Glacier lake outburst floods in Norway & beyond

by Ronja Lappe (PhD student, NTNU)

Bredagen, Klimahuset, Oslo

21.03.2025

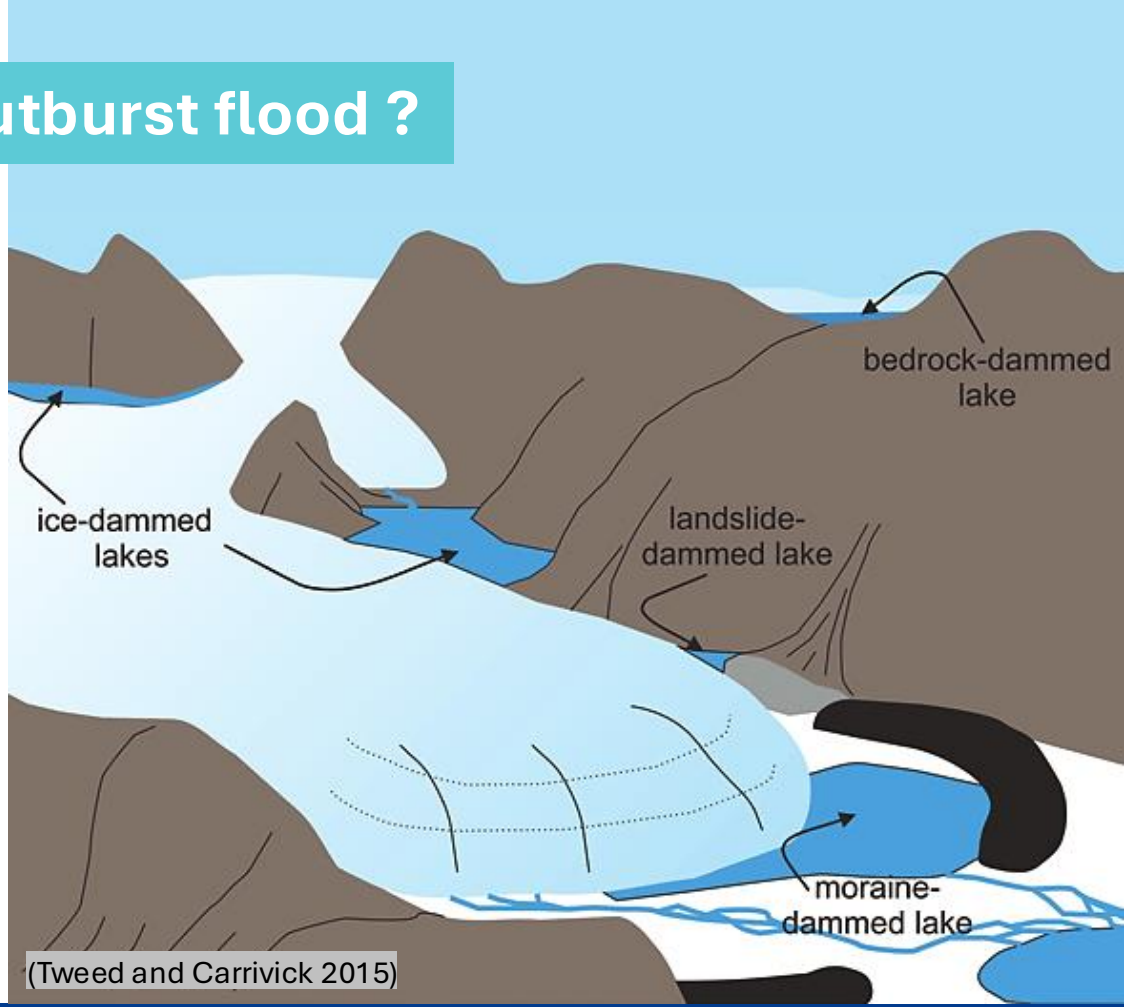
NTNU

NVE

GOTHECA
Glacier Impacts On The Hydrological Systems in Europe and Central Asia

What is a glacier lake outburst flood ?

- Glacier lake outburst flood (GLOF) or *Jøkulhlaup (islandic)*
- Sudden, rapid events with large downstream river discharge
- Caused by dam failure
- Moraine-dammed vs. ice-dammed



(Tweed and Carrivick 2015)

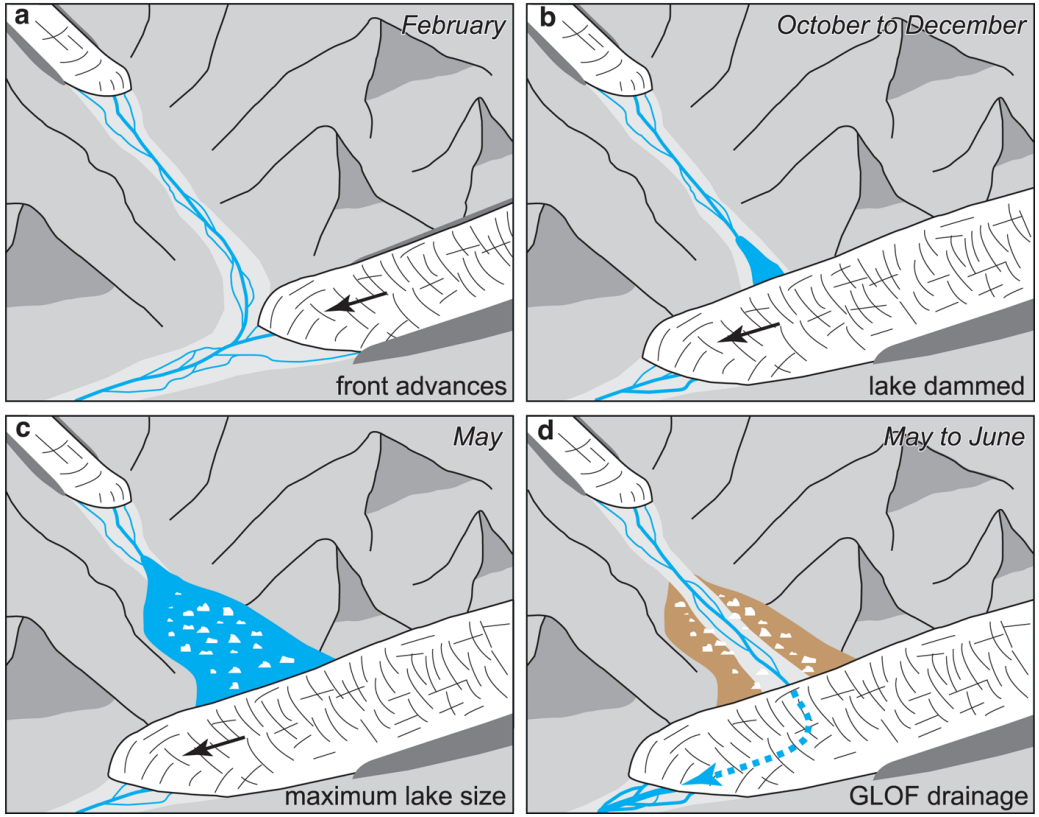
What is a glacier lake outburst flood ?


(Nedre Demmevatnet, Y. Gong 2023)

Ice-dam failures

- Majority of GLOFs from ice-dammed lakes (refilling cycles)
- Drainage through subglacial channels
- Ice dam flotation
- Overspill

What is a glacier lake outburst flood ?



- Lake damming through glacier surge
- Primarily found in High Mountain Asia or Svalbard

(Lovell & Muhammad 2025)

NTNU

Impact of climate change on GLOFs

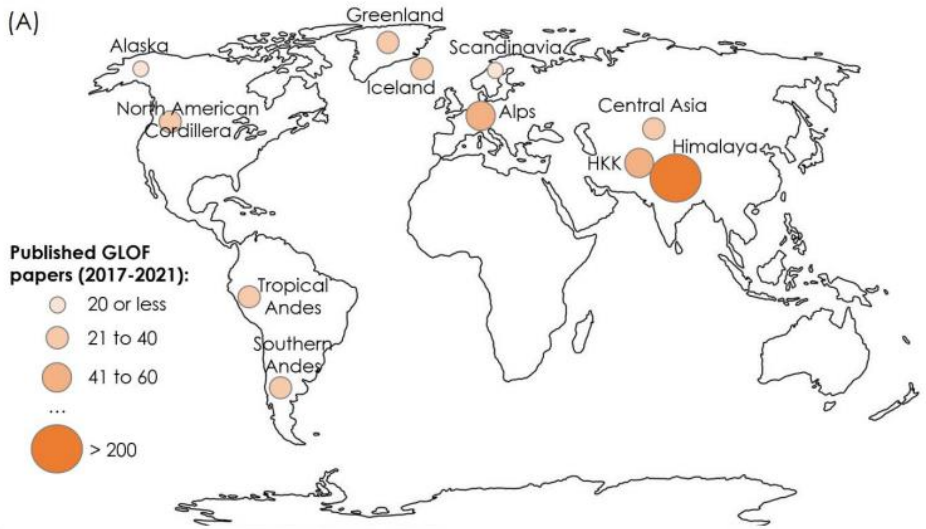
- Global glacier mass loss causes the formation of new and larger glacial lakes (Zhang et al. 2020)
- Glacial lake volume has grown by 48 % between 1990 & 2018 globally (Shugar et al. 2020)
- Especially in high altitudes and latitudes (Shugar et al. 2020)
- GLOF risk is expected to increase (Zheng et al. 2021)
- Exposing 15 million people are the impacts of potential GLOFs (Taylor et al. 2023)

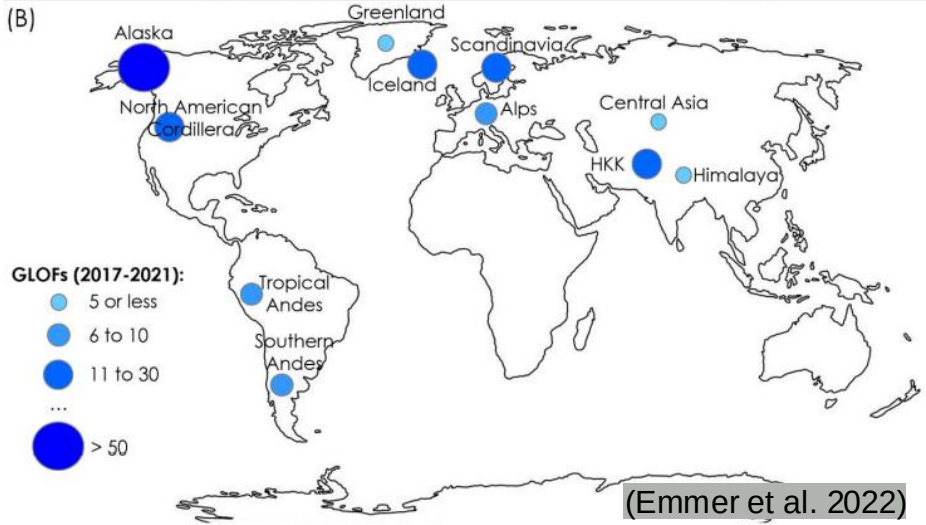
(Nedre Demmevatnet, Lappe 2023)

Where ?

Frequency of GLOFs

- Geographical focus of published GLOF papers vs. reported GLOFs (2017-2021)
- Most reported GLOFs in Alaska, Scandinavia, Karakorum (while being less researched)



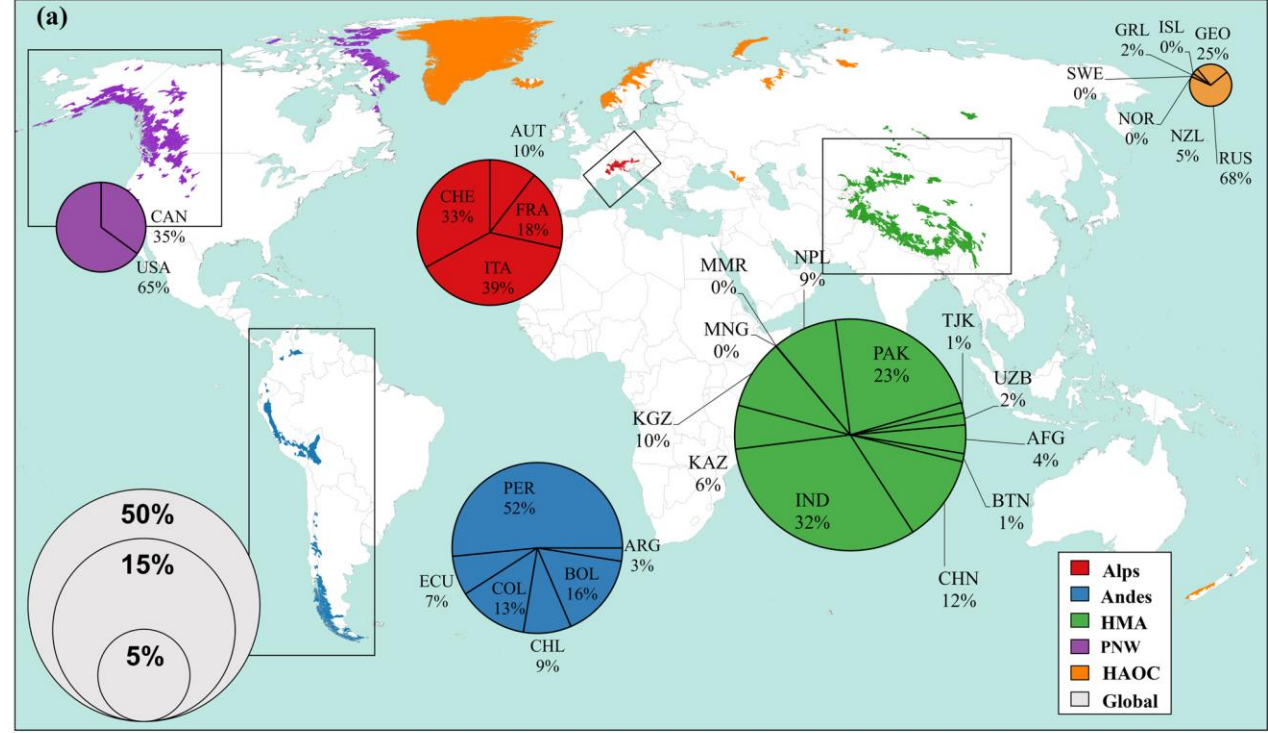


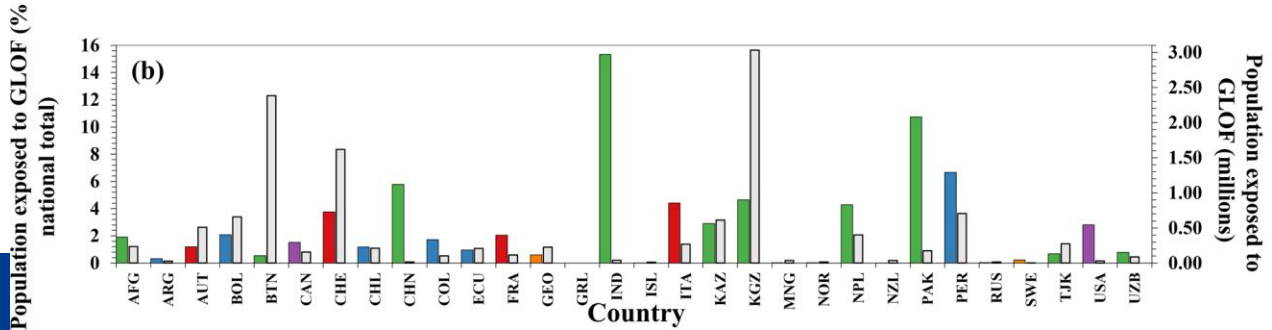
(Emmer et al. 2022)

Where ?

Exposure to GLOFs

- High Mountain Asia (HMA) most exposed (~1 mio people)





(Taylor et al. 2023)

Why should research GLOFs ?

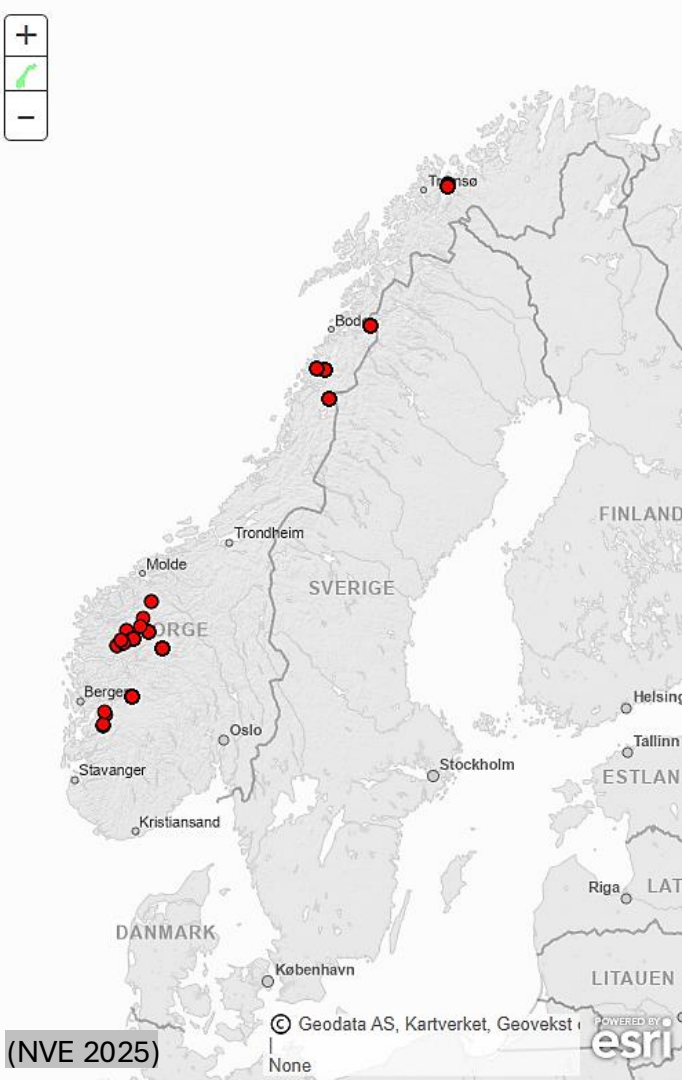
- GLOFs can be highly destructive
- Arrive with little prior warning
- Possible significant damage to infrastructure, farmland and settlements
- Lack of understanding in timing and magnitude (Zheng et al. 2021)
- Substantial data limitation (field data, global multi-temporal lake mapping, robust GLOF modelling) (Zhang et al. 2024)

(Photos: ABDUL MAJEED/AFP(CNN World)

GLOFs in Norway

- 177 GLOFs since 1760
- Mainly from Rembesdalskåka, Blåmannsisen, Mjølkedalsbreen, Harbardsbreen, Koppangsbreen & Svartisen
- Having caused damage to infrastructure

(Blåmannsisen, H. M. Hjemaas 2005)

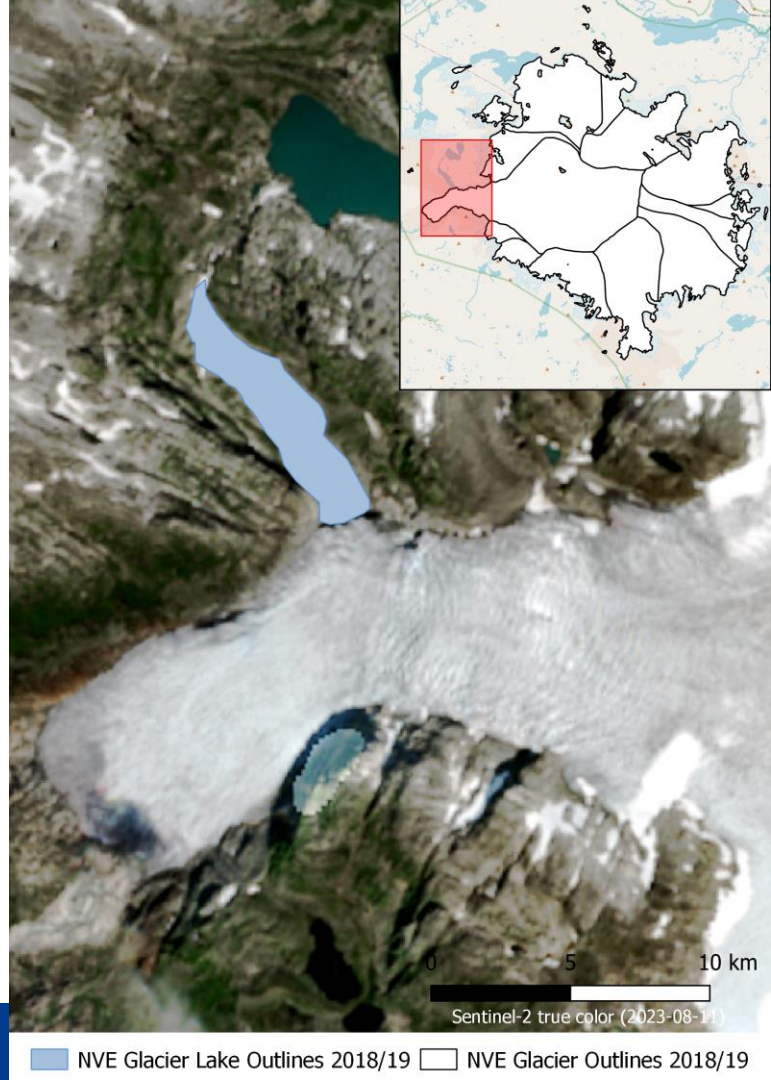


(NVE 2025)

Example: Nedre Demmevatnet

Background

- Rembesdalskåka, Hardangerjøkulen, Southern Norway
- Ice-dammed glacial lake
- GLOF history since 1760
- Construction of artificial drainage tunnels in 1899 & 1937
- Reoccurring GLOFs since 2014

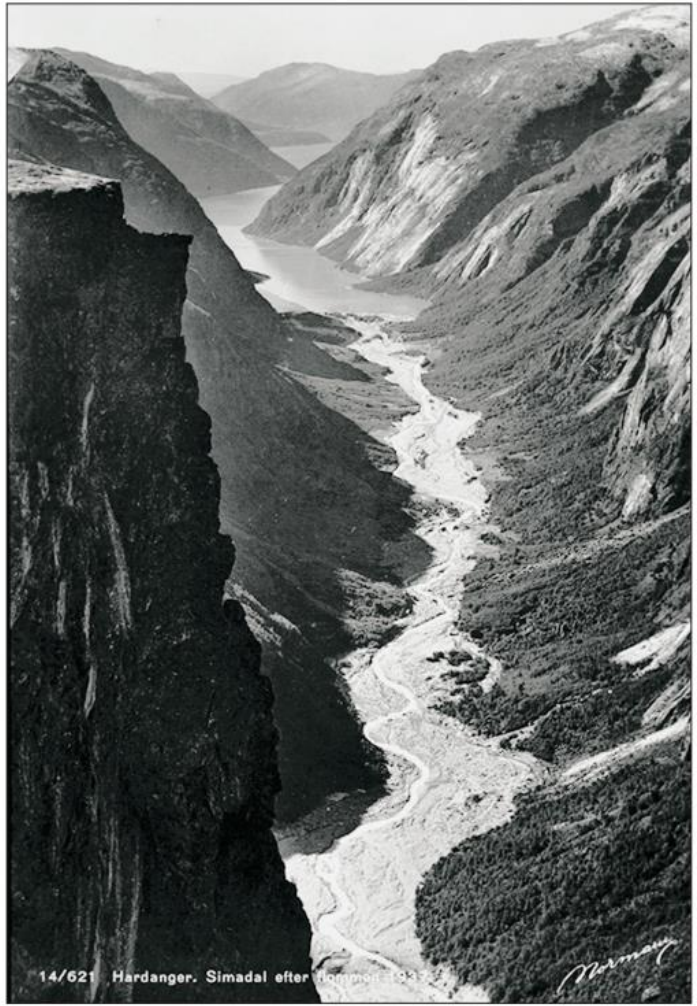


Example: Nedre Demmevatnet

(NRK 2017, artist unkown)

Example: Nedre Demmevatnet

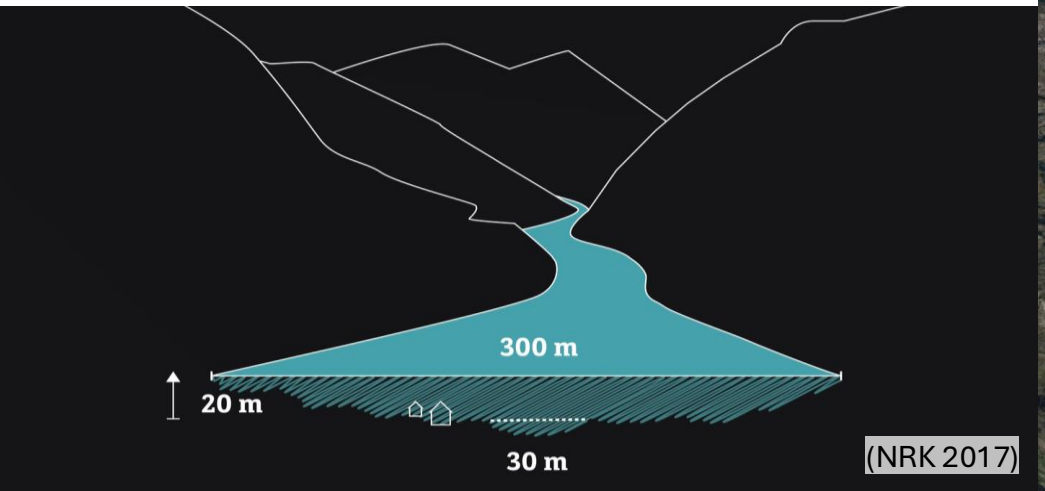
(NRK 2017)



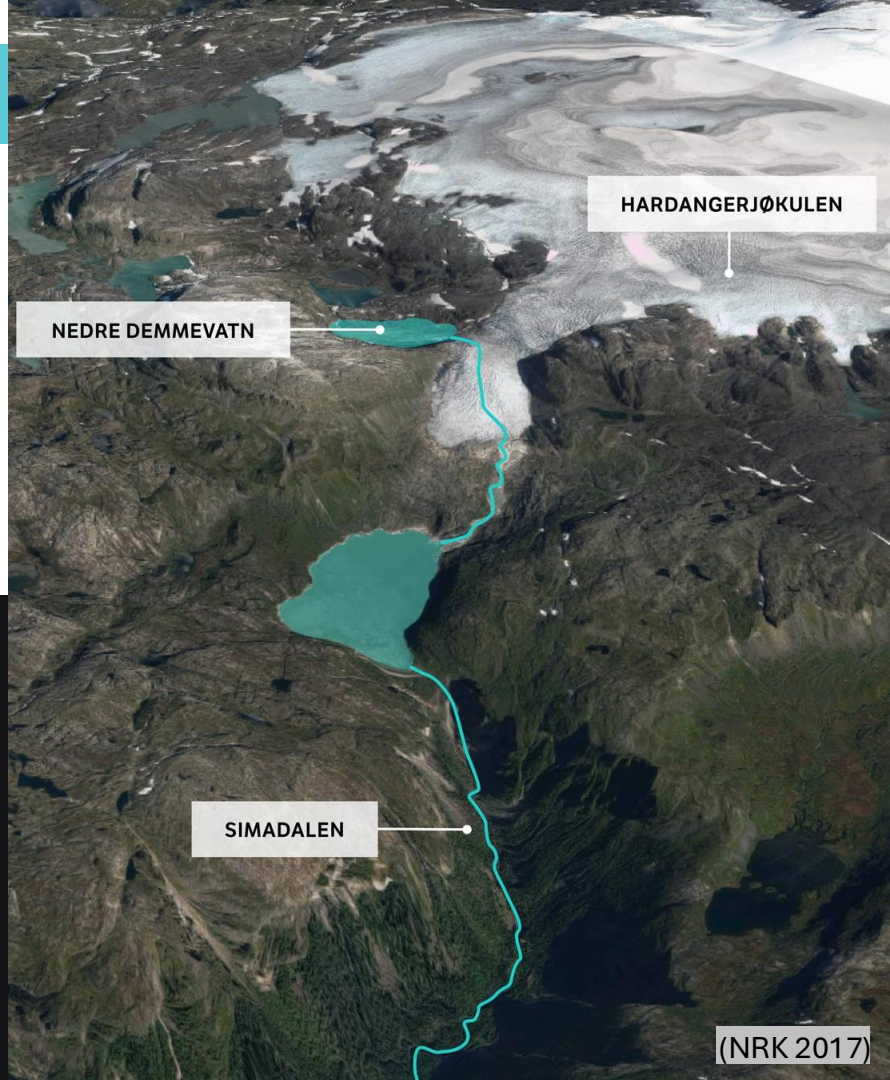
Simadalen etter flaumen i 1937. (Normann)

Example: Nedre Demmevatnet

- GLOF in August 1937 caused large damage on cropland and houses in Simadalen
- Estimated 11 mio m3 in 3-4 hours



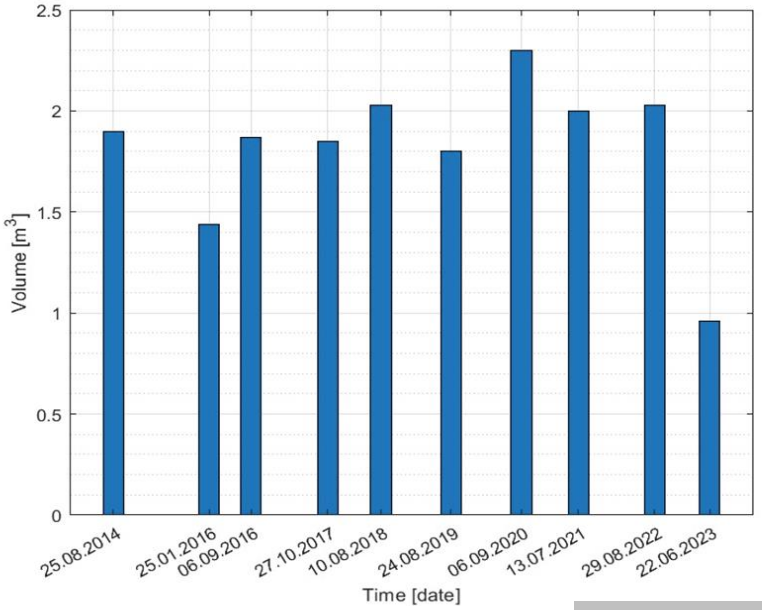
(NRK 2017)



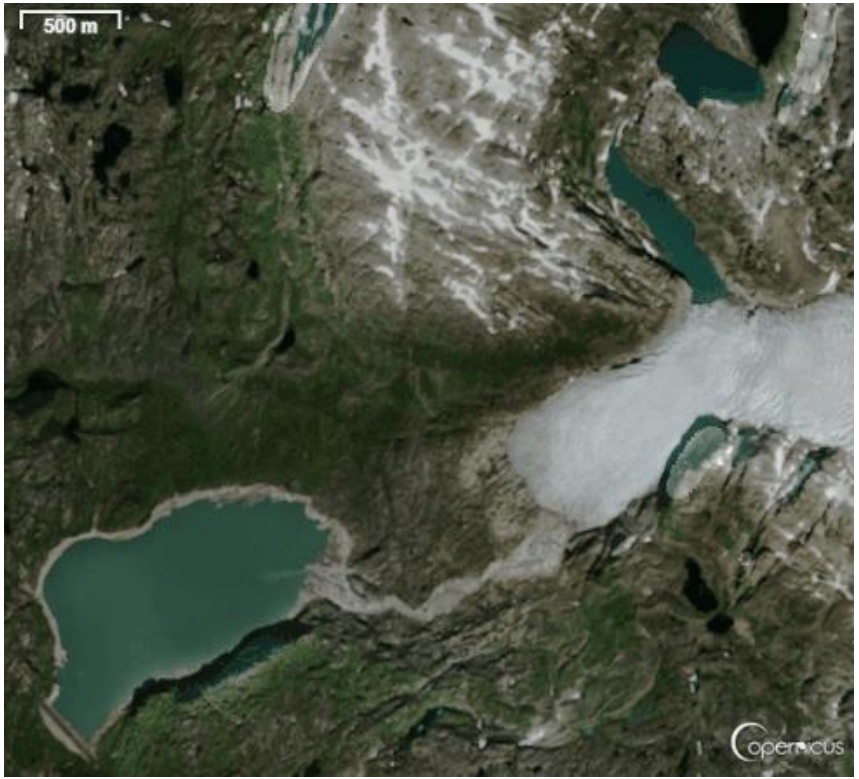
(NRK 2017)

Example: Nedre Demmevatnet

GLOF volumes since 2014



(Ursula Enzenhofer)



NTNU

Example: Nedre Demmevatnet

Most common drainage mechanisms discussed in literature:

(1)

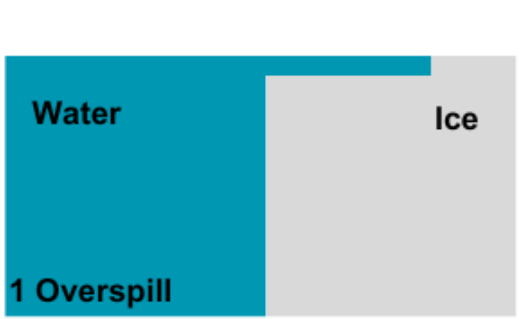
Overspill - Supraglacial drainage documented by many observations

(2)

Ice uplift – including observations of a subglacial channel

(3)

Cutting a channel between rock wall and glacier ice dam



(slide by Ursula Enzenhofer)

Example: Nedre Demmevatnet

Our research

- Reconstruct past GLOF volumes and refilling rates to enhance our understanding of mechanisms & triggers
- Using satellite data analysis, machine learning & fieldwork
- Glacier-& hydrological modeling

GOTHECA-project, PhD projects of Ursula Enzenhofer and Ronja Lappe

(U. Enzenhofer, 2022)

Example: Nedre Demmevatnet

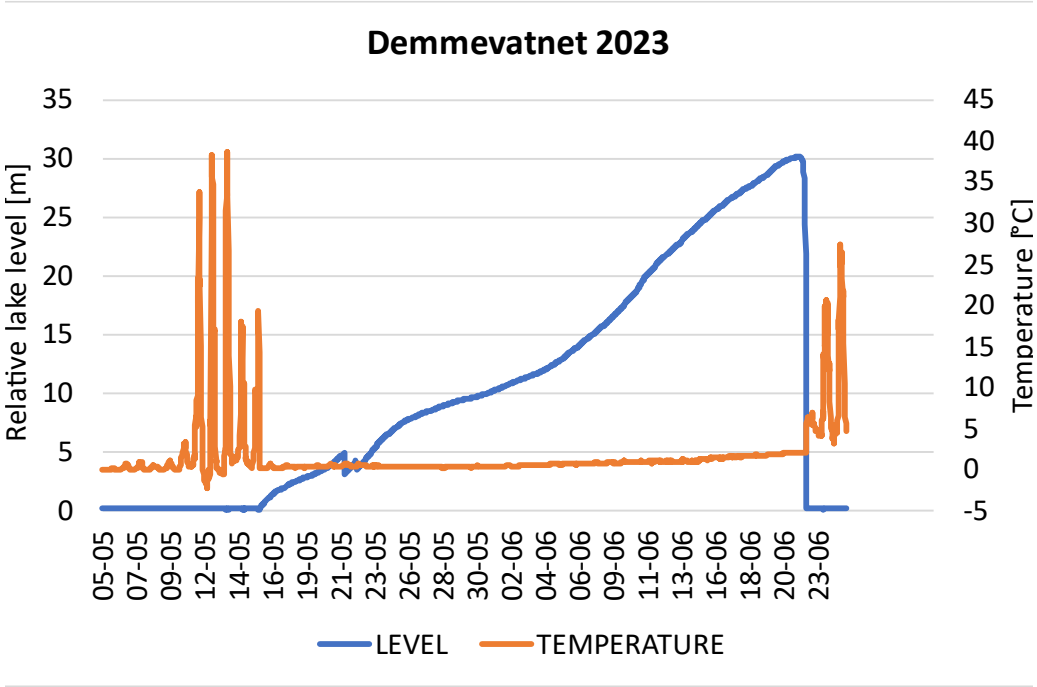
Our research - fieldwork

- Lake level sensors
- Weather stations
- Time-lapse cameras
- Ground penetrating radar (GPR)
- Drone surveys

Example: Nedre Demmevatnet

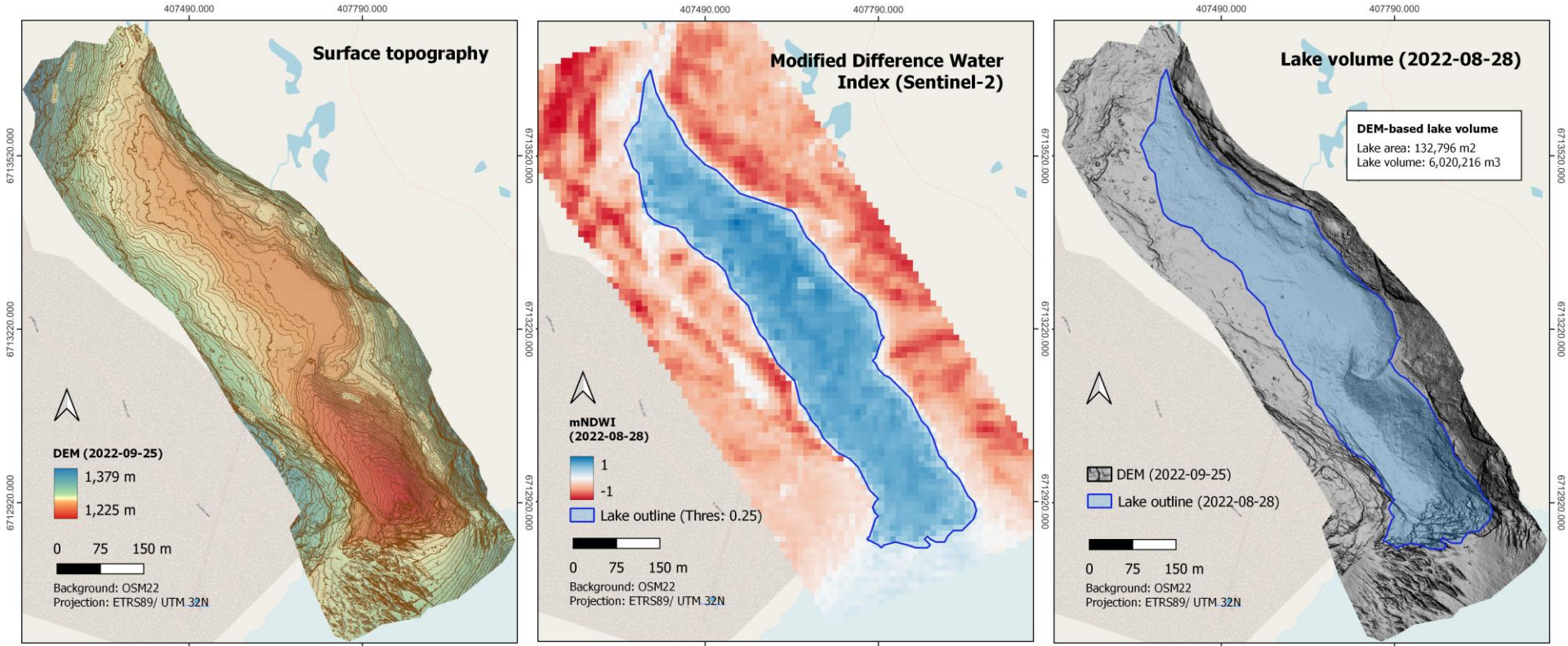
Our research - fieldwork

- Lake level sensors
- Weather station
- Time-lapse cameras
- Ground penetrating radar (GPR)
- Drone surveys



Example: Nedre Demmevatnet

Lake volume estimation based on drone DEM & satellite imagery



Research beyond Norway

- Similar measurement set-up in Tystigbreen, Stryn
- Field campaign to Karakorum mountains in Pakistan in 2024

- Updating Norway's glacier lake inventory using satellite images and machine learning
- Using Deep Learning to automatically identify draining lakes

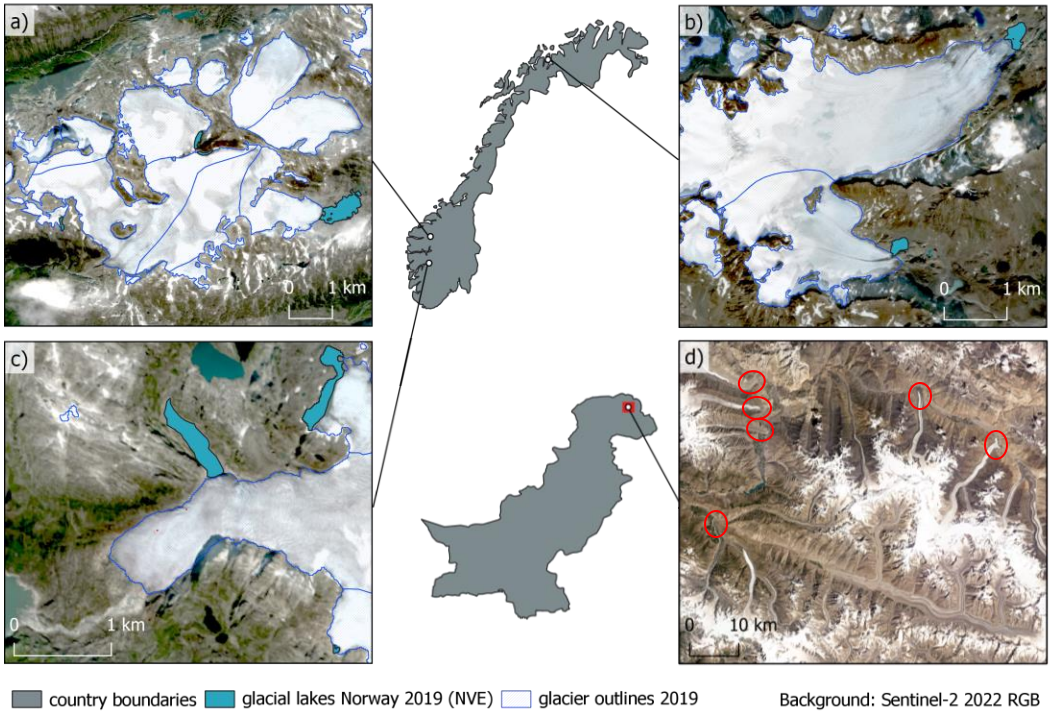


Fig: Field sites a) Tystigbreen, b) Koppangsbreen, c) Rembesdalskåka, d) Kyagar glacier

Pakistan fieldwork

Norway fieldwork

Thanks for your attention. ☺

Questions? Suggestions?

References

- **Carrivick**, J. L., & **Tweed**, F. S. (2016). A global assessment of the societal impacts of glacier outburst floods. *Global and Planetary Change*, *144*, 1–16. https://doi.org/10.1016/j.gloplacha.2016.07.001
- **Emmer**, A., Wood, J. L., Cook, S. J., Harrison, S., Wilson, R., Diaz-Moreno, A., Reynolds, J. M., Torres, J. C., Yarleque, C., Mergili, M., Jara, H. W., Bennett, G., Caballero, A., Glasser, N. F., Melgarejo, E., Riveros, C., Shannon, S., Turpo, E., Tinoco, T., … Poma, C. (2022). 160 glacial lake outburst floods (GLOFs) across the Tropical Andes since the Little Ice Age. *Global and Planetary Change*, *208*, 103722. https://doi.org/10.1016/j.gloplacha.2021.103722
- **Lovell**, H., & **Muhammad**, S. (2025). Multiple phases of ice-dammed lake formation and drainage associated with a surge of Shisper Glacier, western Karakoram. *Journal of Glaciology*, *71*, e10. https://doi.org/10.1017/jog.2024.80
- **Shugar**, D. H., Burr, A., Haritashya, U. K., Kargel, J. S., Watson, C. S., Kennedy, M. C., Bevington, A. R., Betts, R. A., Harrison, S., & Strattman, K. (2020). Rapid worldwide growth of glacial lakes since 1990. *Nature Climate Change*, *10*(10), 939–945. https://doi.org/10.1038/s41558-020-0855-4
- **Taylor**, C., Robinson, T. R., Dunning, S., Rachel Carr, J., & Westoby, M. (2023). Glacial lake outburst floods threaten millions globally. *Nature Communications*, *14*(1), 487. https://doi.org/10.1038/s41467-023-36033-x
- **Zhang**, M., Chen, F., Tian, B., Liang, D., & Yang, A. (2020). Characterization of Kyagar Glacier and Lake Outburst Floods in 2018 Based on Time-Series Sentinel-1A Data. *Water*, *12*(1), 184. https://doi.org/10.3390/w12010184
- **Zheng**, G., Allen, S. K., Bao, A., Ballesteros-Cánovas, J. A., Huss, M., Zhang, G., Li, J., Yuan, Y., Jiang, L., Yu, T., Chen, W., & Stoffel, M. (2021). Increasing risk of glacial lake outburst floods from future Third Pole deglaciation. *Nature Climate Change*, *11*(5), 411–417. https://doi.org/10.1038/s41558-021-01028-3