Gjenbruk av TBM i deponitildekking

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10. april 2025

earthresQue

SFI earthresQue (2020-2028)

Centre for Rescue of Earth Materials and Waste in the Circular Economy

https://www.nmbu.no/forskning/prosjekter/earthresque

Research Institutes

NMBU BI IFE NIVA NIBIO NILU NORSUS NGI

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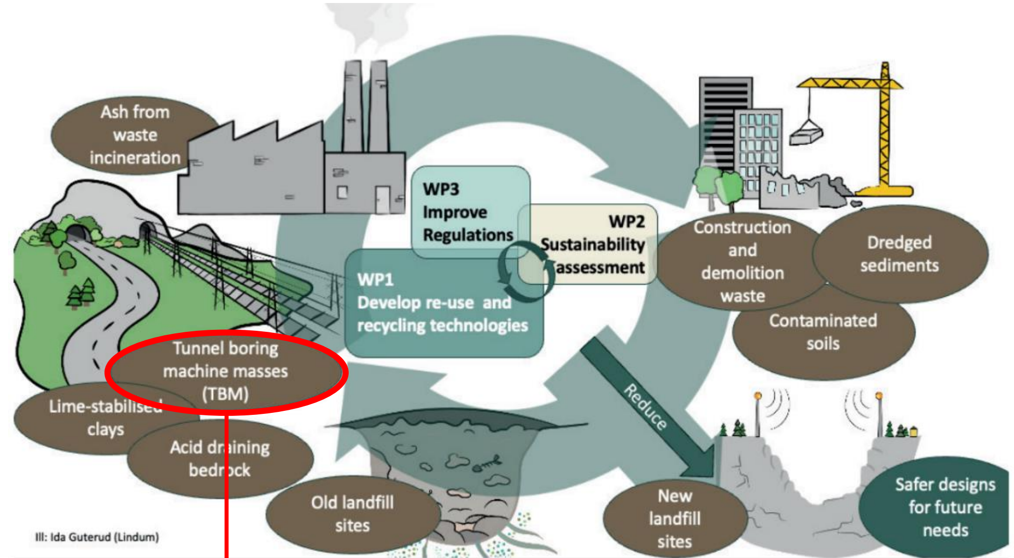

Figure 2, Overview of the earth materials in focus and the scientific interdisciplinarity.

earthresQue Annual Report 2024 (2025)

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NOAH (Ann-Cathrin Stridal og Helga Lassen Bue)
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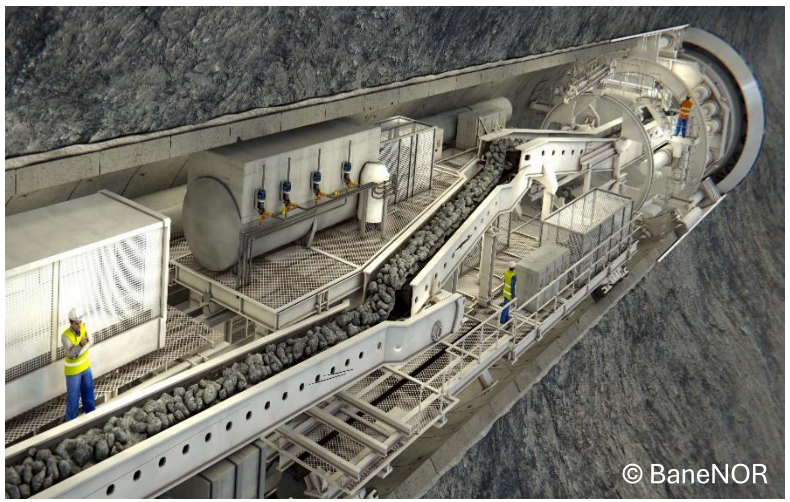
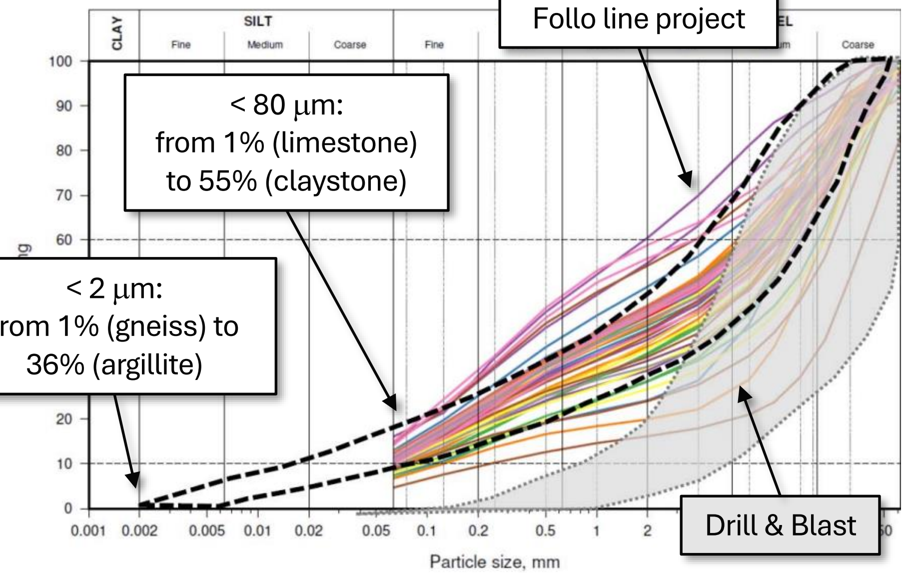
TBM spoils/muck - Properties



Flakiness index from 4% to 44% but tends to decrease with particle size

Langford et al. (2021)

Particle size from a few micrometres to a dozen centimetres



Follo line project

< 80 µm:
from 1% (limestone)
to 55% (claystone)

< 2 µm:
from 1% (gneiss) to
36% (argillite)

Drill & Blast

Langford et al. (2021)

Reference	k_{sat} (m/s)	Comment/details
Alnuaim (2021)	1×10^{-8}	< 4,75 mm, 95% Proctor
	2×10^{-5}	< 19,05 mm
Dahl (2018)	$[1\times10^{-6} ; 8\times10^{-5}]$	Field pit test

Reference	Int. frict. angle	Comment
Alnuaim (2021)	44°	Shearing rate 0,3 mm/min, 95% opt, ASTM D3080
Dahl (2018)	40-50°	Triaxial
NGI (1986)	35-45°	Triaxial, reported by Dahl (2018)

NGI (2025)

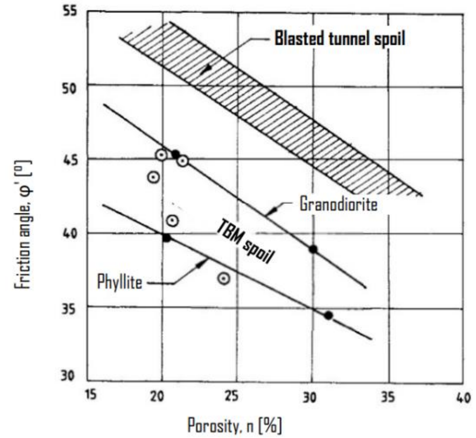
TBM spoils/muck – Reuse/Valorisation potential

Typical applications include:

- road construction
- aggregates in concrete and shotcrete
- filler
- all types of fillings (also in the sea)

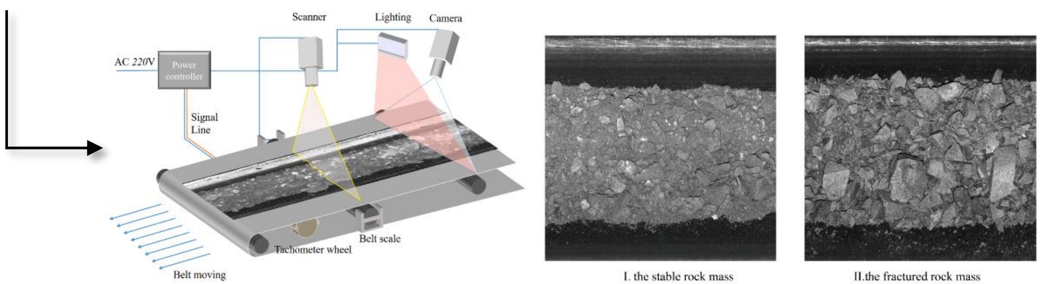
Grinding, crushing (e.g., VSI crusher, impact crusher), sieving, mixing (with binders) and sorting can be used to adjust/adapt the TBM spoils to specific uses; e.g.,

- to reduce the angularity of TBM particles (for reuse in concrete or asphalt)
- to reduce acid generation potential (e.g., by removing sulfides)



Statkraft (1986)

Carigi et al. (2023)

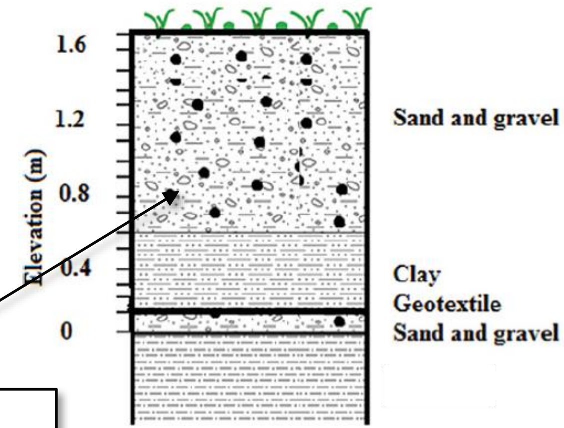


Gong et al. (2021)

© BaneNOR (fill of TBM-spoil at Åsland)

Research objectives

- Tunnel construction generates large volumes of waste geomaterials.
- TBM generate coarse well graded and (often) elongated particles.
- TBM spoil properties depend on geology, construction method (advancement speed, TBM characteristics, disk spacing). Possible to apply treatment (e.g., crushing, sieving).



Cover design = regulatory requirements + case/site specific constraints/opportunities

Bussiere & Guittonny (2021)

Research question:

Can TBM spoils be used in protection layers (against frost and evaporation) in engineered cover systems (e.g., landfills, TSF)?

Outcome: reduce the need for deposition of TBM spoils AND reduce the need for cover materials

Case study:

Material: TBM spoils produced at Råvannstunnel (19 km long), Rhomb porphyry

Site: Langøya Landfill (Oslofjord)

Transport by boat (December 2023)

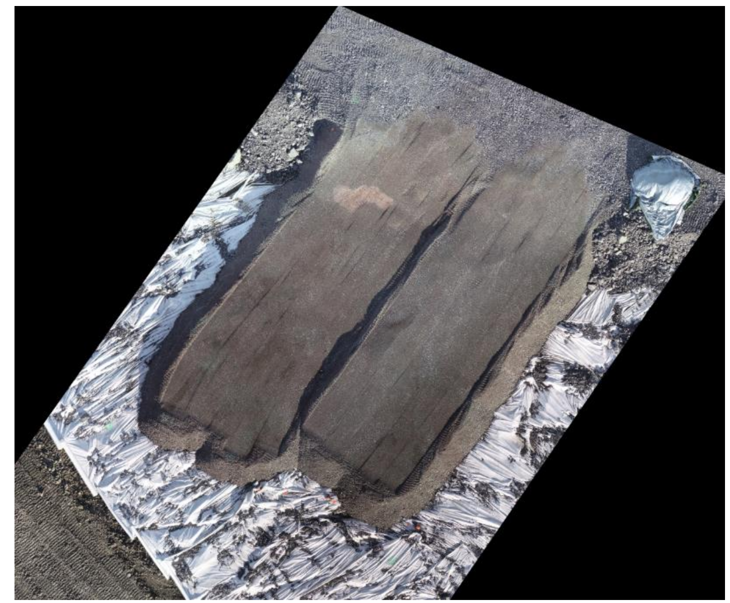
Pilot design

- 3 instrumented field cells on Langøya with triplicates:
  - 140 cm TBM + 60 cm limestone (P60A, B1, B2, and C)
  - 100 cm TBM + 100 cm limestone (P100A, B and C)
  - 200 cm limestone (P200A and C) ← Current plan = limestone only

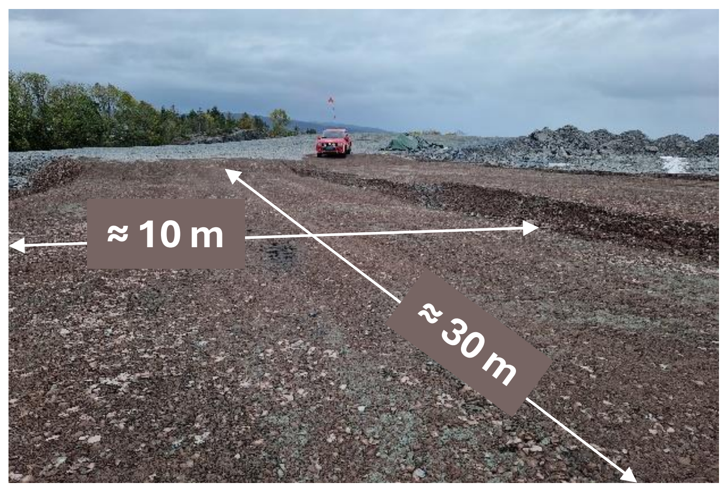
- Cover placed directly over low-permeability clay layer using regular construction / compaction equipment

- Limestone: crushed coarse material produced on site

Limestone to favour growth of local plants

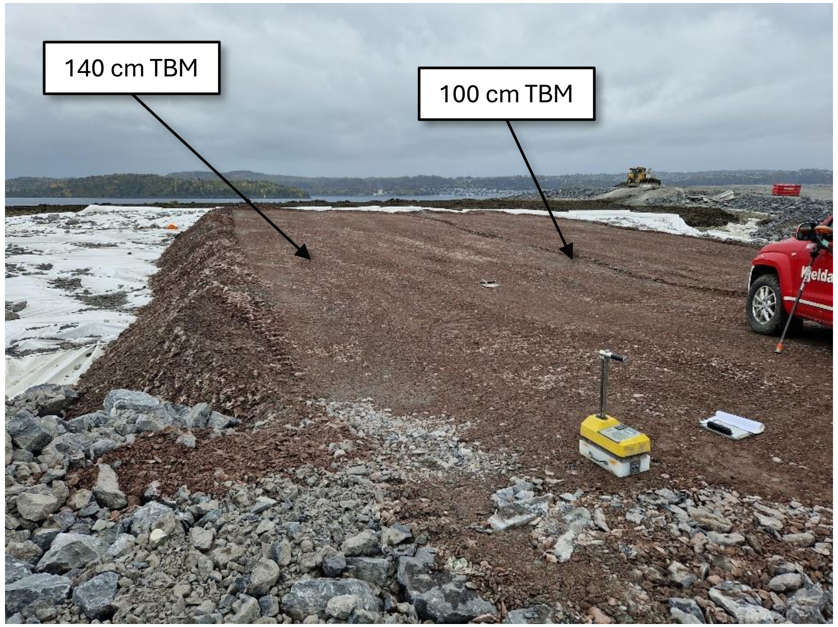


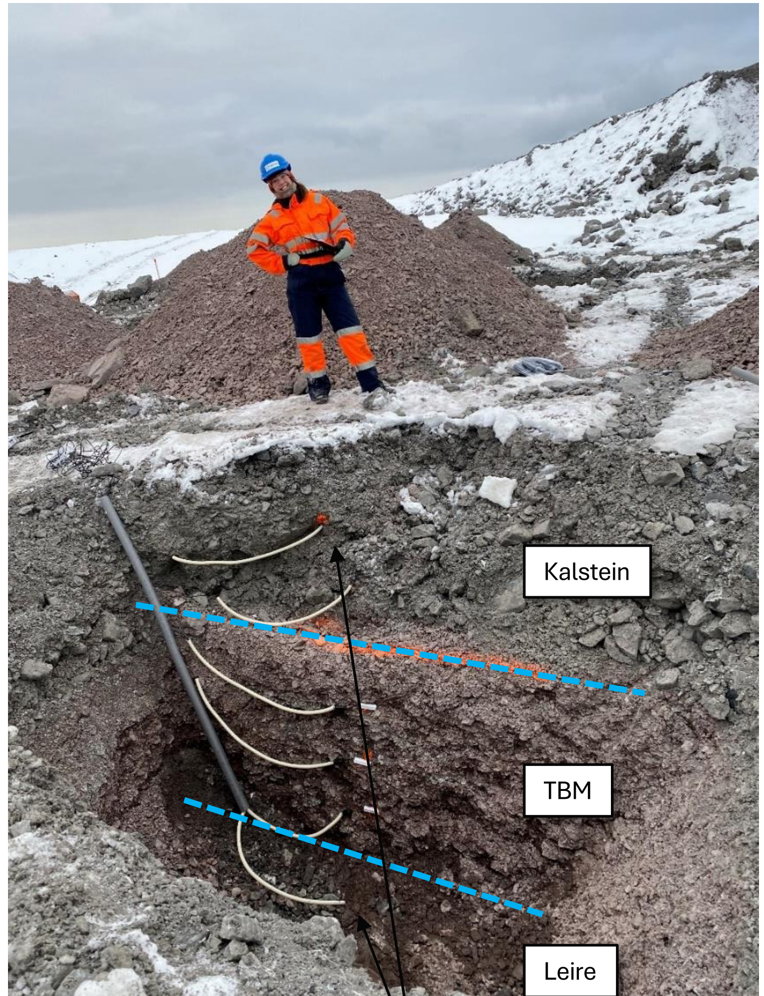
Compaction to mimic final cover construction

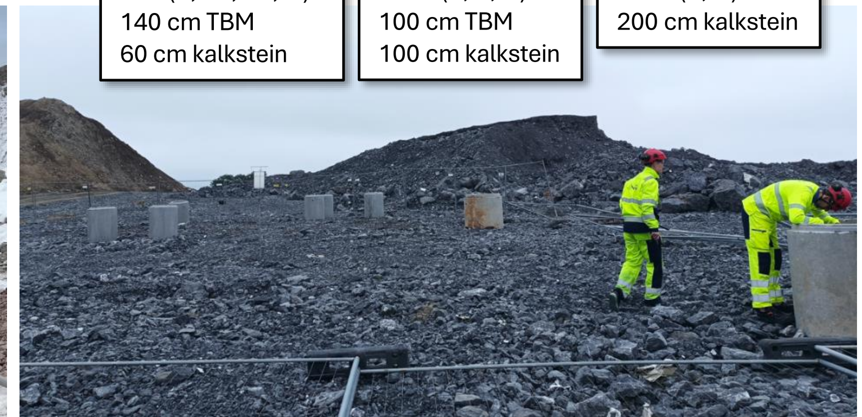


Pilot og instrumentering

9 profiler :		
P60 (A, B1, B2, C) : 140 cm TBM 60 cm kalkstein	P100 (A, B, C) : 100 cm TBM 100 cm kalkstein	P200 (A, C) : 200 cm kalkstein







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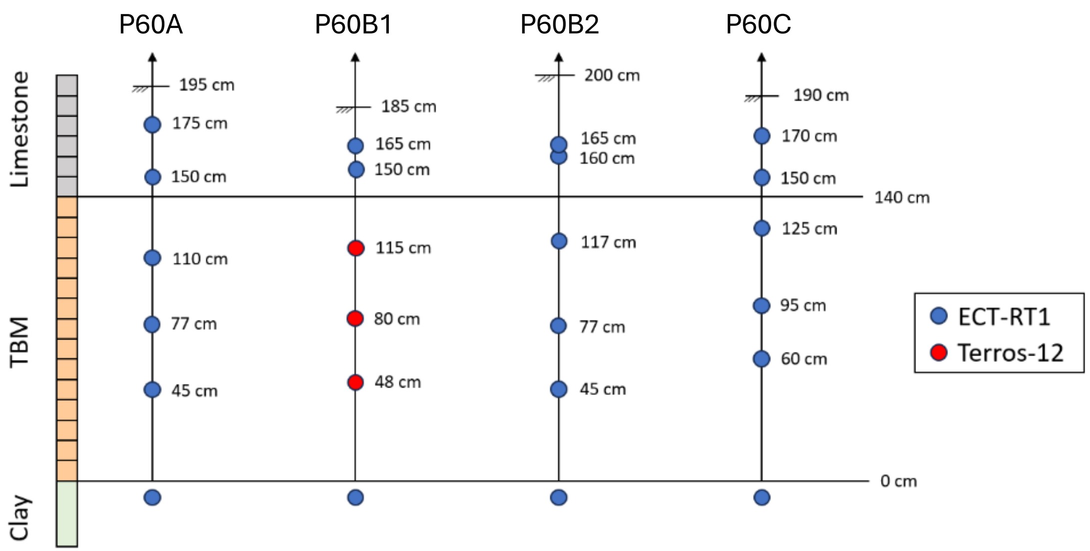
Pilot og instrumentering



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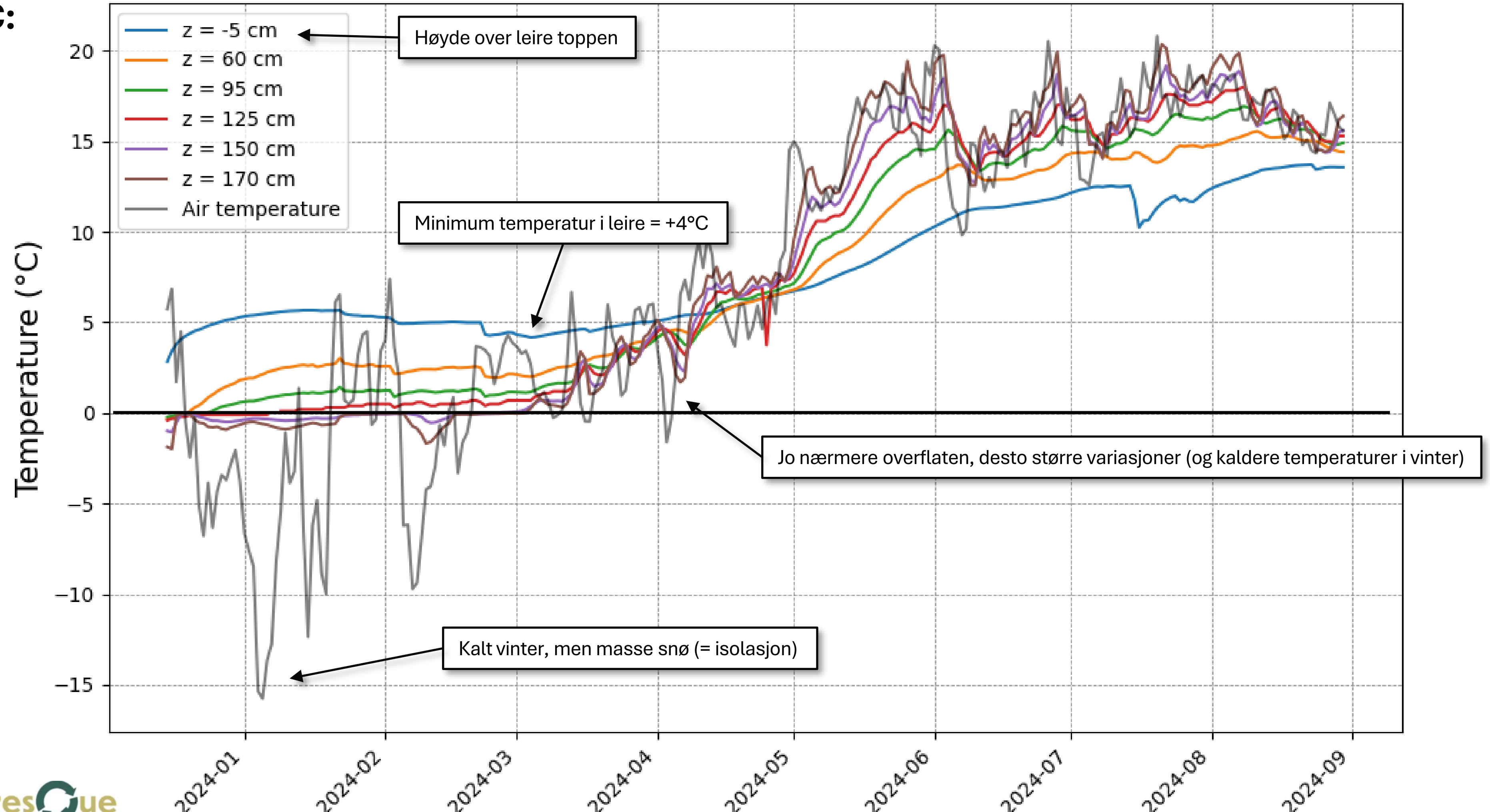
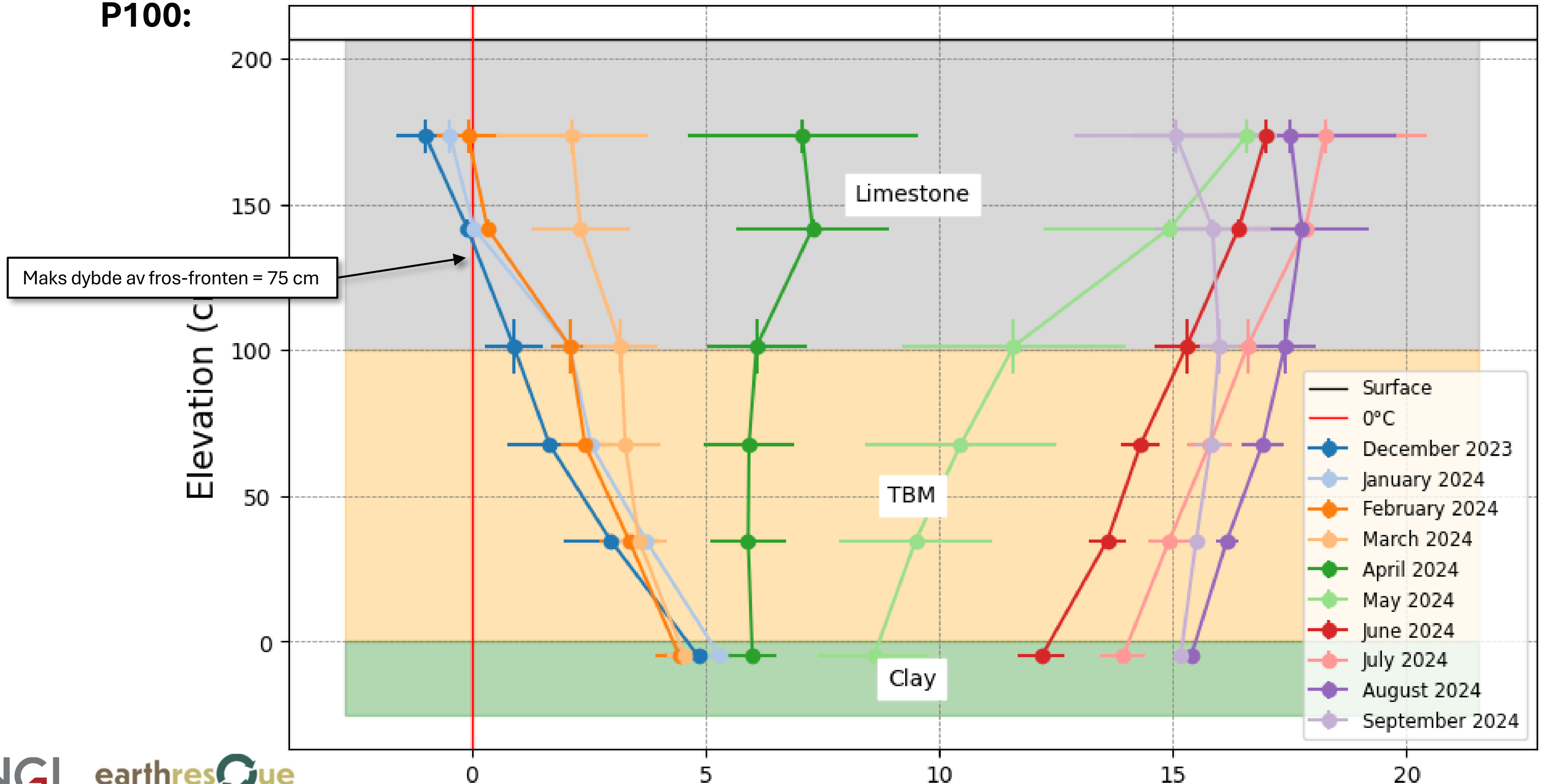
Felt målinger – Variasjoner med tid

P60C:

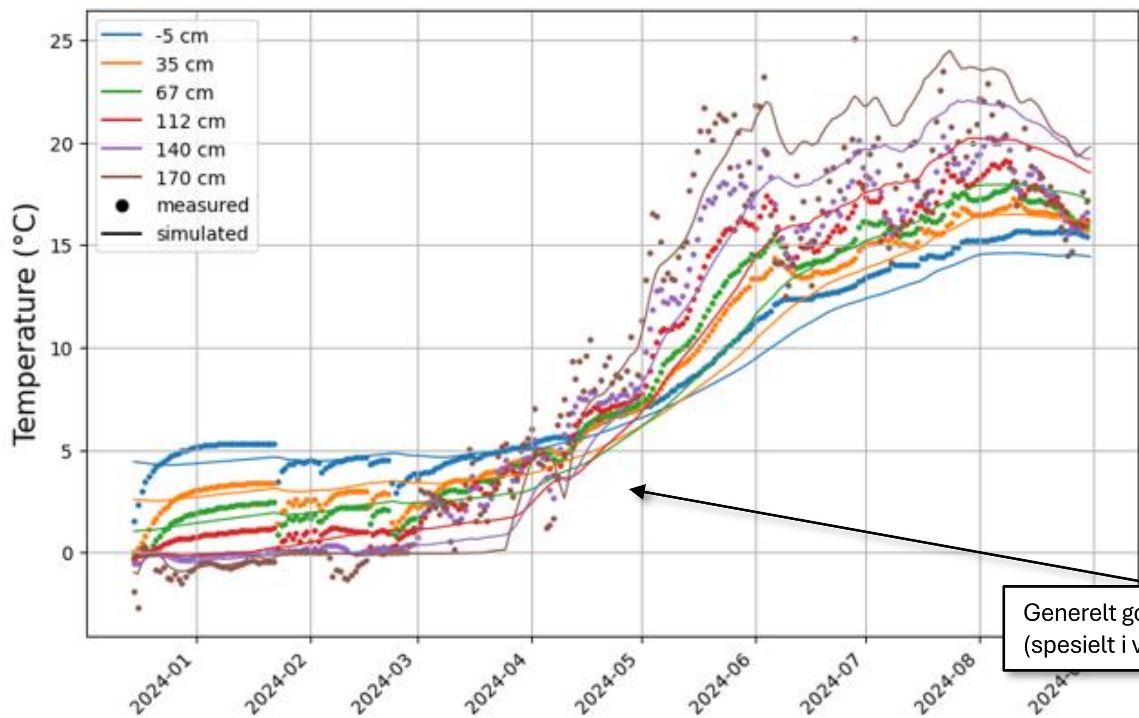


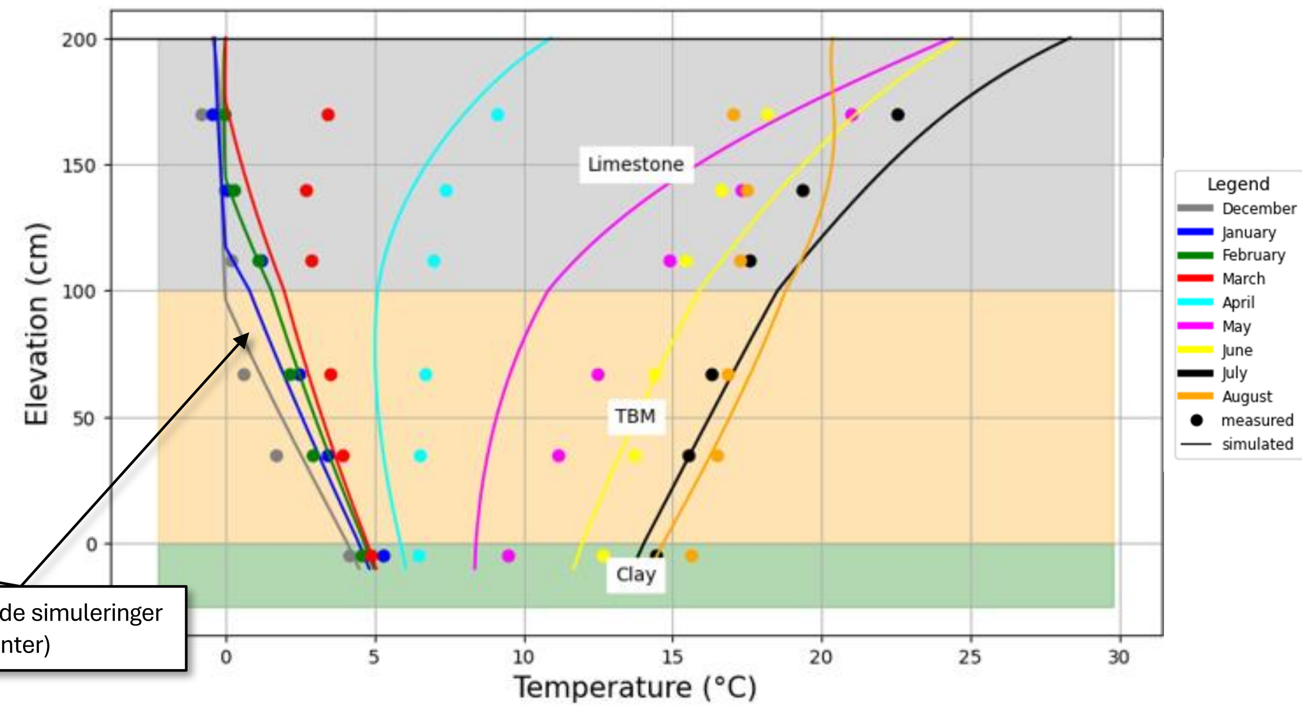
Felt målinger – Variasjoner med dybde

P100:



Numeriske simuleringer - Kalibrering





Generelt gode simuleringer
(spesielt i vinter)

Numeriske simuleringer med Seep/W + Temp/W.
Kalibrering av hydrogeologiske egenskaper +

- Frozen Thermal Conductivity (kJ/sec/m/°C)
- Unfrozen Thermal Conductivity (kJ/sec/m/°C)
- Frozen Volumetric Heat Capacity (kJ/m^3/°C)
- Unfrozen Volumetric Heat Capacity (kJ/m^3/°C)
- Snow density (kg/m^3)
- Snow conductivity (kJ/sec/m/°C)

Optimering med «kalibreringsscore»

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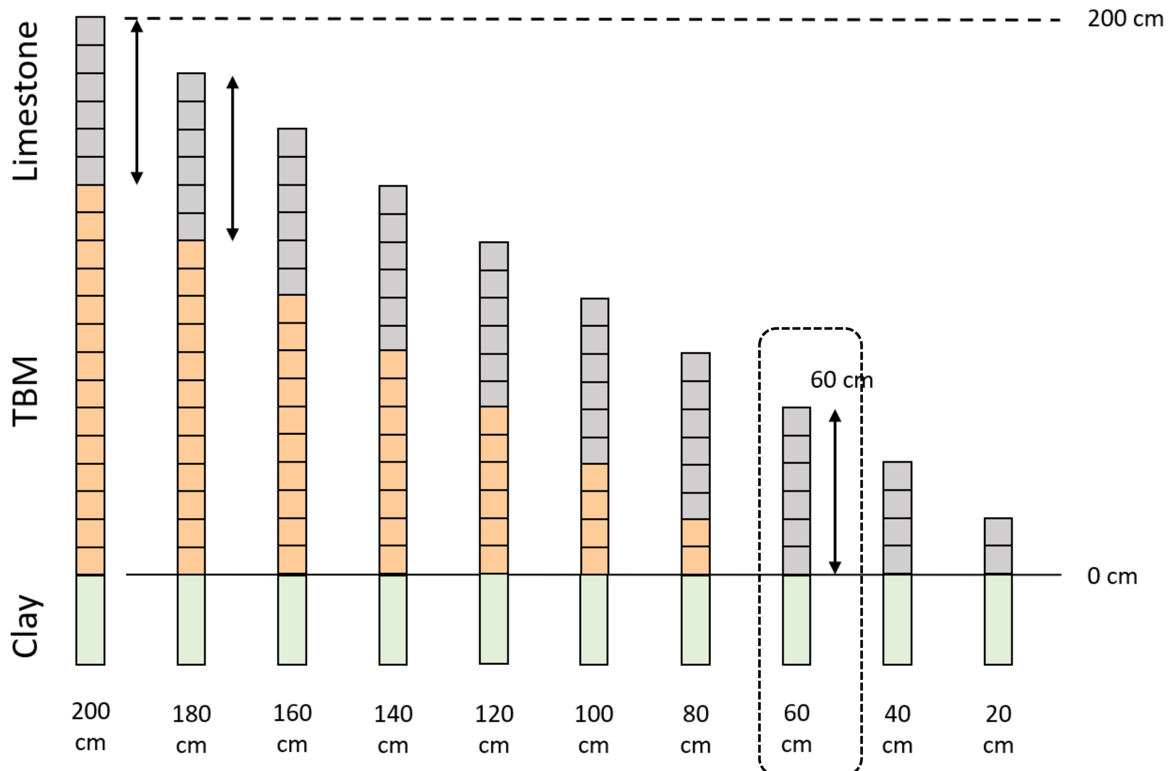
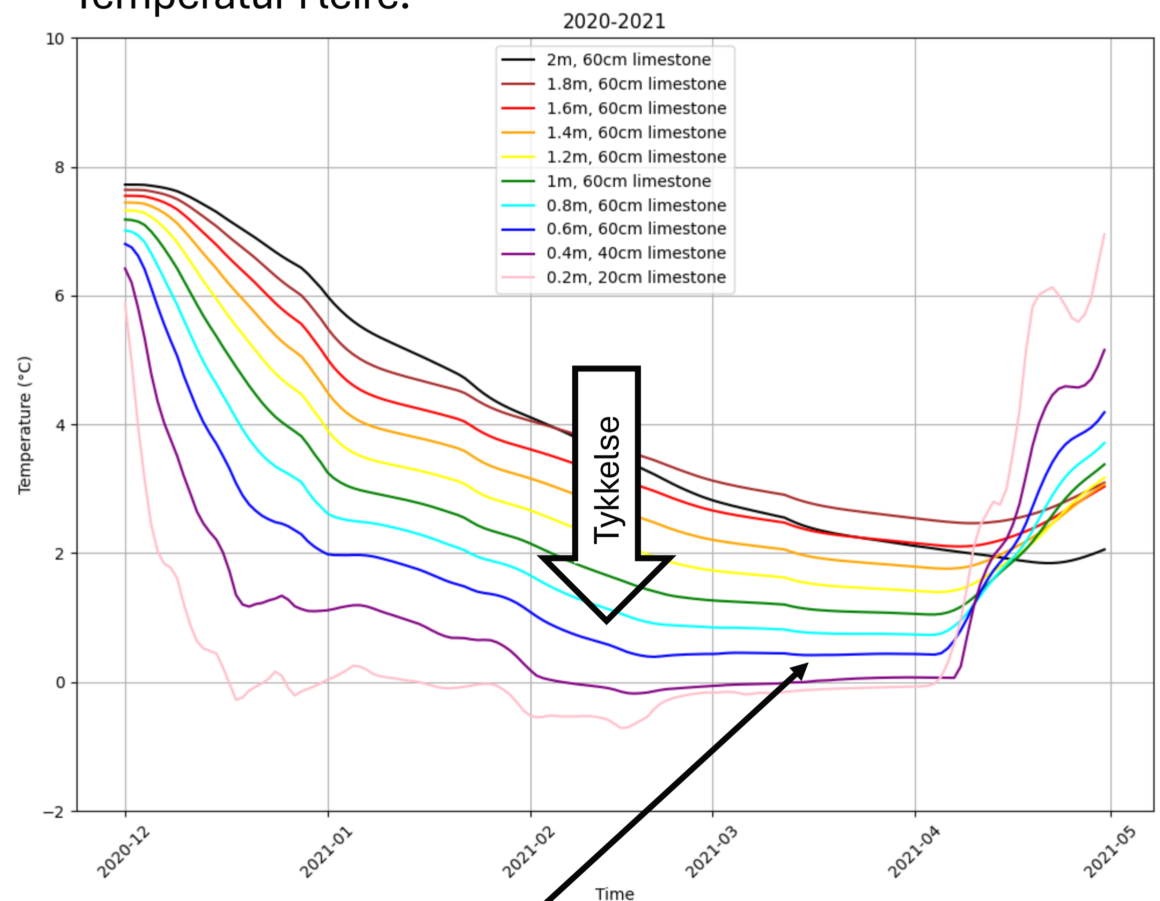
Simuleringer: Optimal beskyttelseslagstykkelse

2020 (kaldeste vinter de siste årene) :



Temperatur i leire:



60 cm av kalkstein er nok til å beskytte leire
Ingen betydelig forskjell observert mellom kalkstein og TBM

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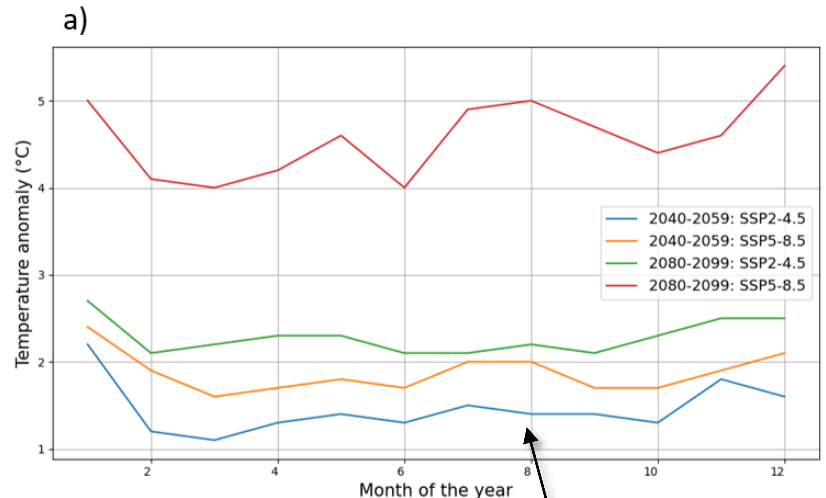
Simuleringer: Effekt av klima endringer

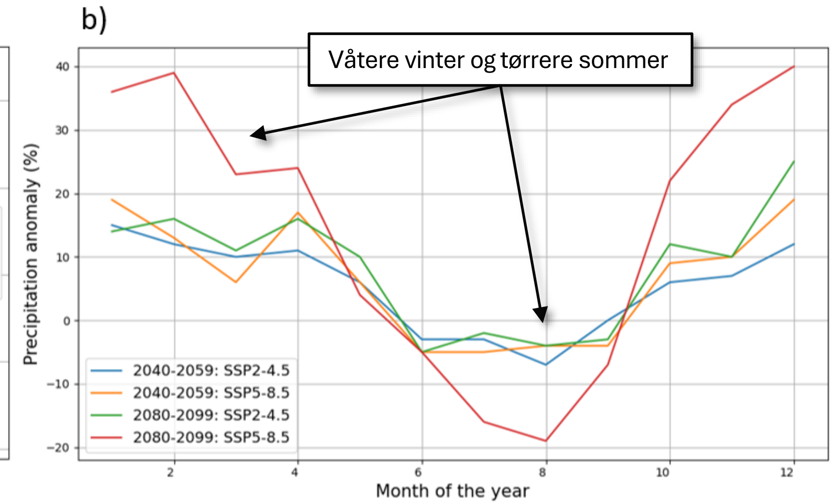
Shared Socioeconomic Pathways (SSP)(6th IPCC report):

Selected scenarios:
- SSP2-4.5
- SSP5-8.5

Selected periods of time:
- 2050-2053
- 2090-2093

a) Temperature anomaly b) Precipitation anomaly
With the reference period 1995-2014

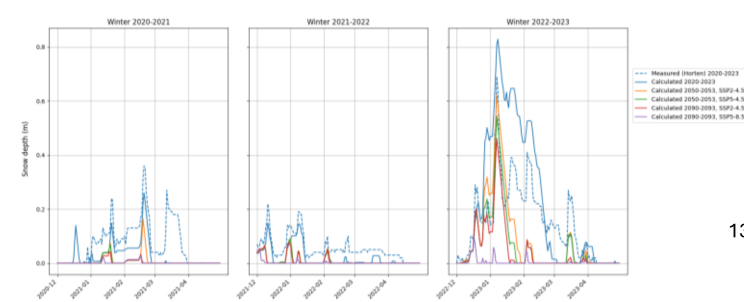




SSP2-4.5 Intermediate GHG emissions: CO_2 emissions around current levels until 2050, then falling but not reaching net zero by 2100
SSP5-8.5 Very high GHG emissions: CO_2 emissions triple by 2075

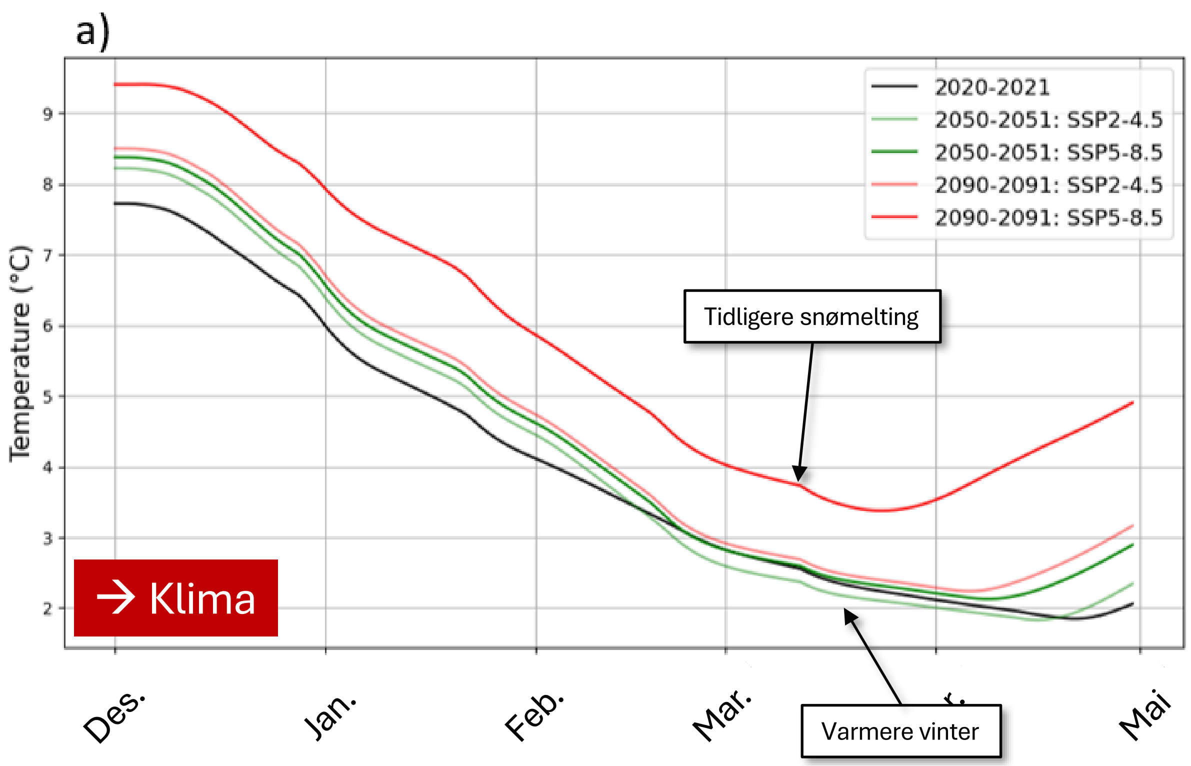
Betydelig men jevn temperatur økning

+ beregnet snødybde

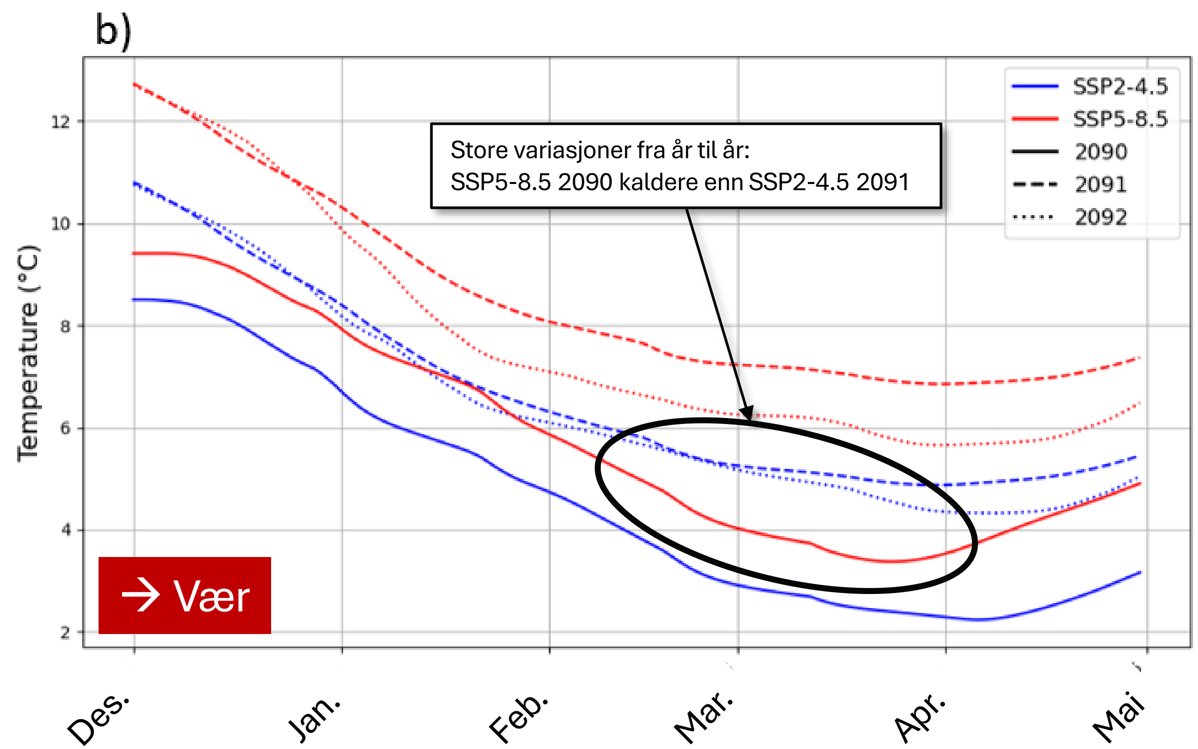


Simuleringer: Effekt av klima endringer

a) Simulated clay temperature
Winters 2020/2050/2090
Scenarios SSPS2-4.5 and SSP5-8.5



b) Simulated clay temperature
Winters 2090/2091/2092
Scenarios SSPS2-4.5 and SSP5-8.5



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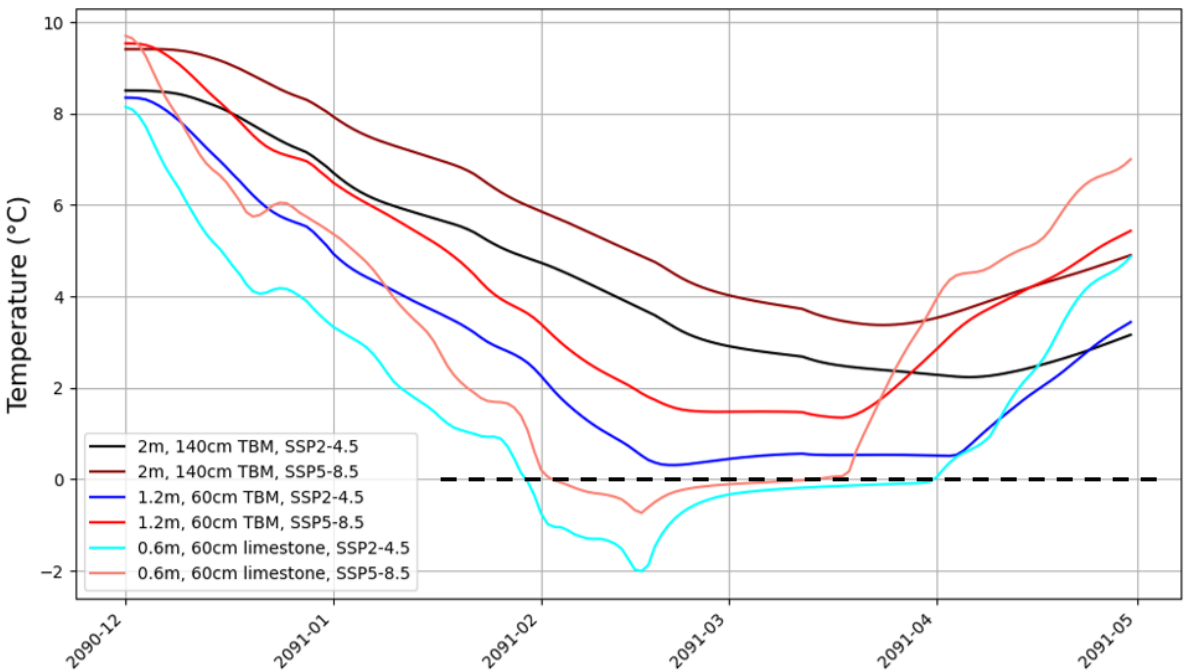
Simuleringer: Optimering mht. klima endringer

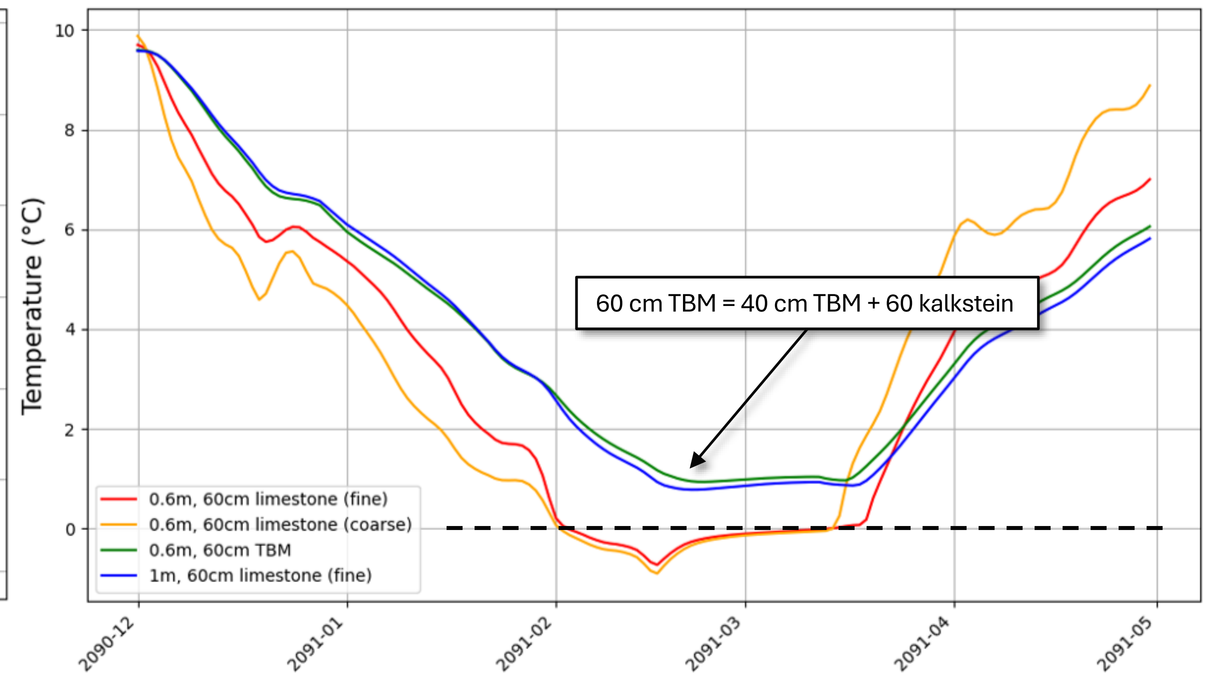
a) Simulated clay temperature
Winter 2090/2091
Scenarios SSP2-4.5 and SSP5-8.5
Different cover thicknesses

a)



b) Simulated clay temperature
Winter 2090/2091
Scenario SSP5-8.5
Different thicknesses and materials

b)



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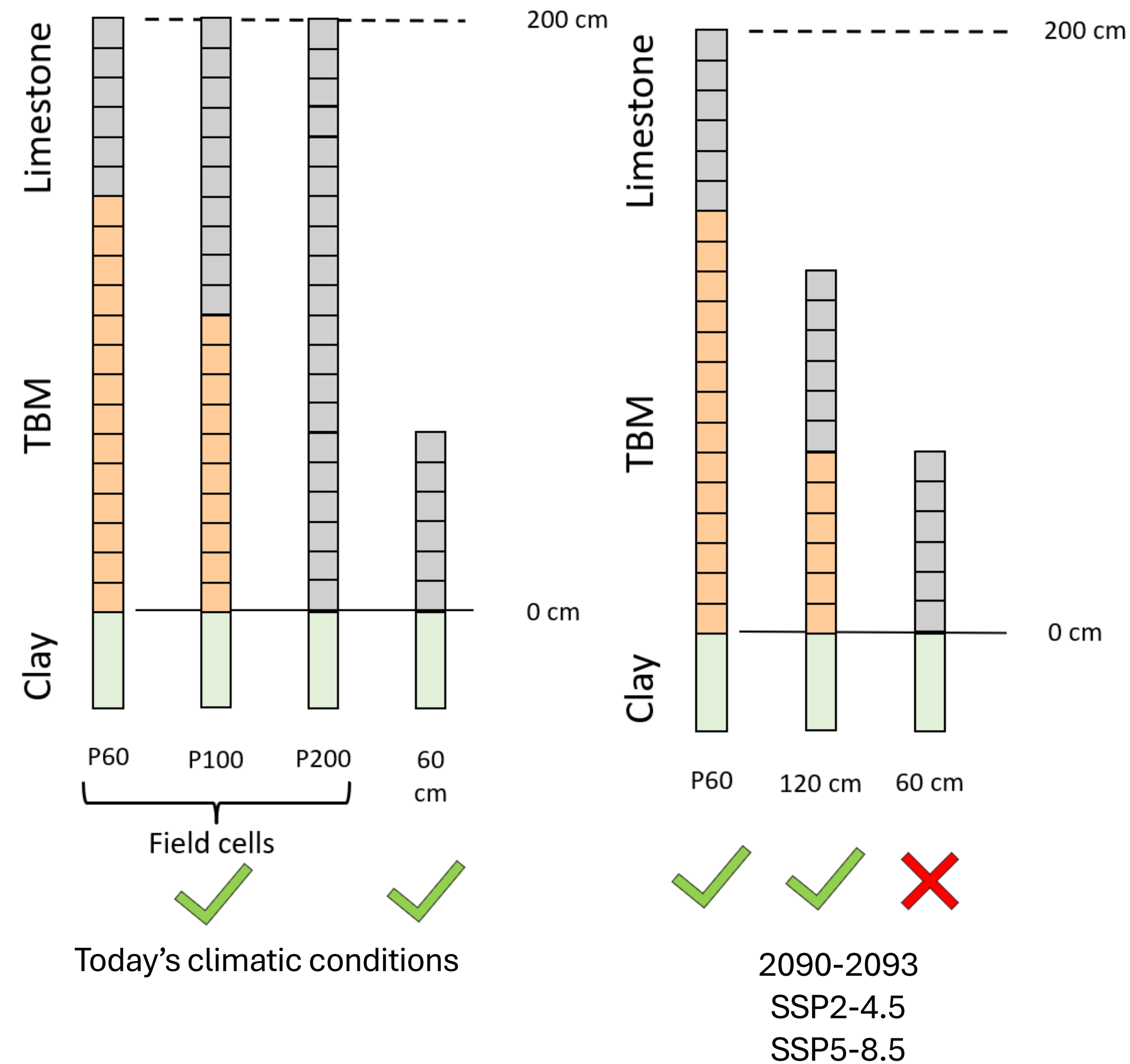
Konklusjoner

- Modellen simulerer bra målinger (kalibrering)
- Et 60 cm kalkstein- eller TBM-beskyttelseslag er effektivt for dagens klimatiske forhold
- Kompleks effekt av klimaendringer om vinteren: mindre snø, men høyere temperaturer → høyre risiko for frostinntrengning
- Mulig (og muligens positivt) å erstatte (minst delvis) kalkstein med TBM

Største effekt (og usikkerhet): snødekke/dybde

Neste trinn: oppfølging/oppdatering 2025

Varmere vinter og mindre snø



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På sikker grunn