional del Agua - Peru

Aim

- Global analysis of sites with potential future formation of glacial lakes
  - Hazards
  - Risks
  - Opportunities

- Approach: Identification of depressions (overdeepenings) in glacier beds



A. Linsbauer

Global ice thickness data (Farinotti et al. 2019)

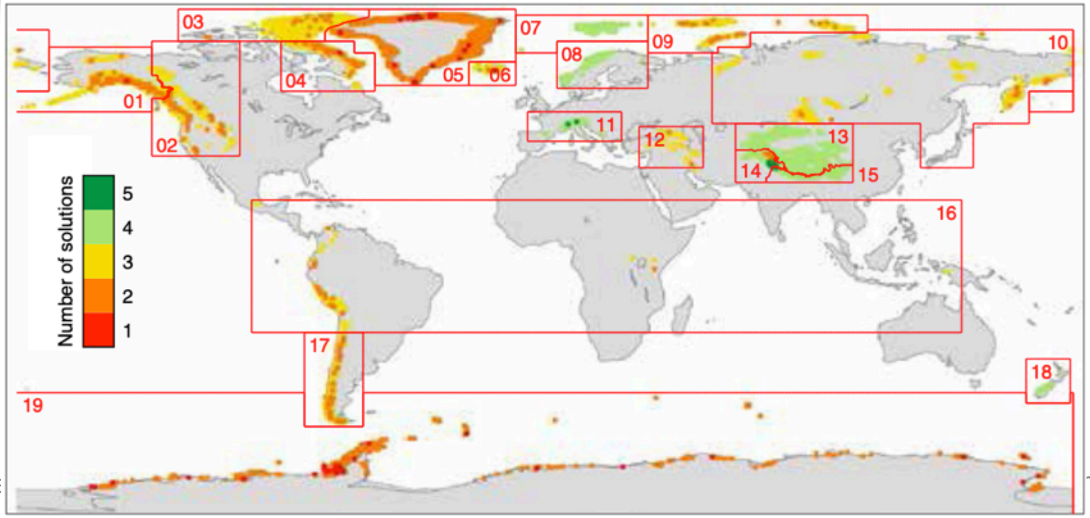
nature geoscience ARTICLES
https://doi.org/10.1038/s41561-019-0300-3

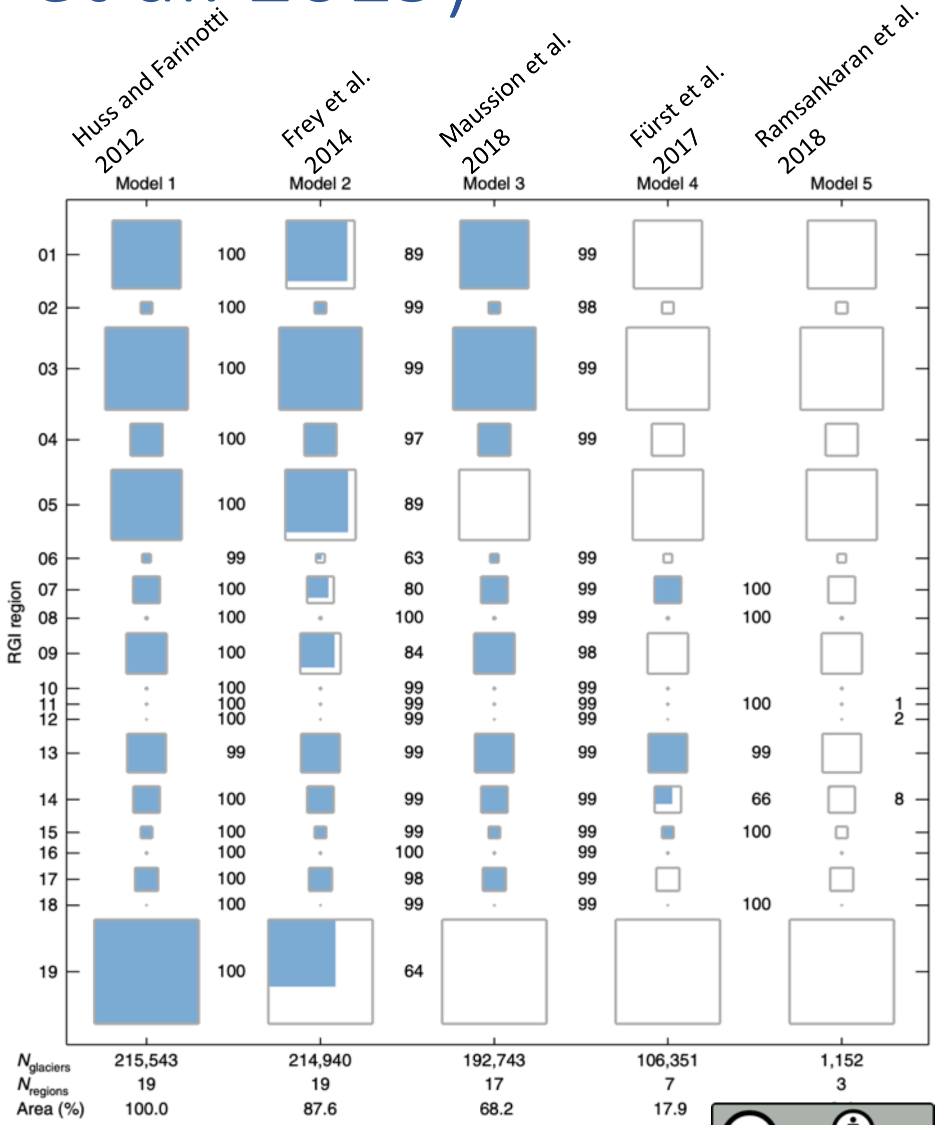
A consensus estimate for the ice thickness distribution of all glaciers on Earth

Daniel Farinotti[1,2]*, Matthias Huss[1,3], Johannes J. Fürst[4], Johannes Landmann[1,2], Horst Machguth[3,5], Fabien Maussion[6] and Ankur Pandit[7,8]

Knowledge of the ice thickness distribution of the world's glaciers is a fundamental prerequisite for a range of studies. Projections of future glacier change, estimates of the available freshwater resources or assessments of potential sea-level rise all need glacier ice thickness to be accurately constrained. Previous estimates of global glacier volumes are mostly based on scaling relations between glacier area and volume, and only one study provides global-scale information on the ice thickness distribution of individual glaciers. Here we use an ensemble of up to five models to provide a consensus estimate for the ice thickness distribution of all the about 215,000 glaciers outside the Greenland and Antarctic ice sheets. The models use principles of ice flow dynamics to invert for ice thickness from surface characteristics. We find a total volume of 158 ± 41 × 10³ km³, which is equivalent to 0.32 ± 0.08 m of sea-level change when the fraction of ice located below present-day sea level (roughly 15%) is subtracted. Our results indicate that High Mountain Asia hosts about 27% less glacier ice than previously suggested, and imply that the timing by which the region is expected to lose half of its present-day glacier area has to be moved forward by about one decade.

Farinotti et al. (2019)

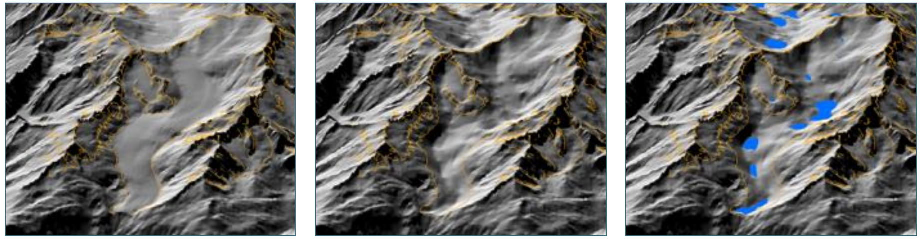




Currently in progress: ‘Number crunching’

University of Zurich[UZH]

Using R



Subtraction → **Overdeepenings** → **Shapefile & .csv**

Subtraction

DEM minus ice thickness

Overdeepenings

- Identify sinks
- Fill sinks
- Min. 4x4 pixels

Shapefile & .csv

- Shapefile with overdeepenings
- CSV file per region (w/ lake attributes)

Calculation time RGI region 11 (Central Europe): about 1h
(4 models, 3927 glaciers / 2091 km^2 each)

First results: Central Europe (RGI region 11)

University of Zurich[UZH]

All future lakes

	Number of sinks	Total volume (m^3)	Total area (m^2)	Mean depth (m)
Huss & Farinotti	408	434'727'626	26'285'625	11
GlabTop2	251	1'120'912'383	33'623'125	14
Maussion	448	1'659’341'018	52'366'250	15
Composite	*164*	*281'324'392*	*16'415'625*	*10*

Largest values individual lake

	Volume (m^3)	Area (m^2)	Max depth (m)	Mean depth (m)
Huss & Farinotti	26'146'011	1'132'500	247	85
GlabTop2	199'305'748	2'392'500	344	123
Maussion	228'074'247	1'730'000	320	132
Composite	48'382'059	1'187'500	*352*	131

Performance of models in view of identifying overdeepenings needs to be evaluated

Moment of formation

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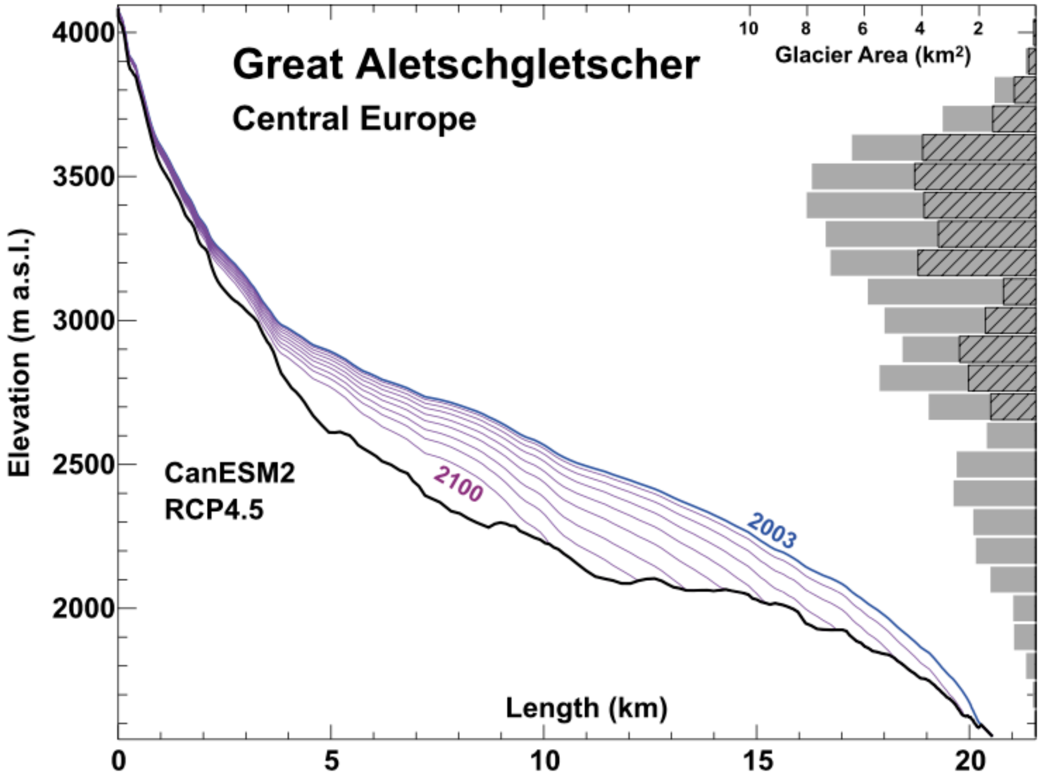
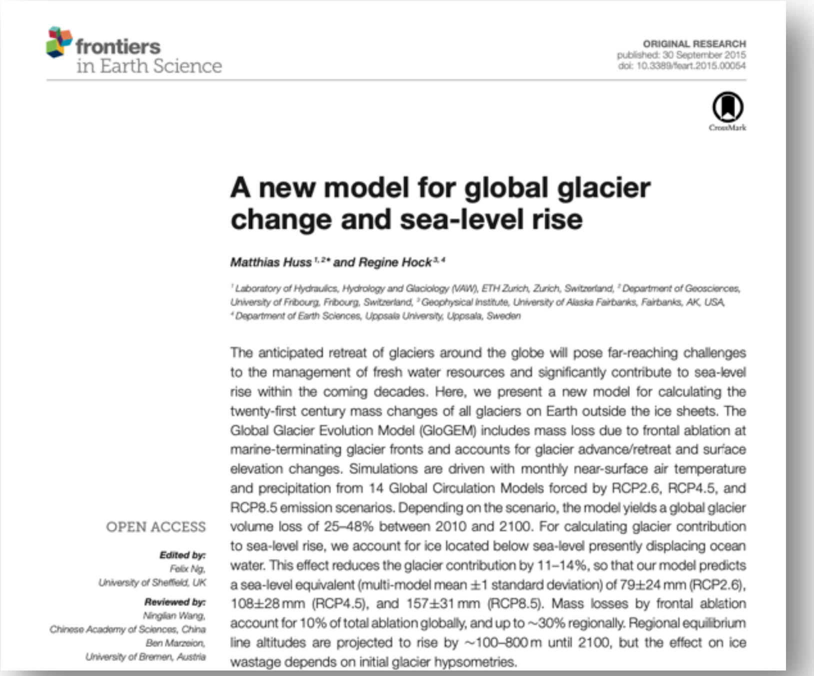
Intersection of overdeepenings with future glacier extents from GloGEM (Global Glacier Evolution Model)



Huss and Hock, 2015

Huss and Hock (2015)


frontiers in Earth Science

ORIGINAL RESEARCH
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CrossMark

A new model for global glacier change and sea-level rise

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The anticipated retreat of glaciers around the globe will pose far-reaching challenges to the management of fresh water resources and significantly contribute to sea-level rise within the coming decades. Here, we present a new model for calculating the twenty-first century mass changes of all glaciers on Earth outside the ice sheets. The Global Glacier Evolution Model (GloGEM) includes mass loss due to frontal ablation at marine-terminating glacier fronts and accounts for glacier advance/retreat and surface elevation changes. Simulations are driven with monthly near-surface air temperature and precipitation from 14 Global Circulation Models forced by RCP2.6, RCP4.5, and RCP8.5 emission scenarios. Depending on the scenario, the model yields a global glacier volume loss of 25–48% between 2010 and 2100. For calculating glacier contribution to sea-level rise, we account for ice located below sea-level presently displacing ocean water. This effect reduces the glacier contribution by 11–14%, so that our model predicts a sea-level equivalent (multi-model mean ±1 standard deviation) of 79±24 mm (RCP2.6), 108±28 mm (RCP4.5), and 157±31 mm (RCP8.5). Mass losses by frontal ablation account for 10% of total ablation globally, and up to ~30% regionally. Regional equilibrium line altitudes are projected to rise by ~100–800 m until 2100, but the effect on ice wastage depends on initial glacier hypsometries.

→ Moment of lake formation, considering RCP2.6 and RCP8.5

- Snapshots for 2 -3 points in time (e.g. 2035, 2050, 2100)

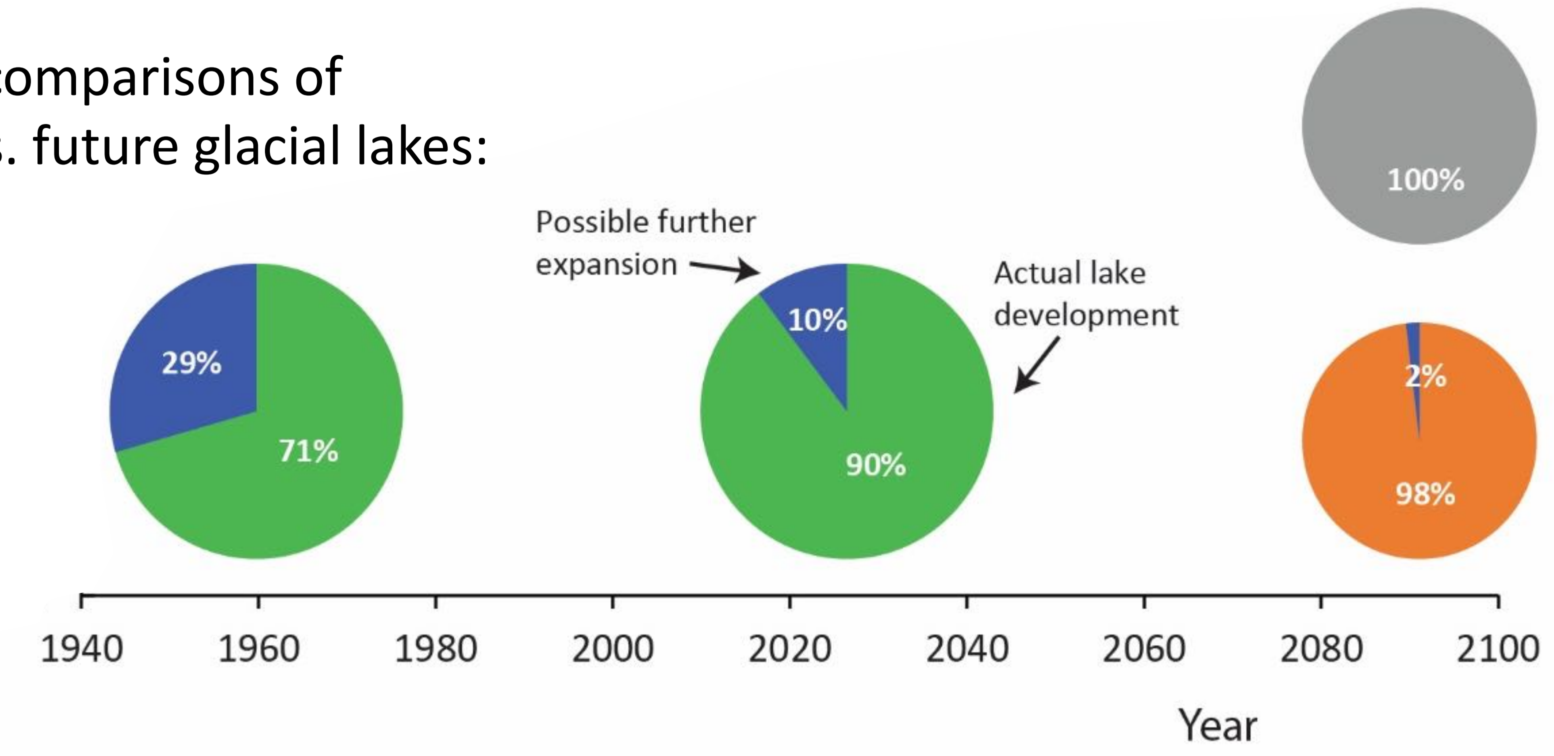
Existing vs. future lakes

Shugar et al. 2019:

→ Global inventory of glacial lakes (Earth Engine), comparison 1990 to 2015

→ 2015: > 13,000 lakes, 1990-2015: Volume increased by 48% (to 156 km^3) [new paper in review for Nat CC]

Regional comparisons of existing vs. future glacial lakes:



Emmer et al. (in press), modified

Hazard estimation

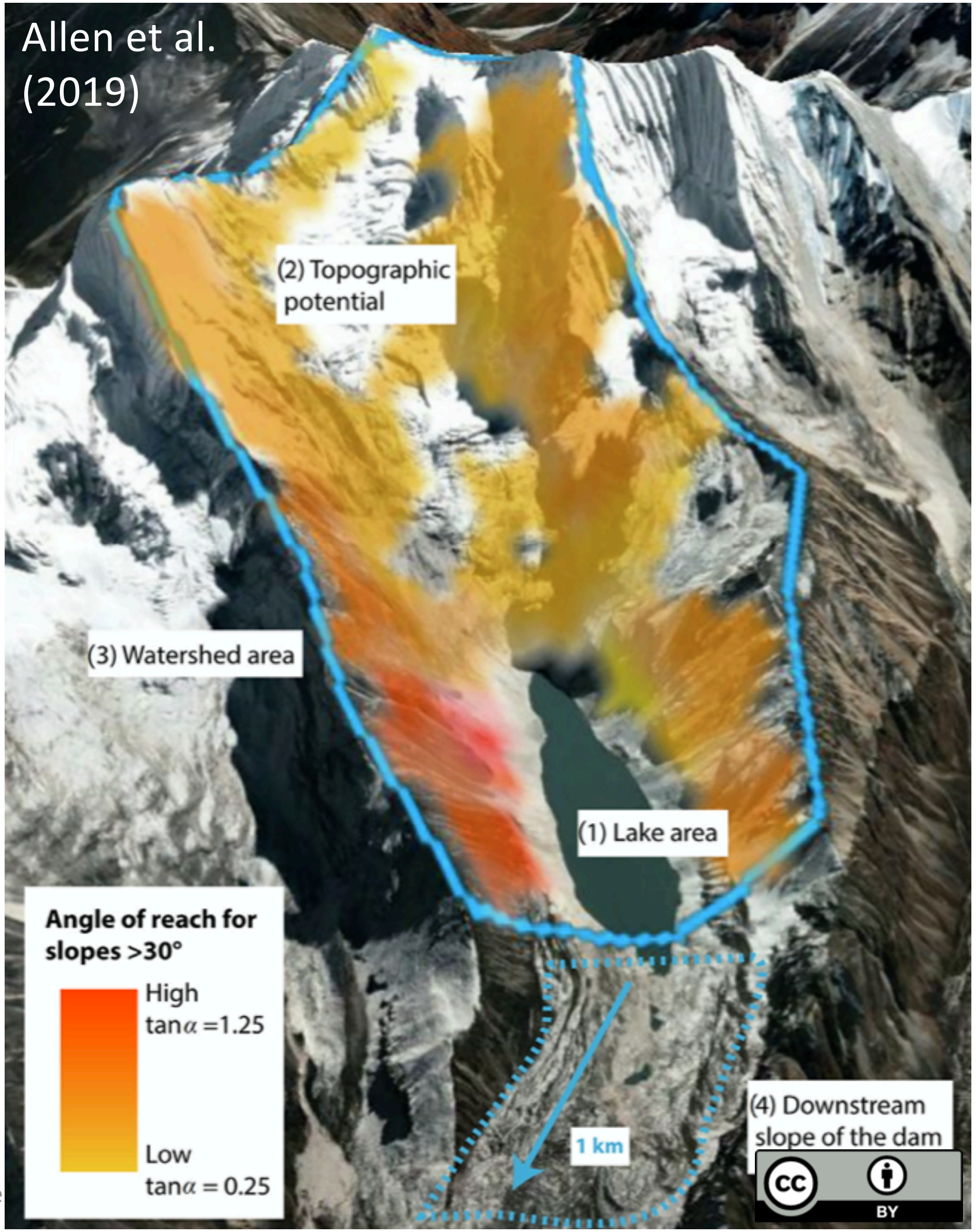
Susceptibility for mass movement impacts:

- Topographic potential of the catchment area

Downstream effects:

- Simple flow routing (D8 approach, no flow spreading; max. reach = 3° angle of reach)

Include other triggers? (permafrost, seismicity, temperature, rainfall extremes)?



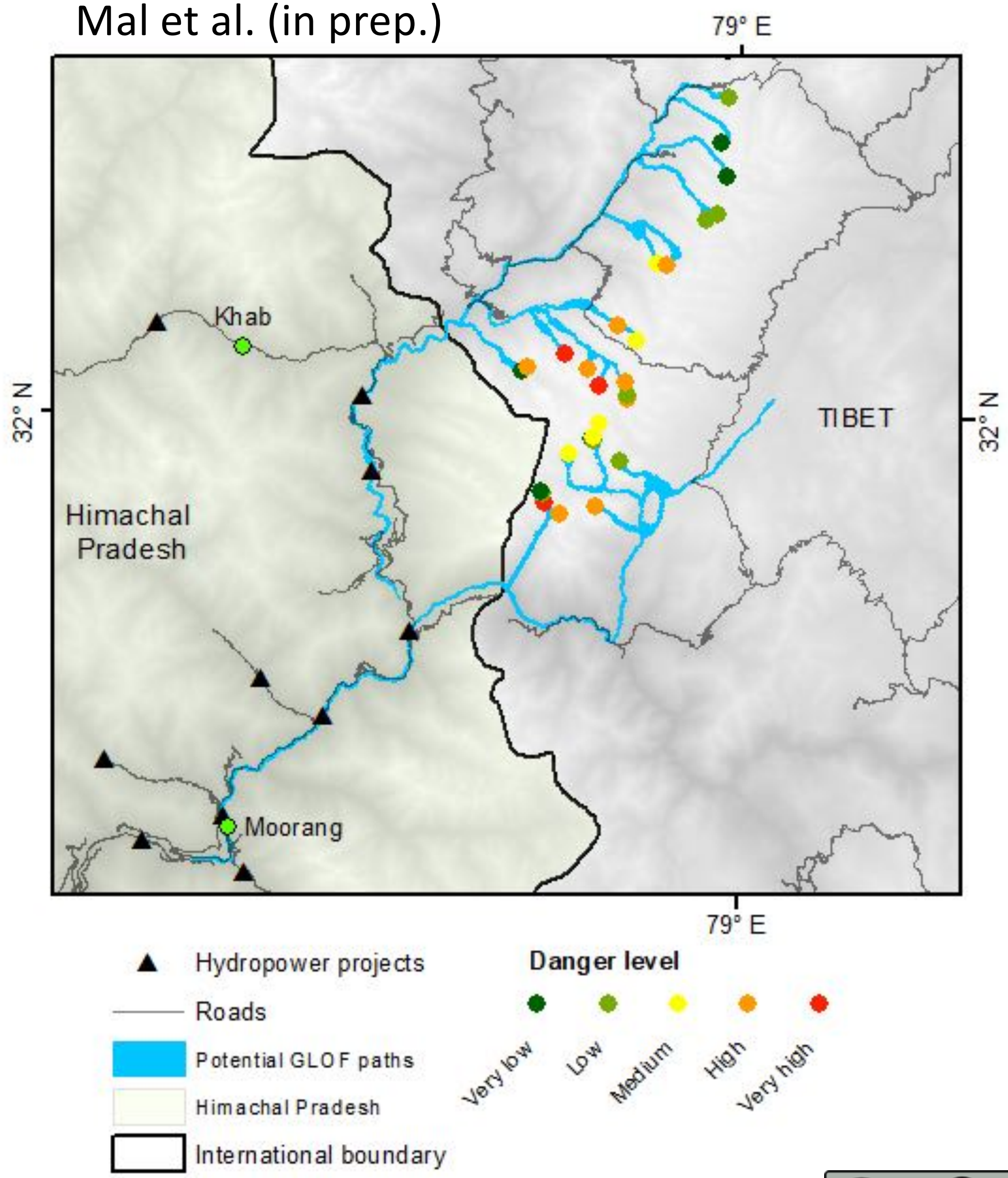
Risk estimation (exposure)

Intersection of potential GLOF trajectories with:

- Settlements
- Hydropower installations
- Roads / railroads
- Energy lines

Suitable global database(s)? OSM?

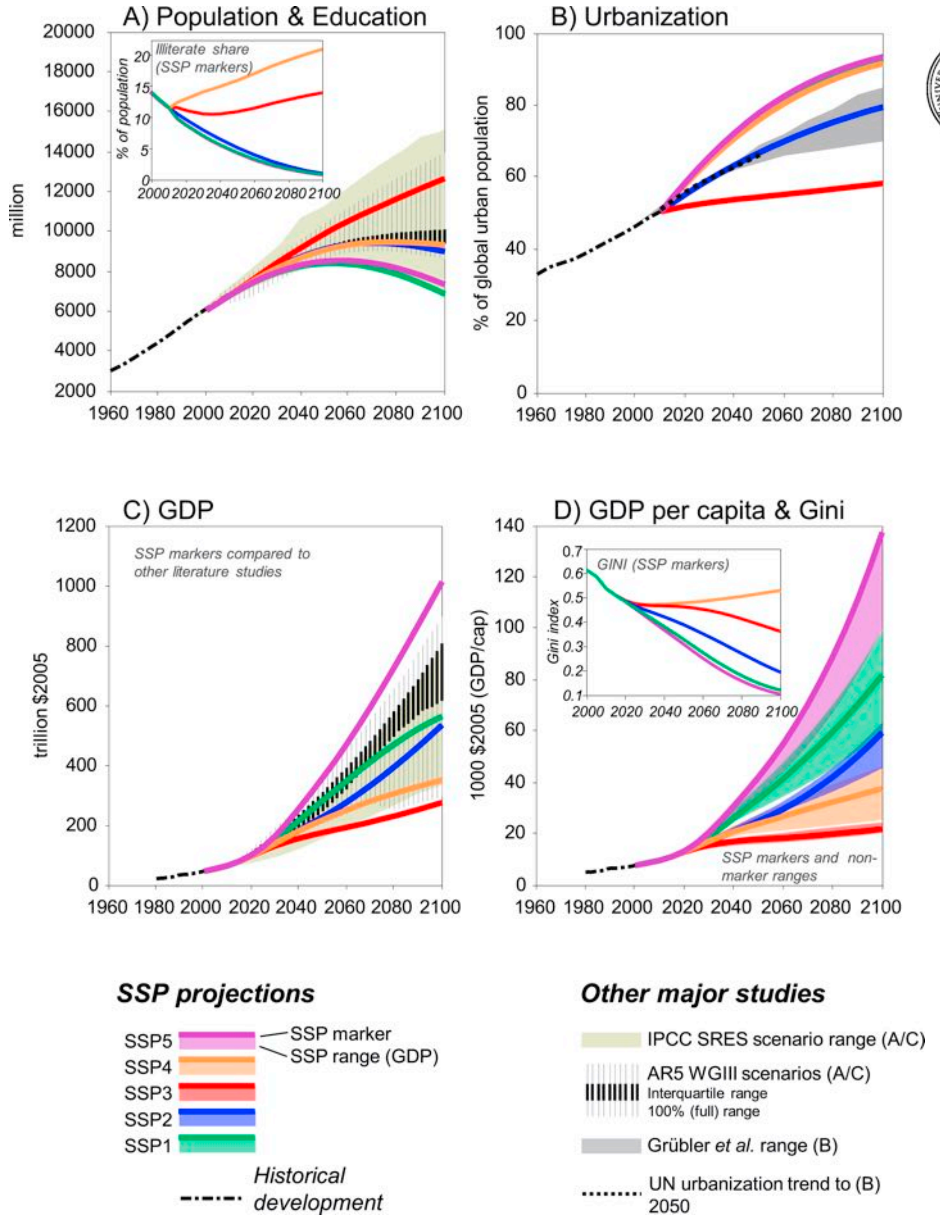
Mal et al. (in prep.)



Risk estimation (vulnerability)

Intersection of flow routing trajectories with demographic, socio-economic indicators for vulnerability

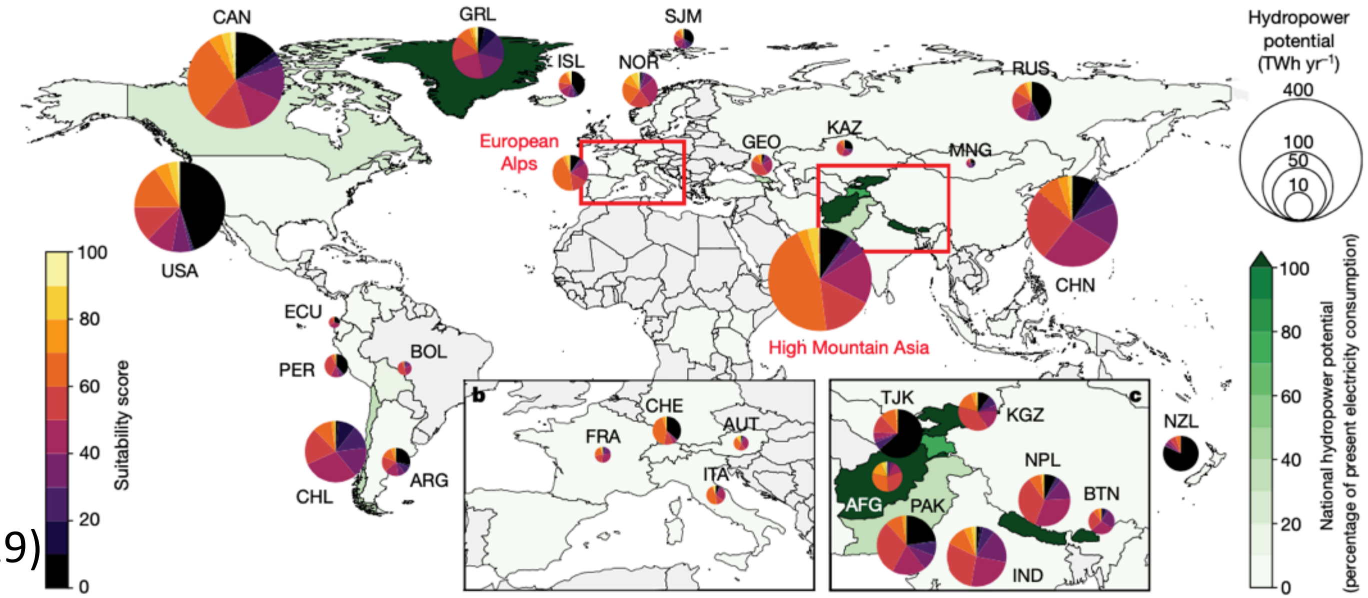
Evaluation of considering gridded SSP (Shared Socioeconomic Pathways) information as proxies for future vulnerabilities



Riahi et al. (2017)

Opportunities

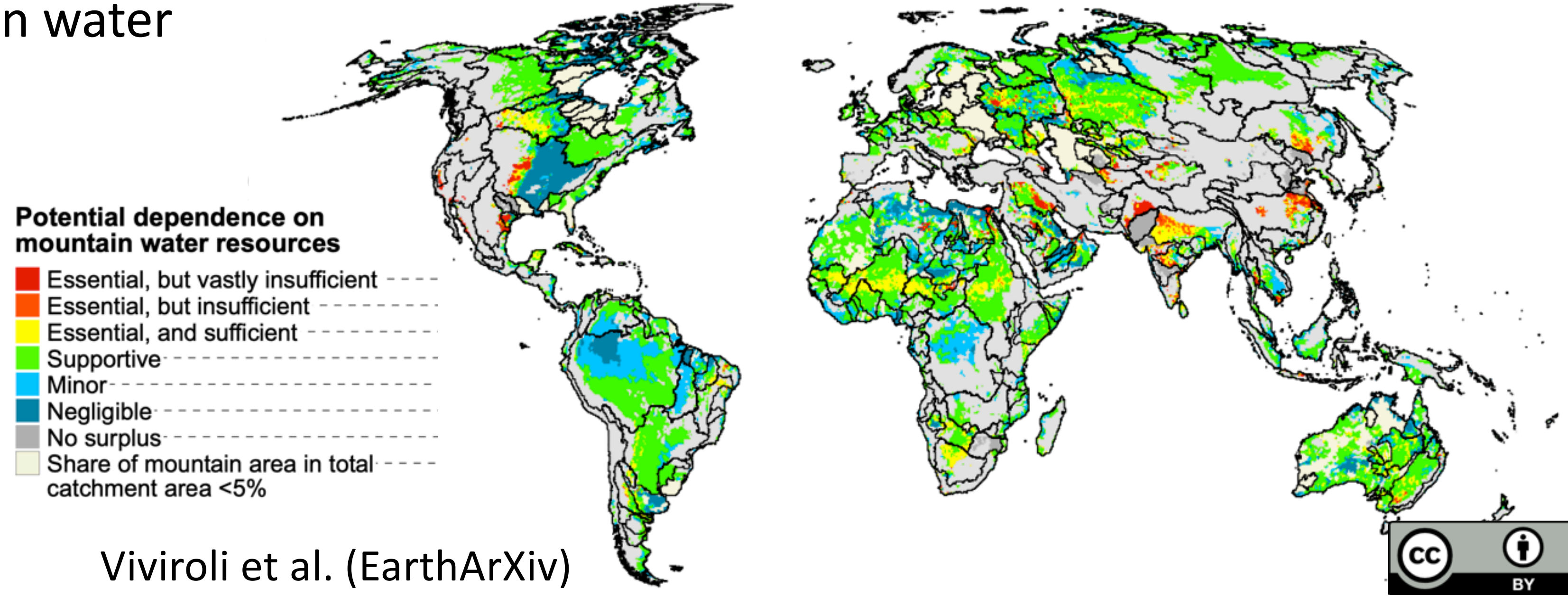
- Hydropower potential
- Domestic use
- Irrigation / agriculture
- Industrial use



Farinotti et al. (2019)

Dependence on mountain water resources (2041-2050)

Other (global) studies / datasets / indicators for evaluating opportunities?



Viviroli et al. (EarthArXiv)