Hydropower water level regulation: effects on the ice cover of two Norwegian reservoirs

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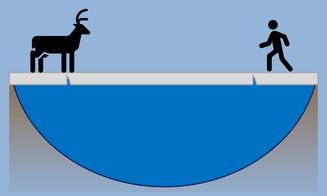
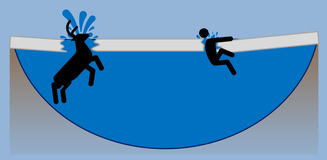
BACKGROUND

Relevance?

Integrity and bearing capacity of lake ice cover are crucial to *safety*





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In hydropower (HP) reservoirs, plant operations = large and rapid *water level variations* (Δh)

↓

Research questions

1. What is the effect of Δh on ice cover integrity?
2. Are Δh or other stressors (rapid cooling) the main driver of ice cracking?

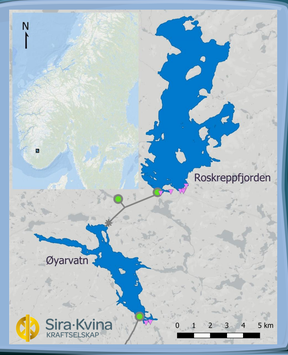
Challenges

- In-situ monitoring of ice covers is logistically difficult
- The role of HP regulation on reservoir ice stability is not fully understood, especially in lakes with *complex bathymetry*

How tackled? →

STUDY AREA

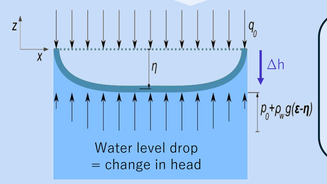
System of two HP reservoirs with complex bathymetries – head of HP cascade system in southern Norway



METHODS

Visual analysis of multispectral and SAR satellite imagery	▪ Ice cracks detection ▪ Crack patterns analysis
Water level (📏) and air temperature (🌡) data analysis	▪ Dynamics during the entire ice season and before cracks
Simple mechanical and thermal-expansion models	▪ Role of the forcings ▪ Critical forcing variations

Mechanical model



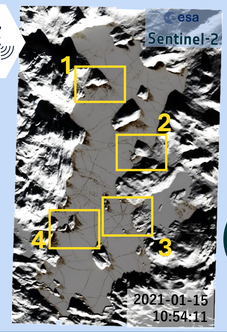
Elastic line equation

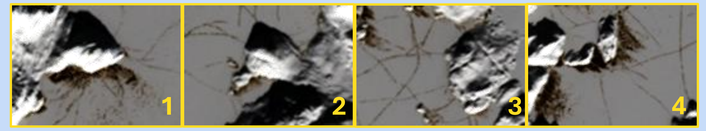
$$EI\frac{d^4\eta}{dx^4} = \rho_w g(\varepsilon - \eta)$$

EI: flexural rigidity of the ice beam; η: ice beam deflection; ε: variation of piezometric head; $\rho_w g(\varepsilon-\eta)$: response of the water foundation

+ **intermediate support** introduced to simulate presence of **bathymetric obstacle** (▲)

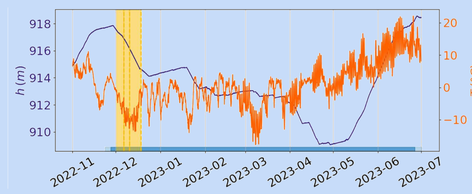
RESULTS

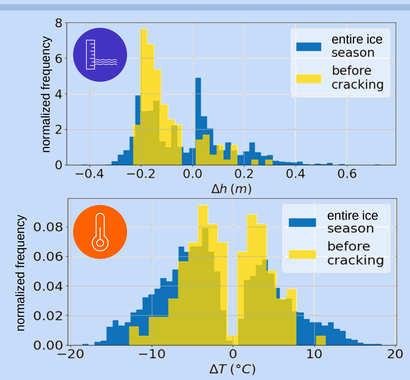




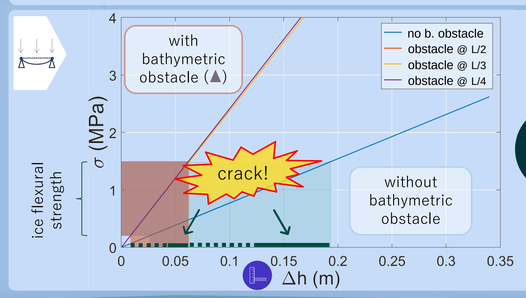
There is a **critical period** (early winter) for crack formation in the study sites

Cracks propagate from **bathymetric obstacles**





Dynamics before cracking:
predominant decrease
no clear dynamics



Cracks can form even with small drops in water level above **bathymetric obstacles**

CONCLUDING REMARKS

Negative **water level** variations: **leading cause** of ice cover cracking in the study reservoirs

Role of **water level variations** = role of **HP regulation** (€) on ice cover integrity!

Importance of studying effect of HP modulation during the critical period for crack formation.

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REFERENCES:

1. Hinegk, F. et al. (2025). *Ice Cracking in Hydropower Reservoirs with Complex Bathymetry: the Response to Hydraulic and Thermal Forcings*. Manuscript under review.
2. Billfalk, L. (1981). *Formation of shore cracks in ice covers due to changes in the water level.* In Proceedings of the international symposium on ice (Vol. II,pp. 650–662). Québec, Canada.
3. Evans, R.J., & Untersteiner, N. (1971). *Thermal cracks in floating ice sheets*. Journal of Geophisical Research.

ABSTRACT

This presentation participates in OSPP

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