

On Thermal Conditions of Culverts in Cold Regions

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Introduction

Material properties

Construction
quality

Dimensions

Inclination





1st field installation

- 3 culverts (0.6/0.8/3.4 m)
- Temperature inside the culvert
- Air flow velocity



2nd field installation

- 1 culvert (0.6 m)
- Temperature inside the culvert
- Air flow velocity
- Temperature around the culvert



1st field installation



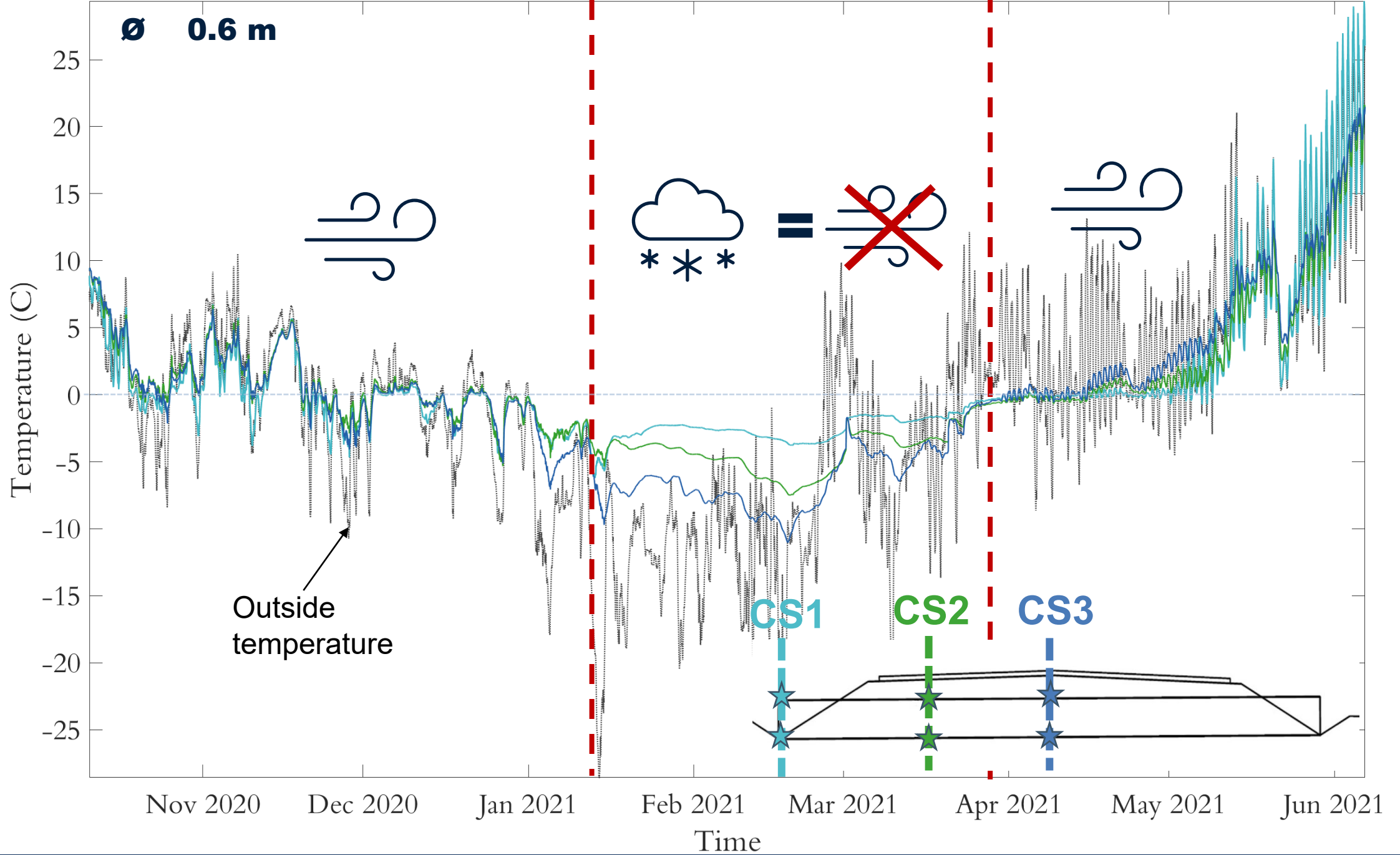
0.6 m

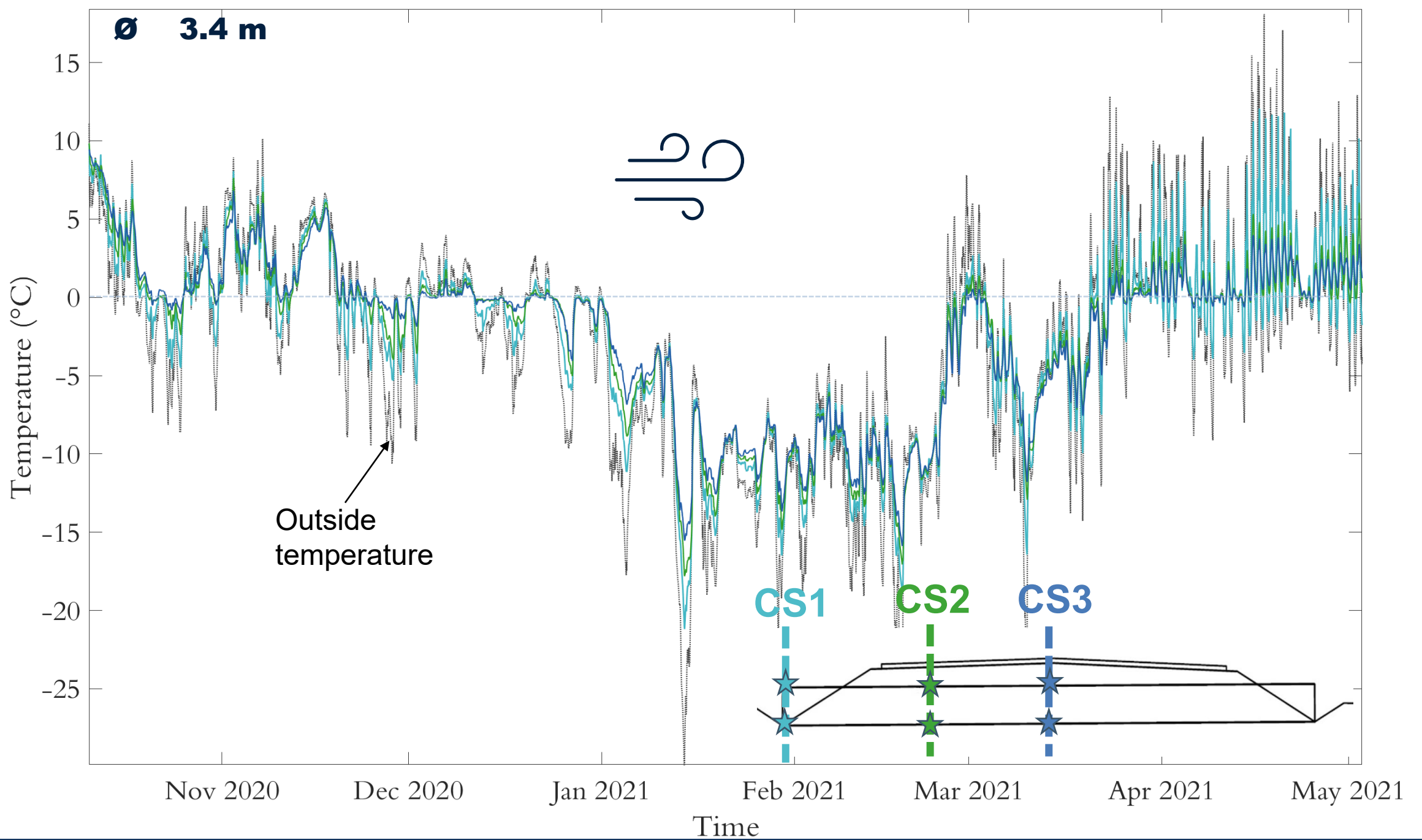


0.8 m



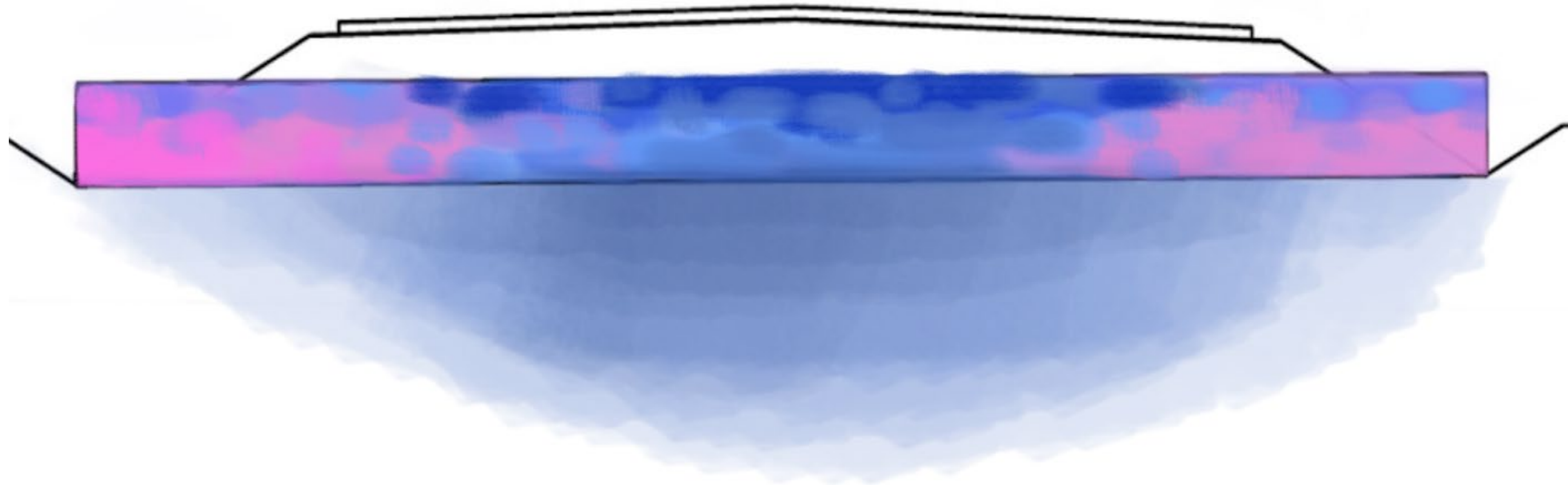
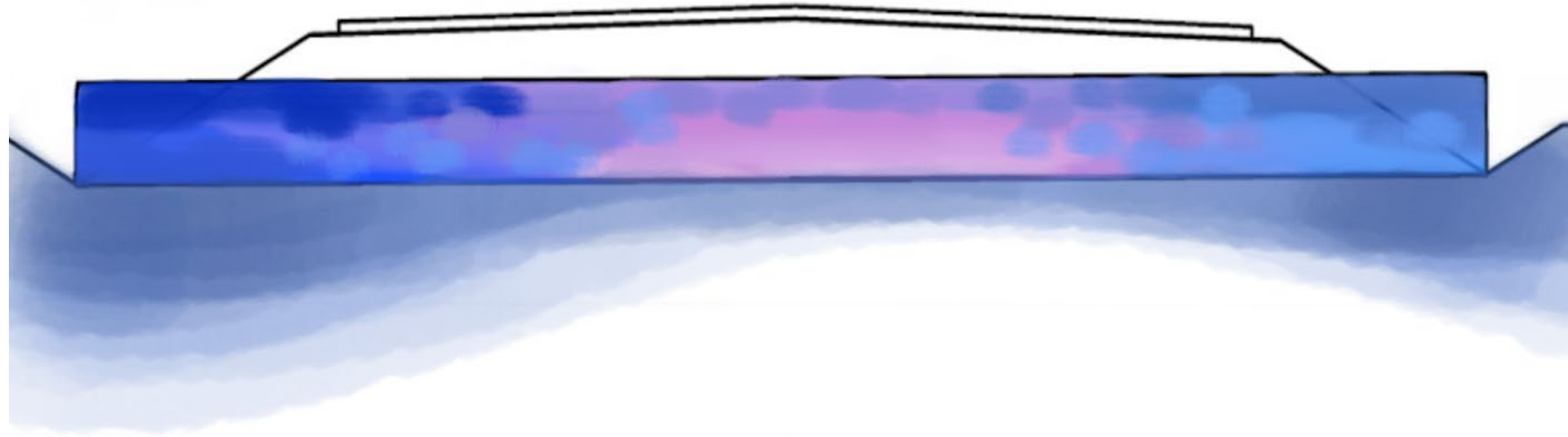
3.4 m



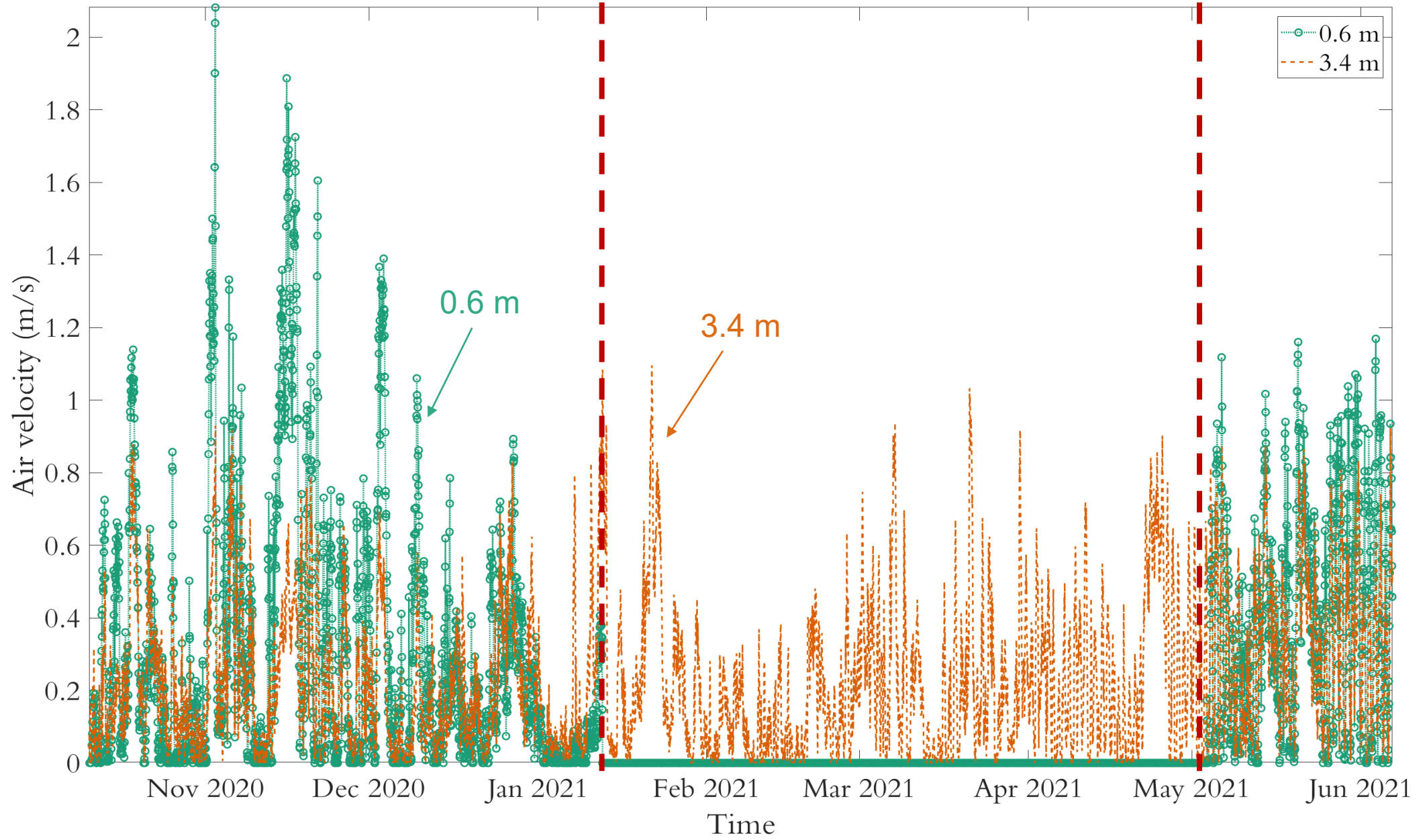


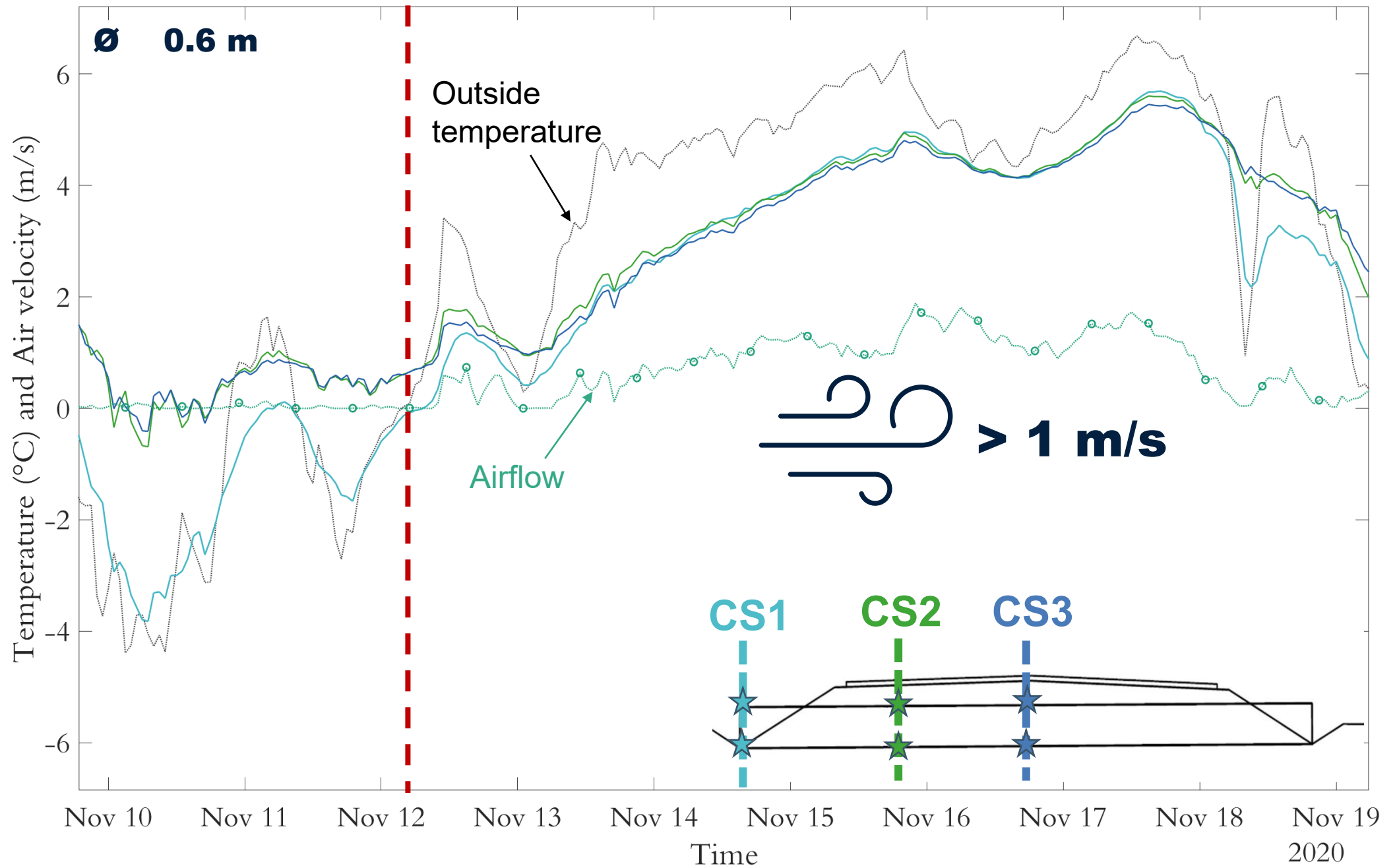
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Ø 0.6 & 3.4 m



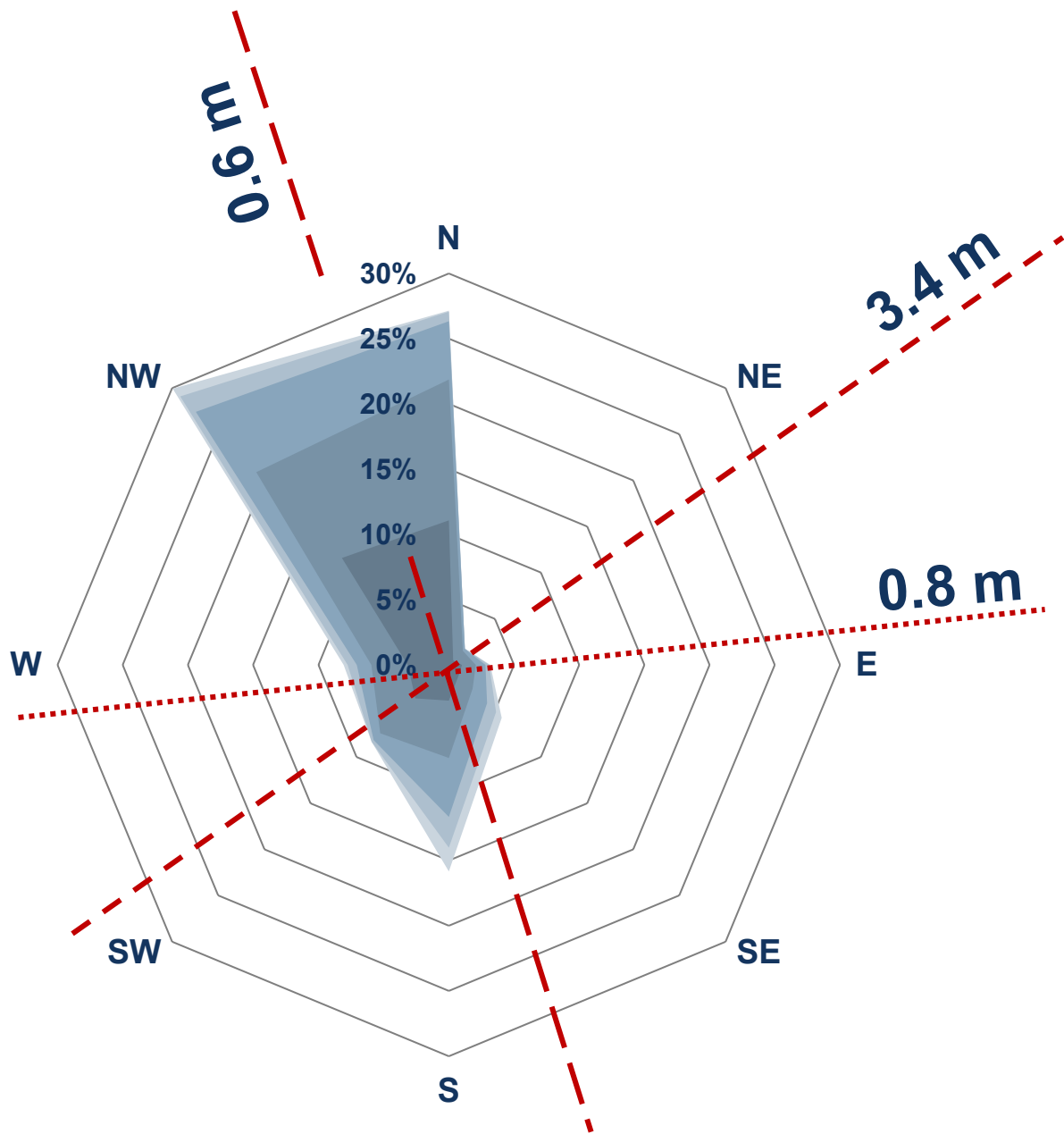


Ø 0.8 m
Max. 0.8 m/s

Ø 0.6 m
Max. 2.1 m/s

Ø 3.4 m
Max. 1.1 m/s





- >8 m/s
- 7-8 m/s
- 5-6 m/s
- 3-4 m/s
- 1-2 m/s

1st field installation



Temperature variation in culverts



Two temperature distributions

Culvert closed
Culvert open



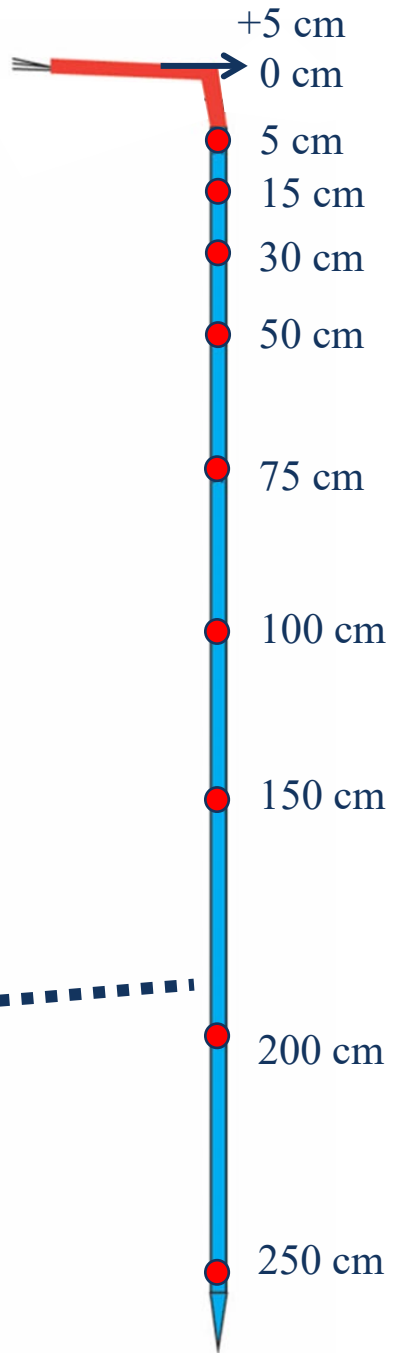
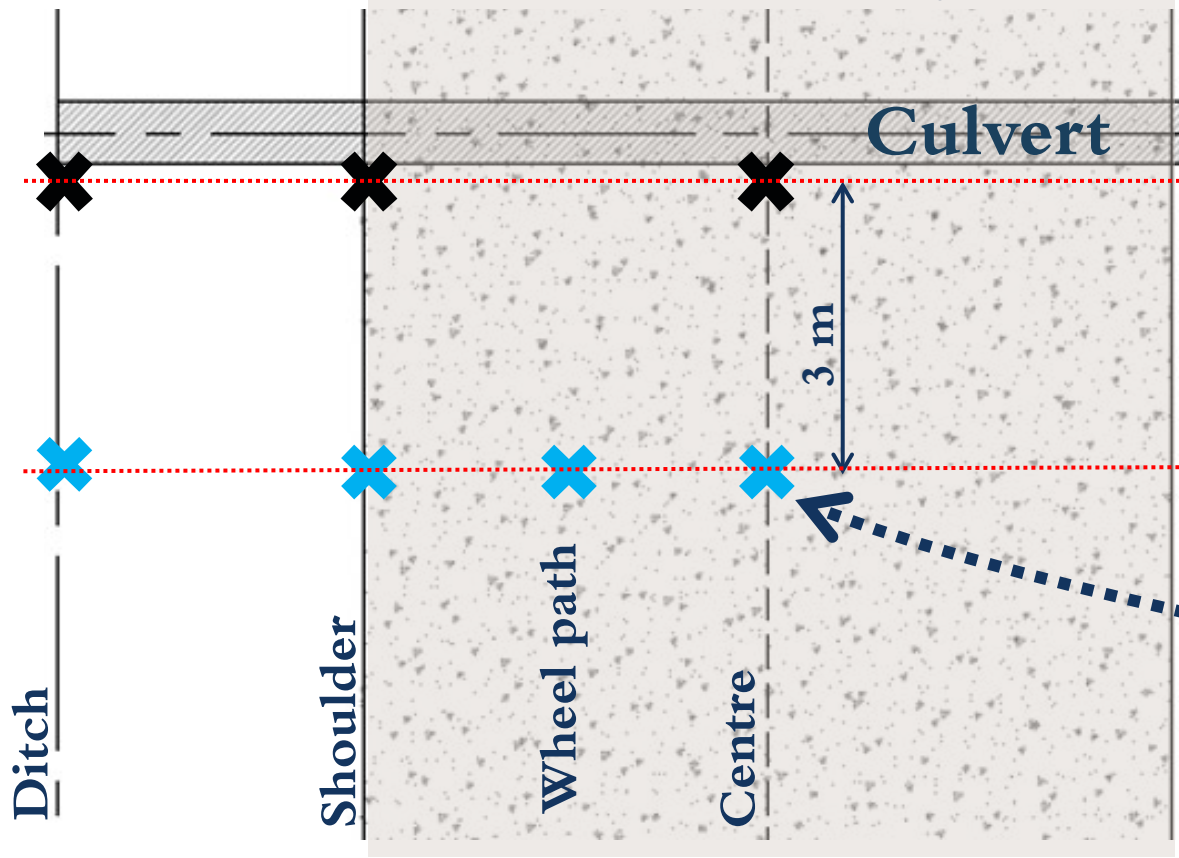
Air flow influences temperature distribution

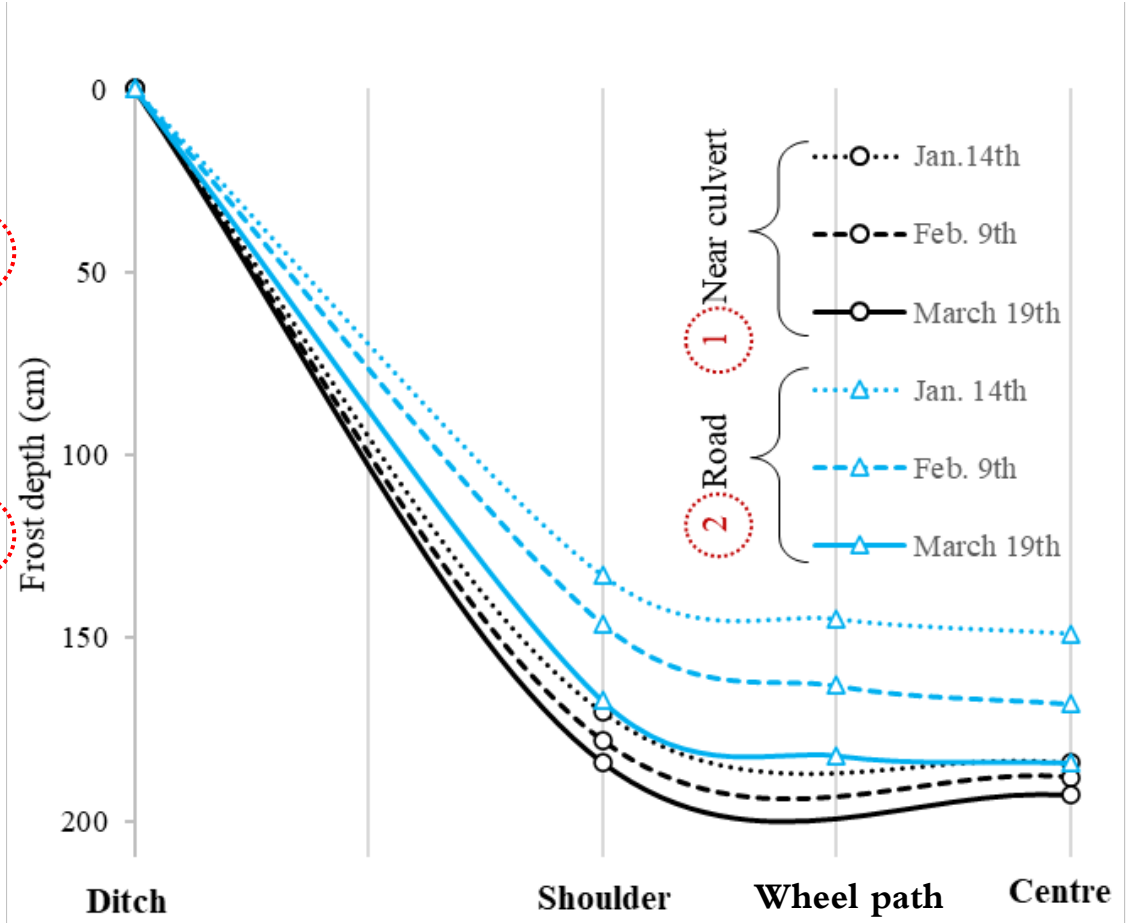
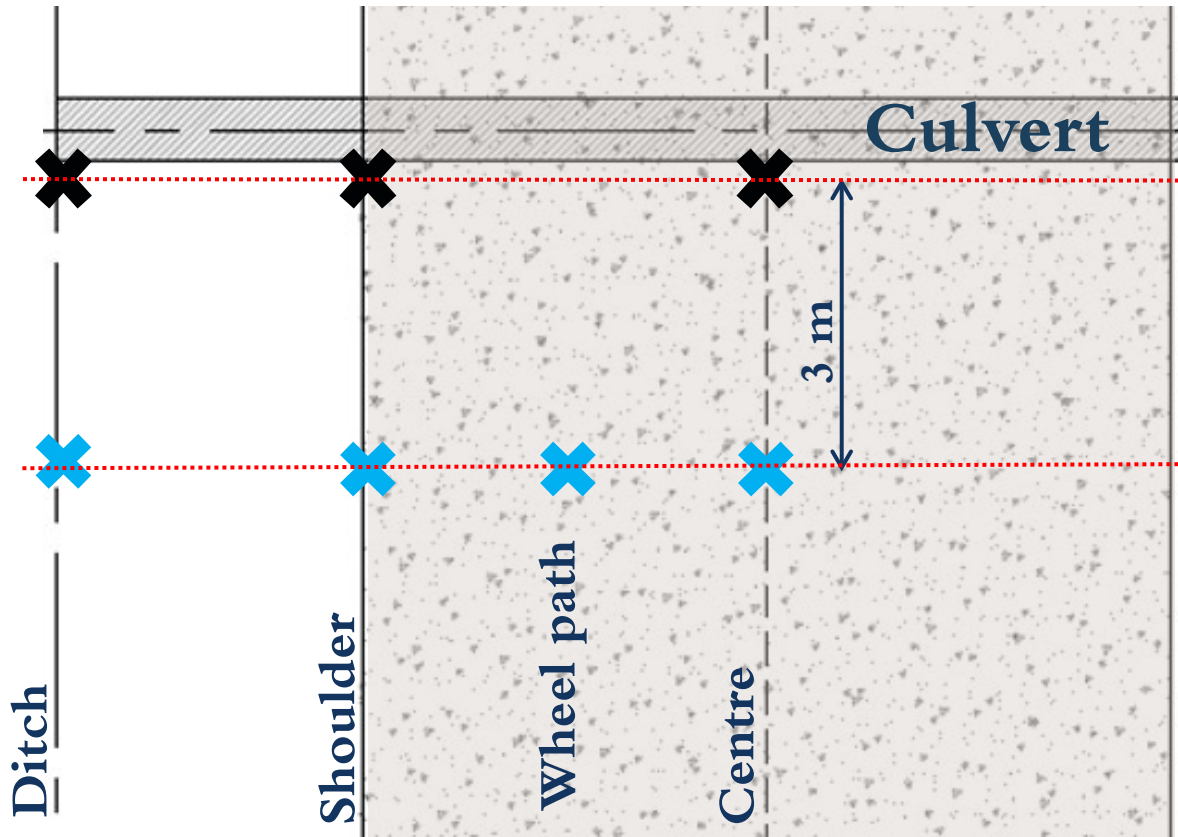
Velocity
Direction

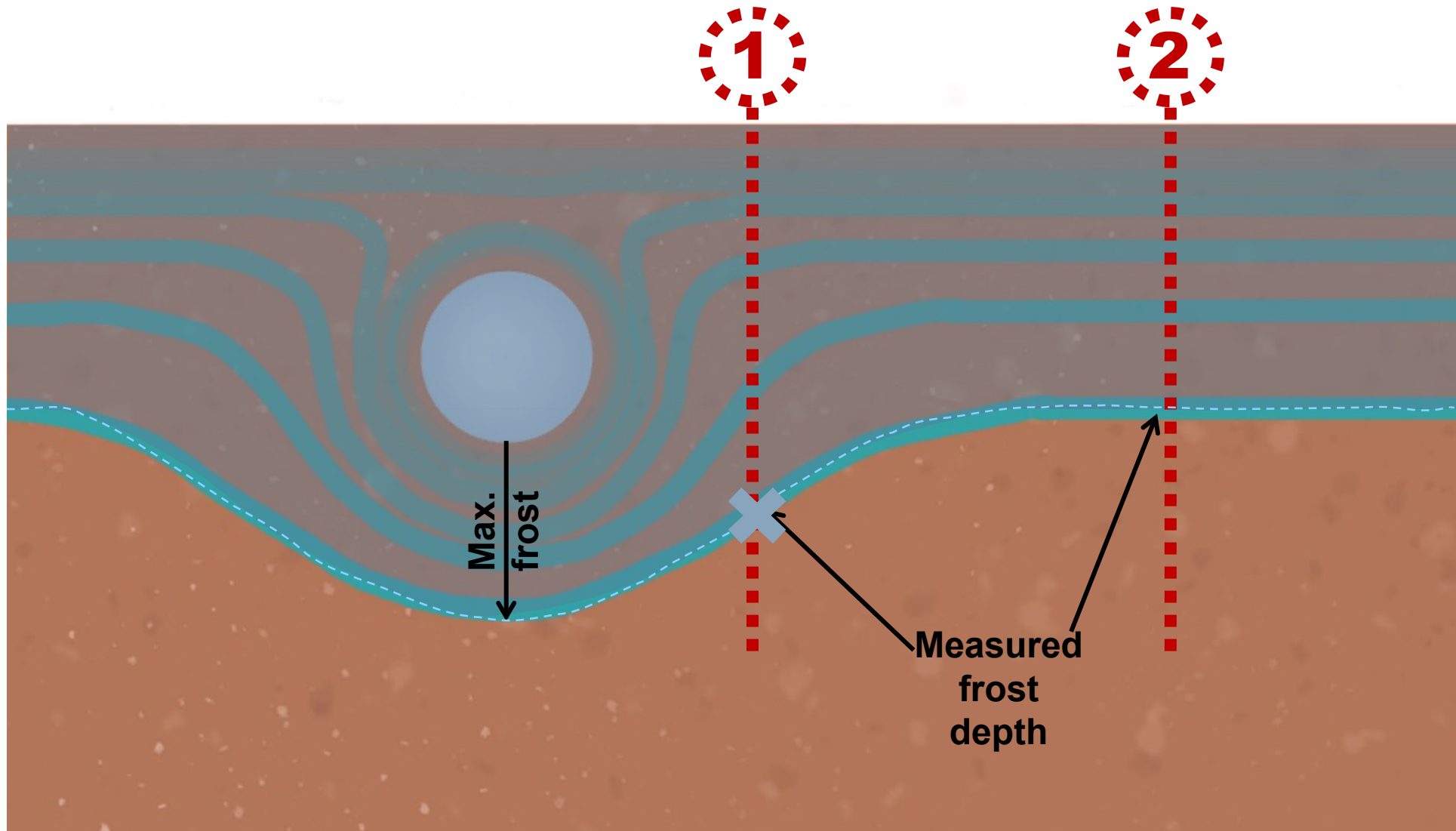


2nd field installation









Numerical modelling

- Airflow

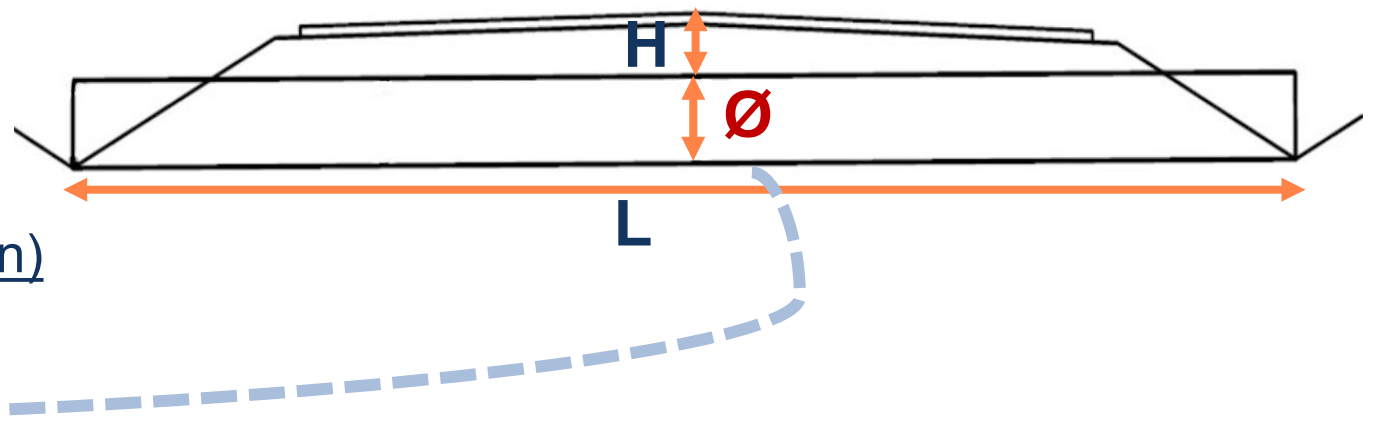
- Wind velocity and directionality

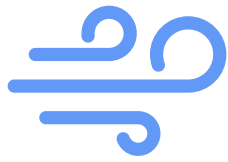
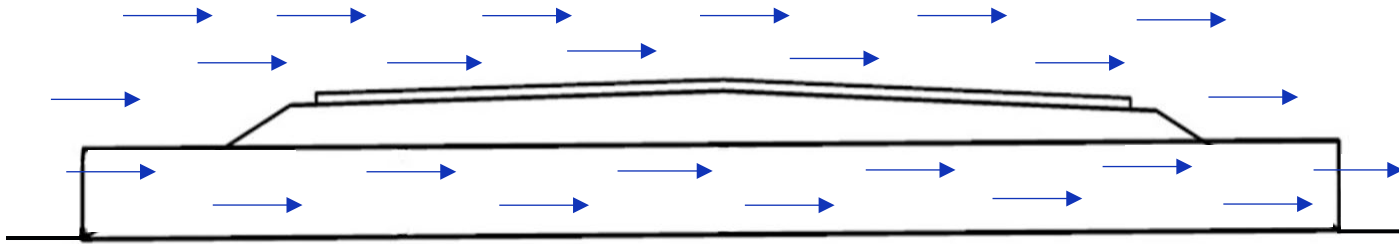
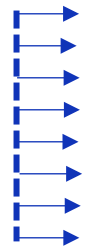
- Frost depth

- Airflow velocity
- Outside temperature
- (No snow vs. snow)

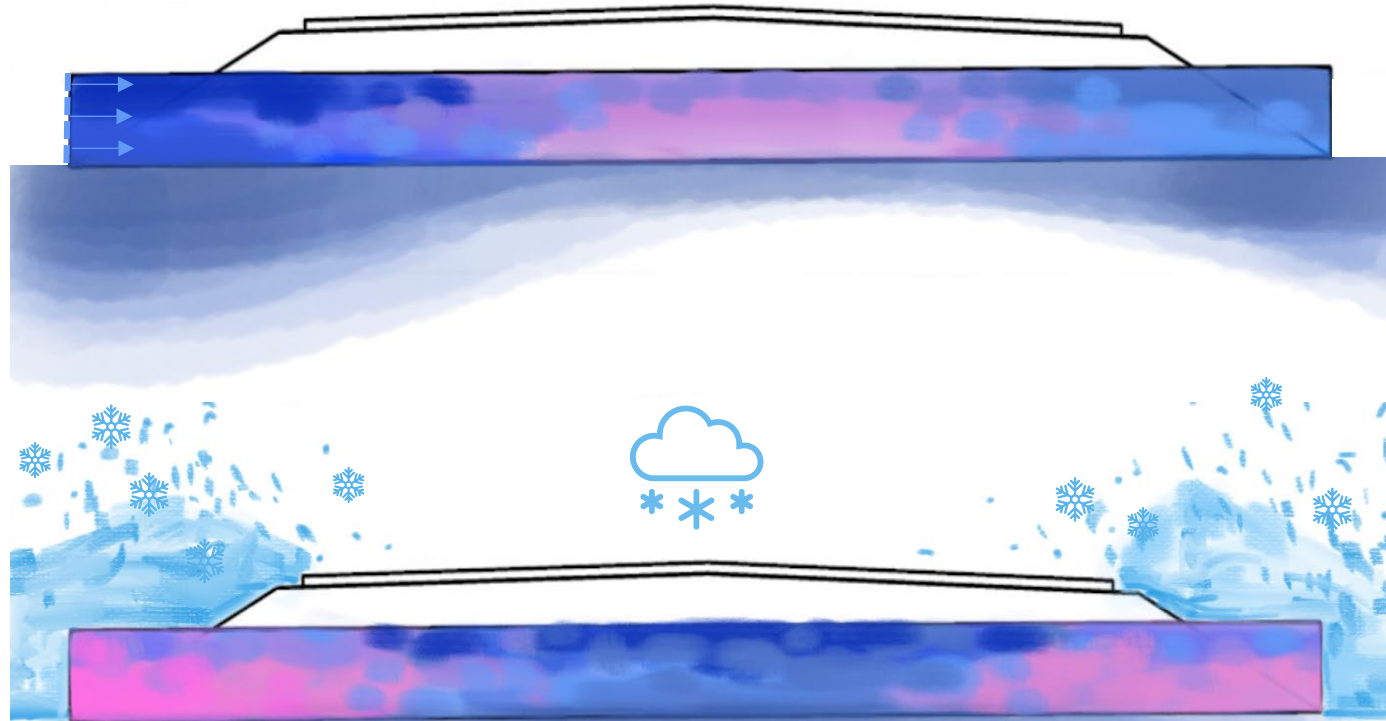
- Culverts \emptyset

- 0.6 m (based on 2nd field installation)
- 0.8 m
- 1.0 m
- 1.5 m
- 2.0 m





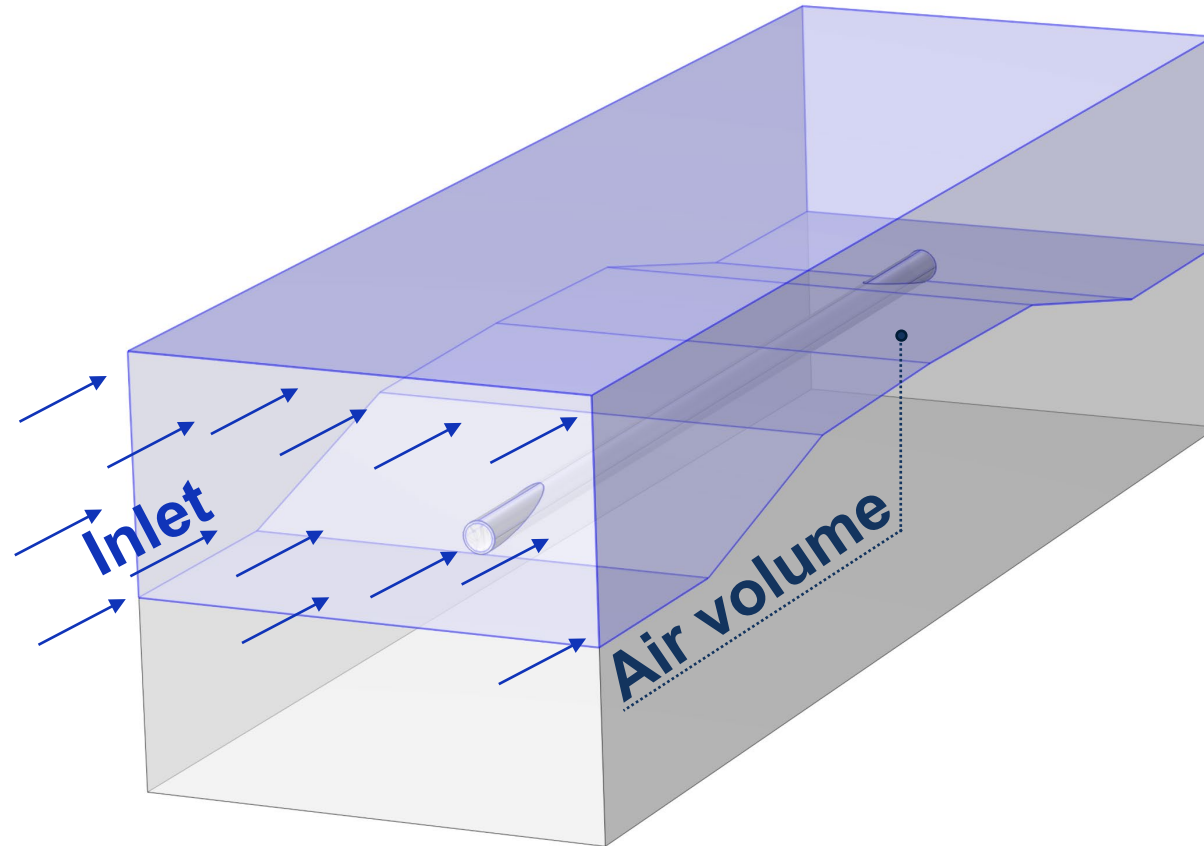
+

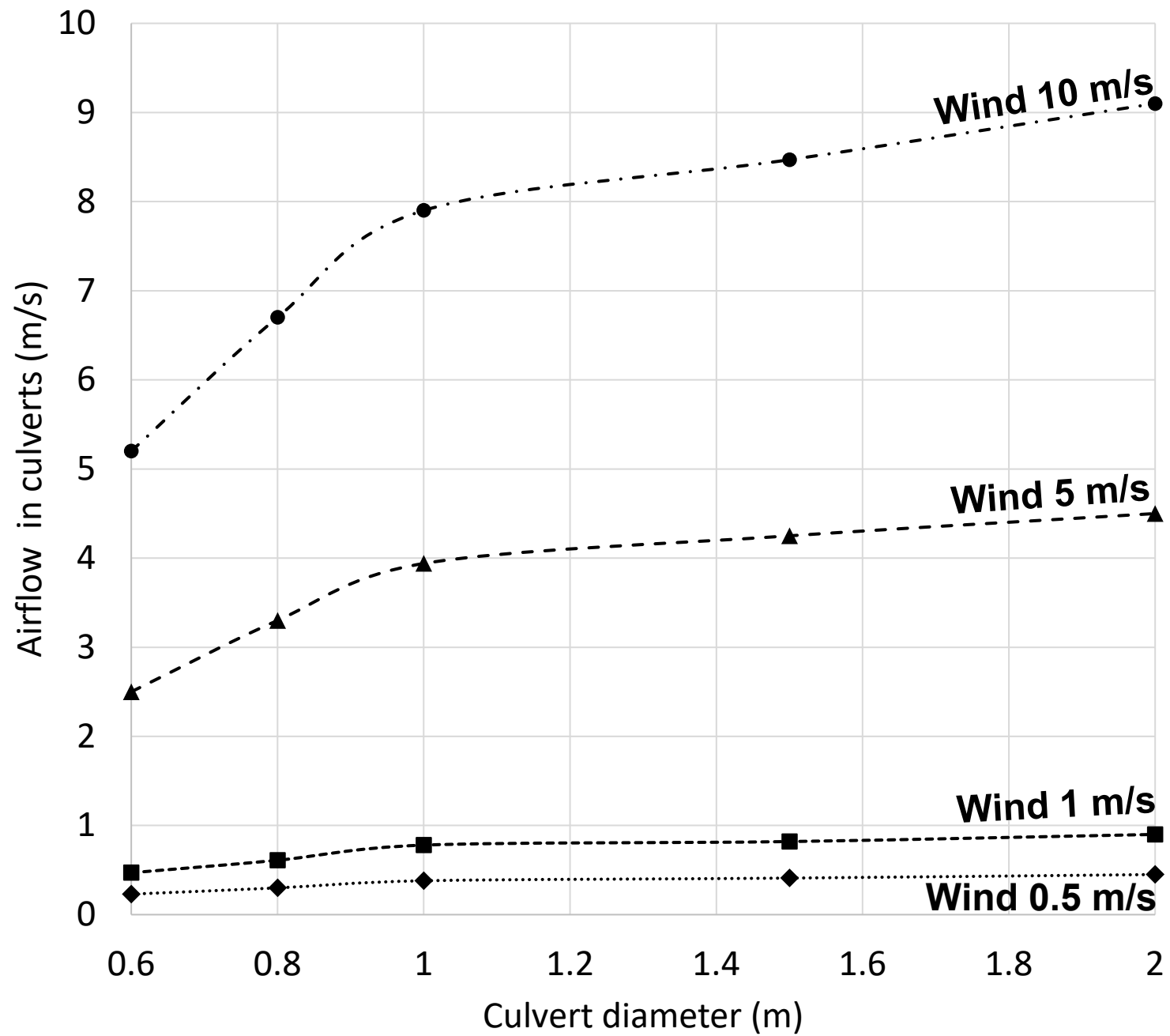


60 Days

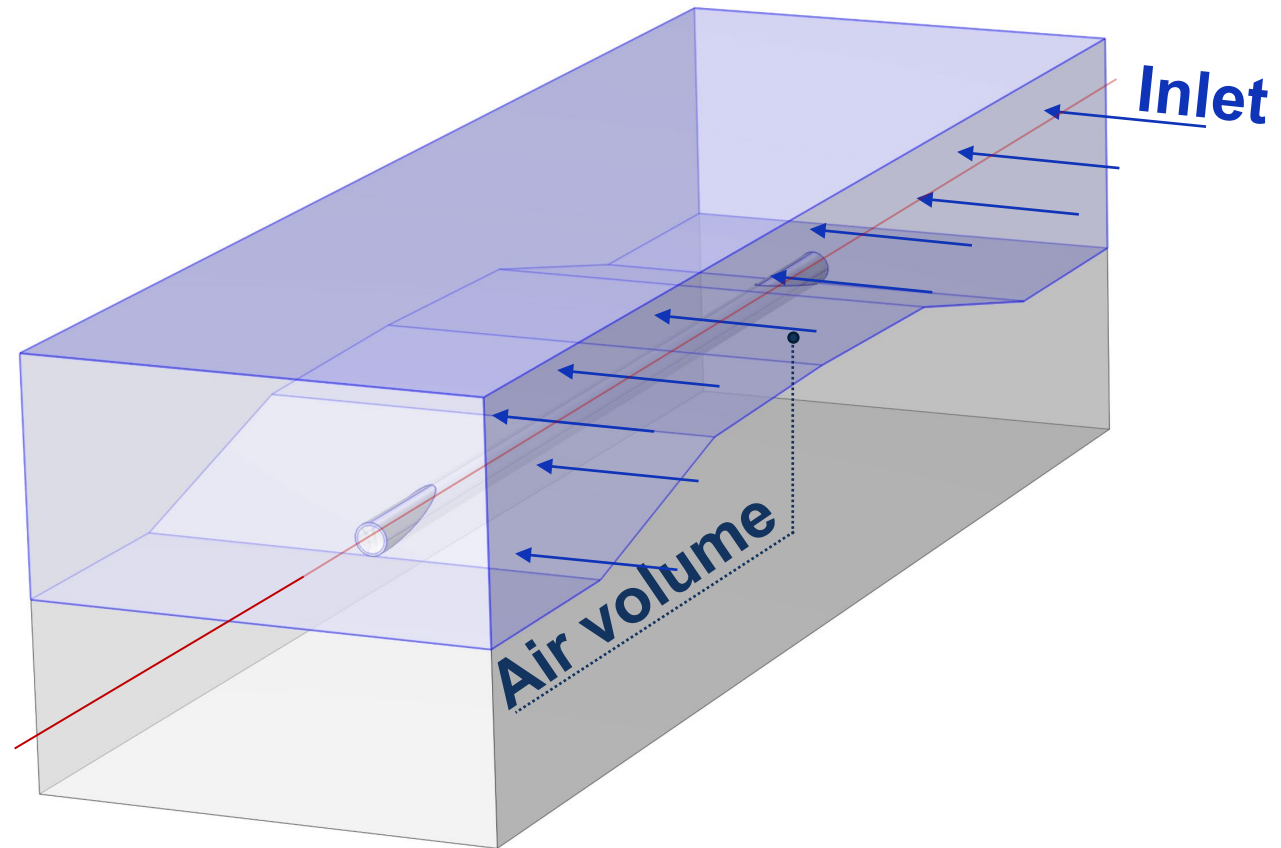
60 Days

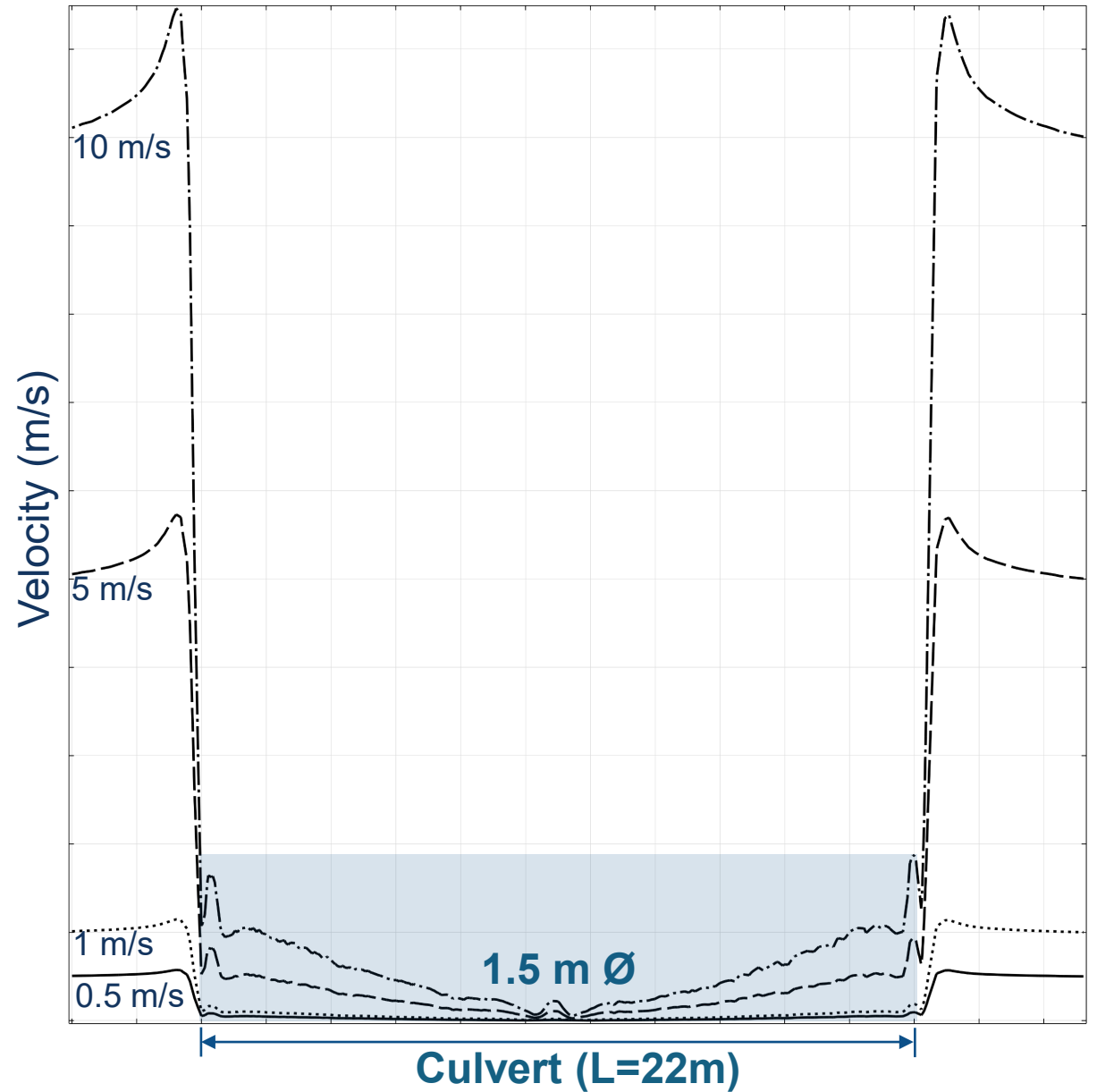
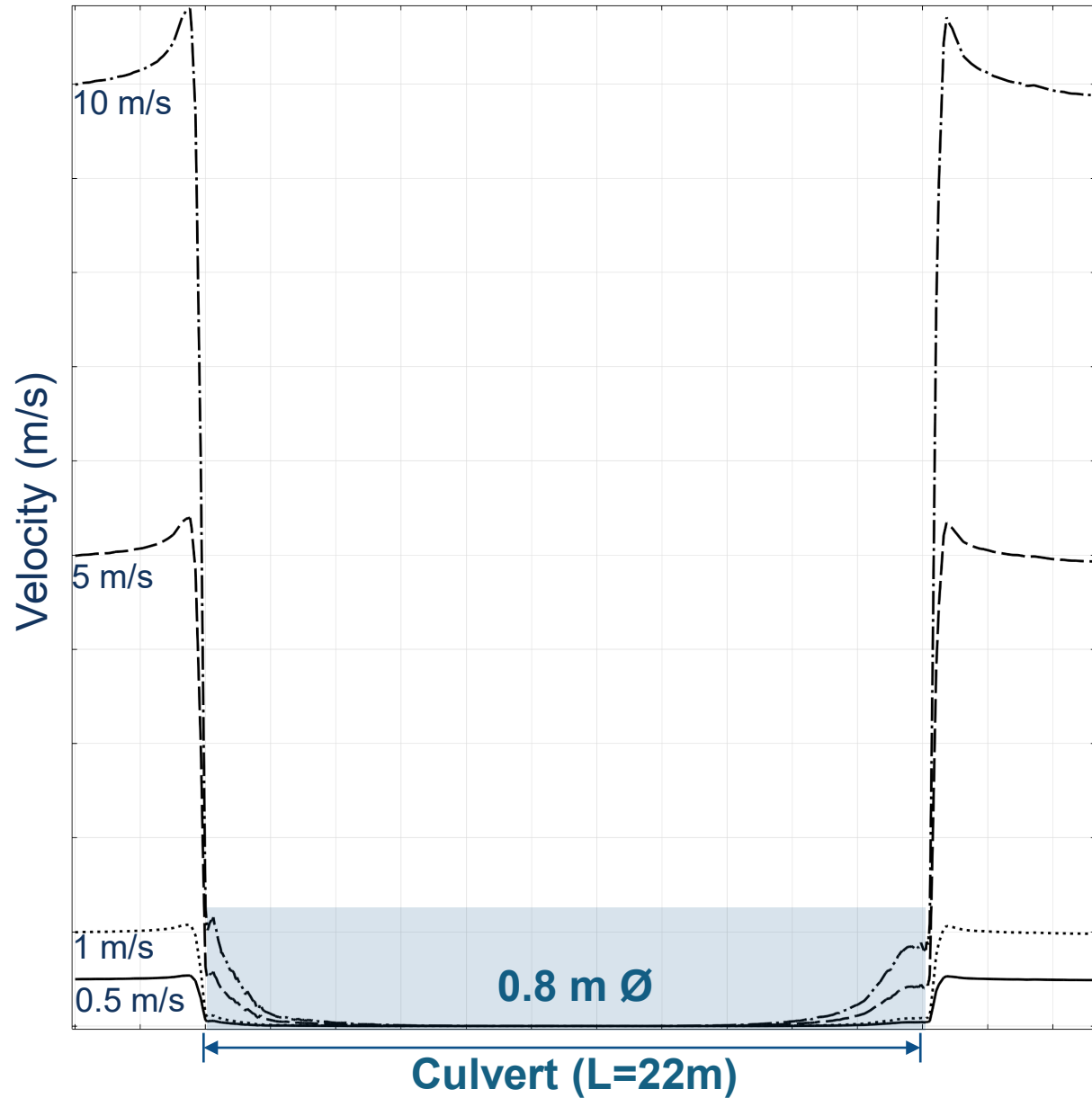
Numerical modelling- air flow



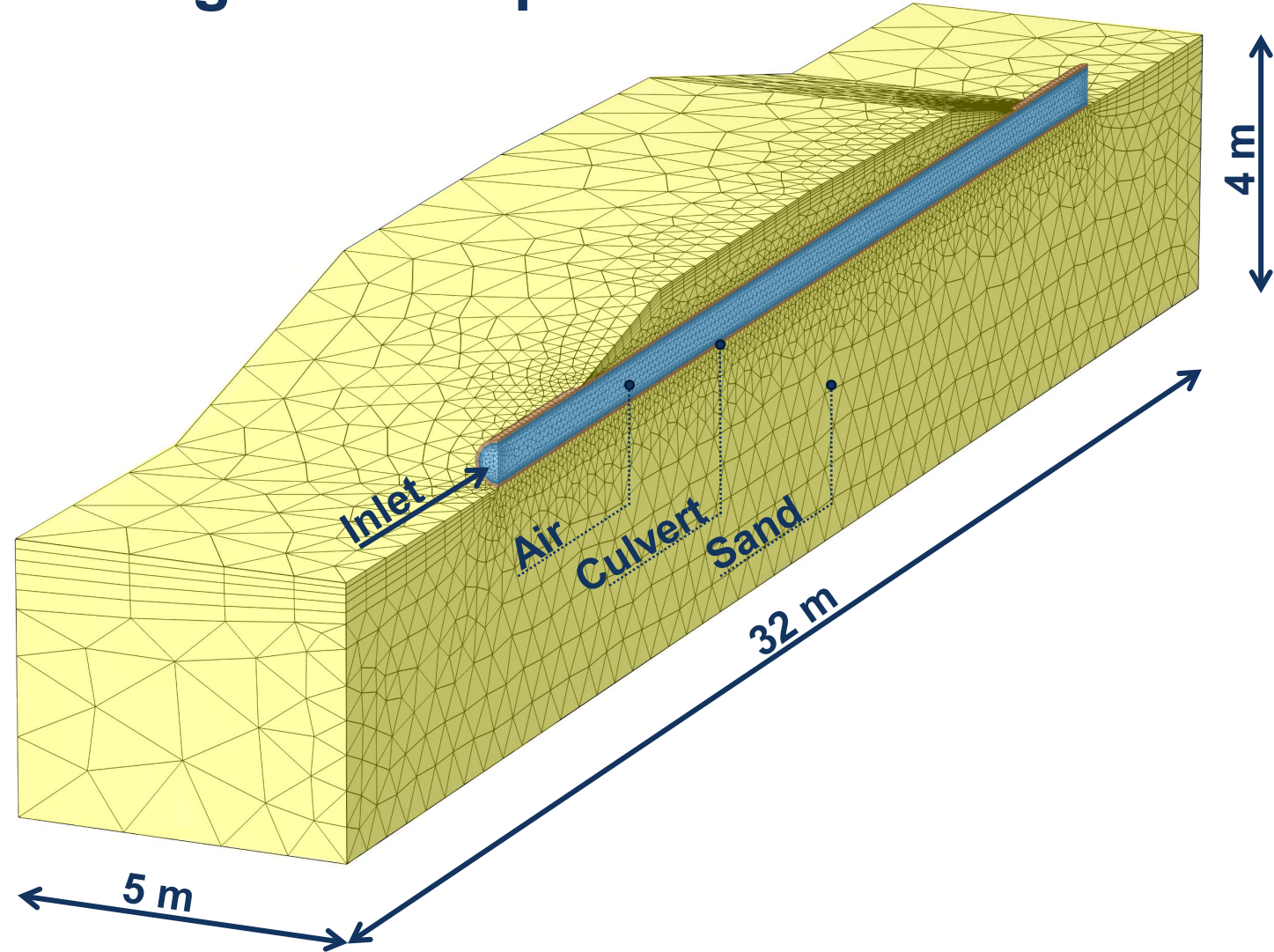


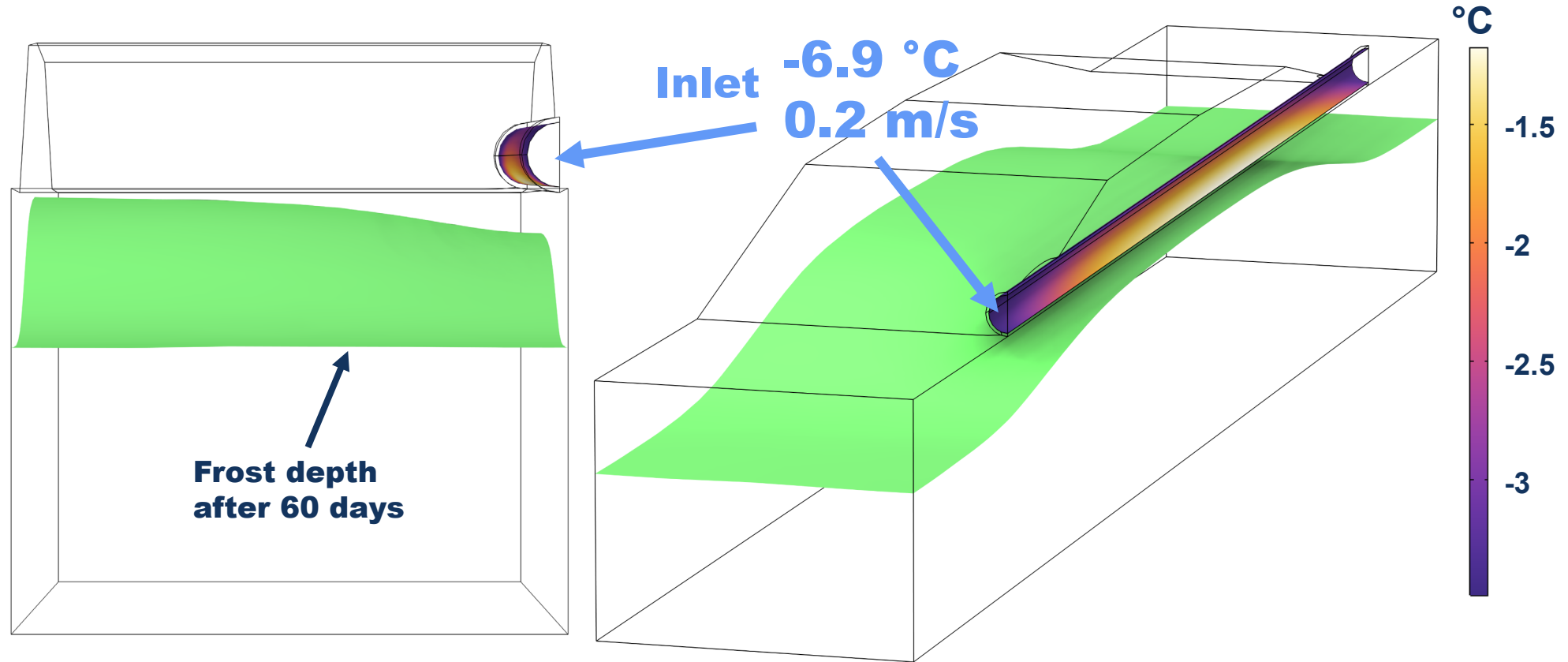
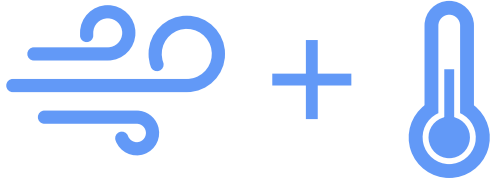
Numerical modelling- air flow

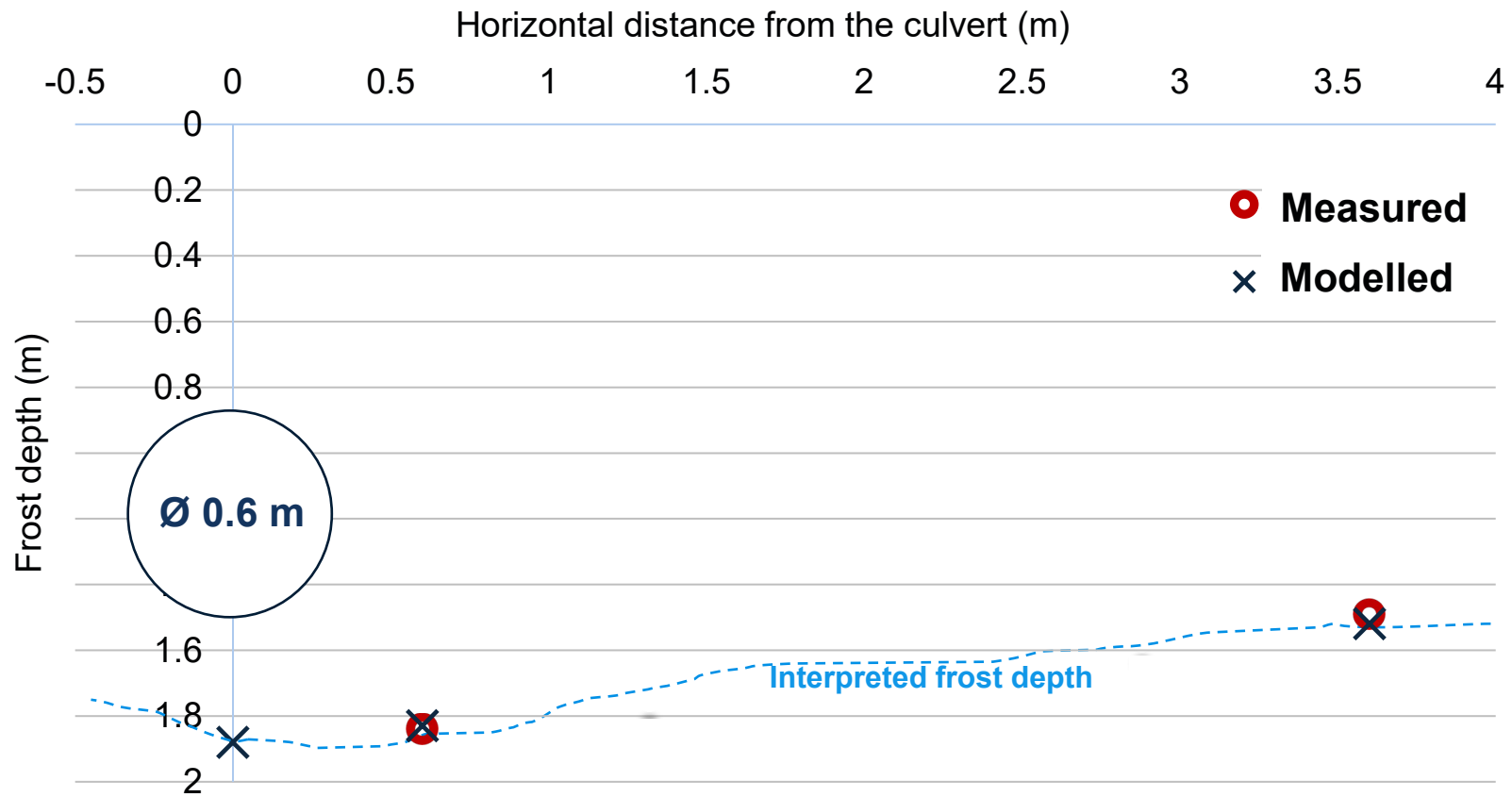


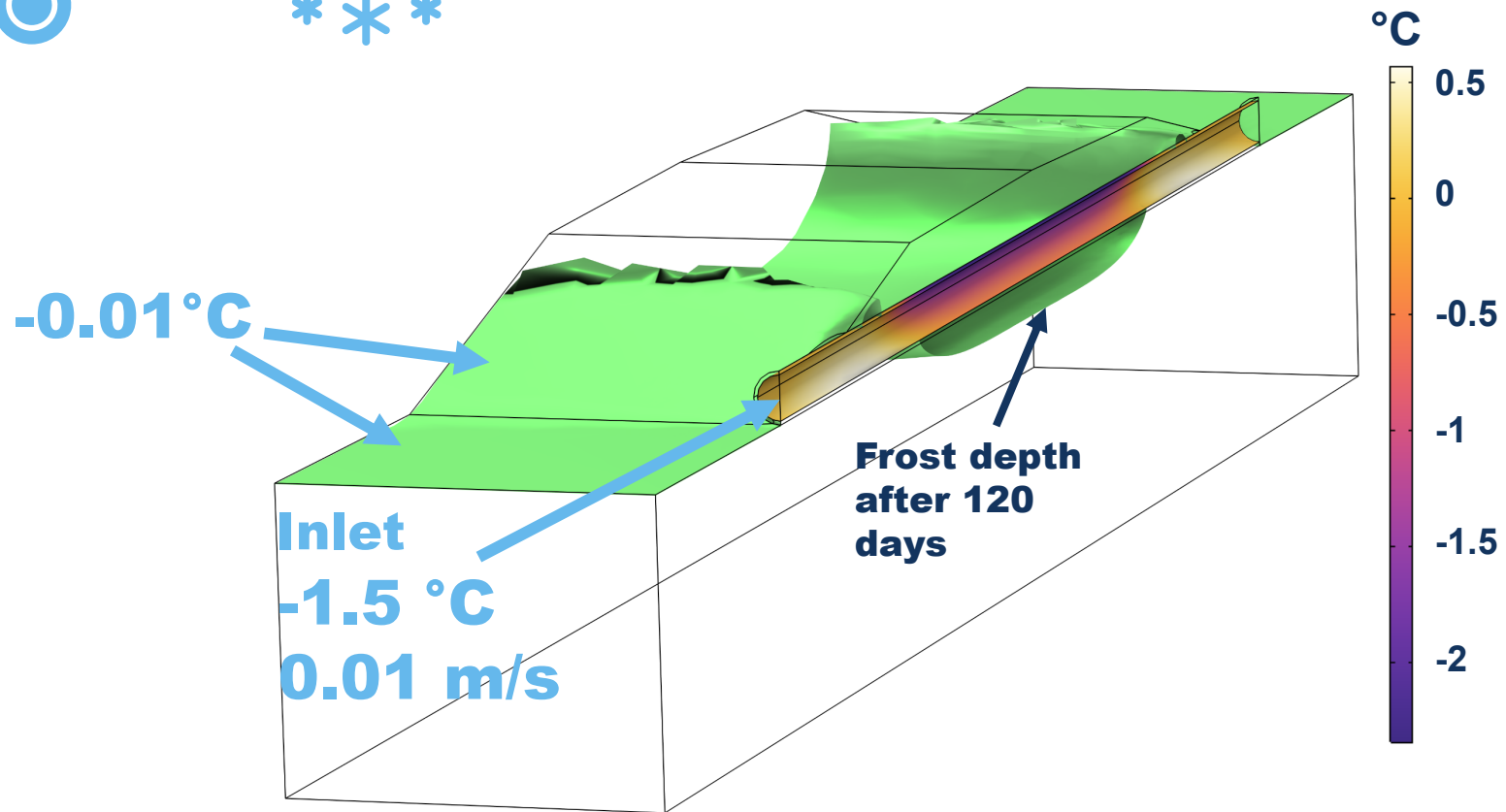
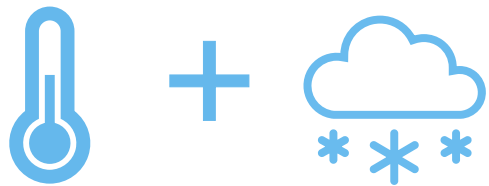


Numerical modelling- frost depth





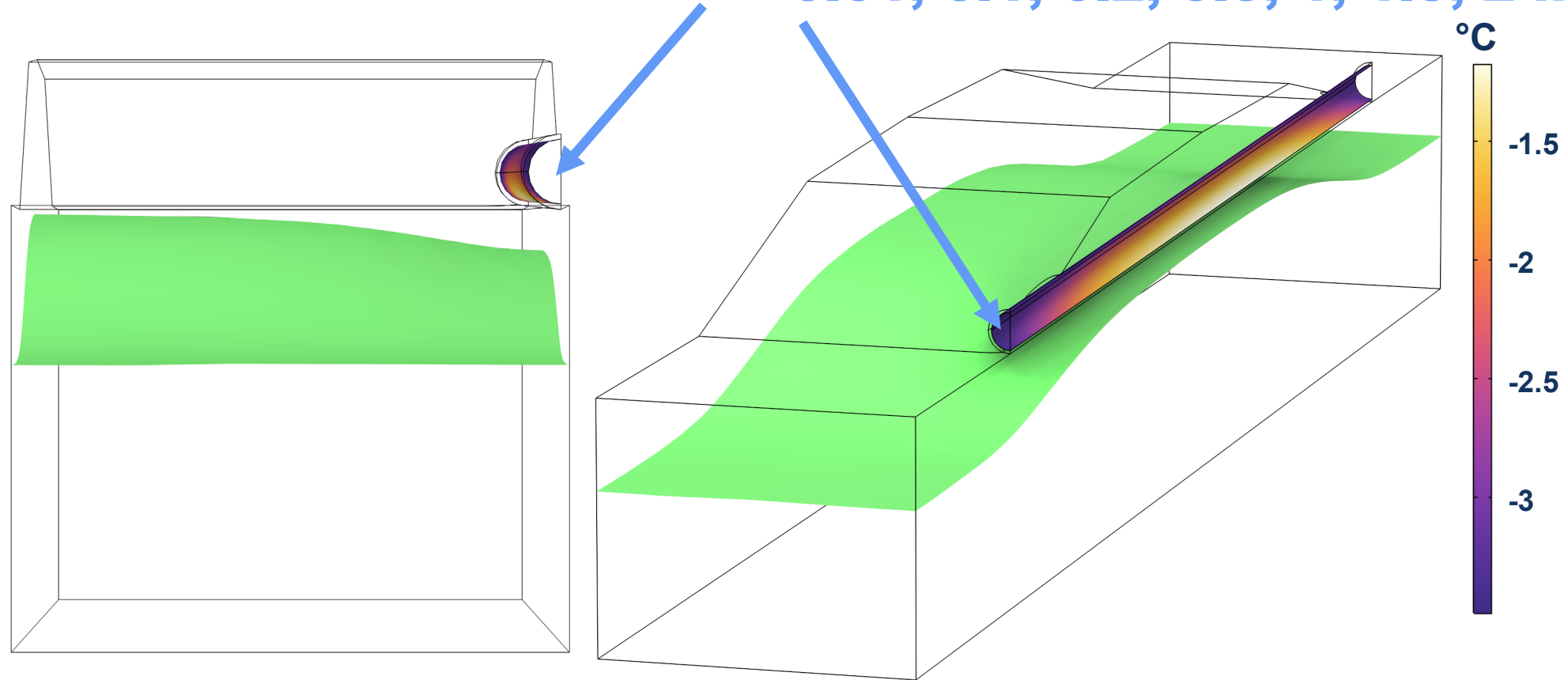




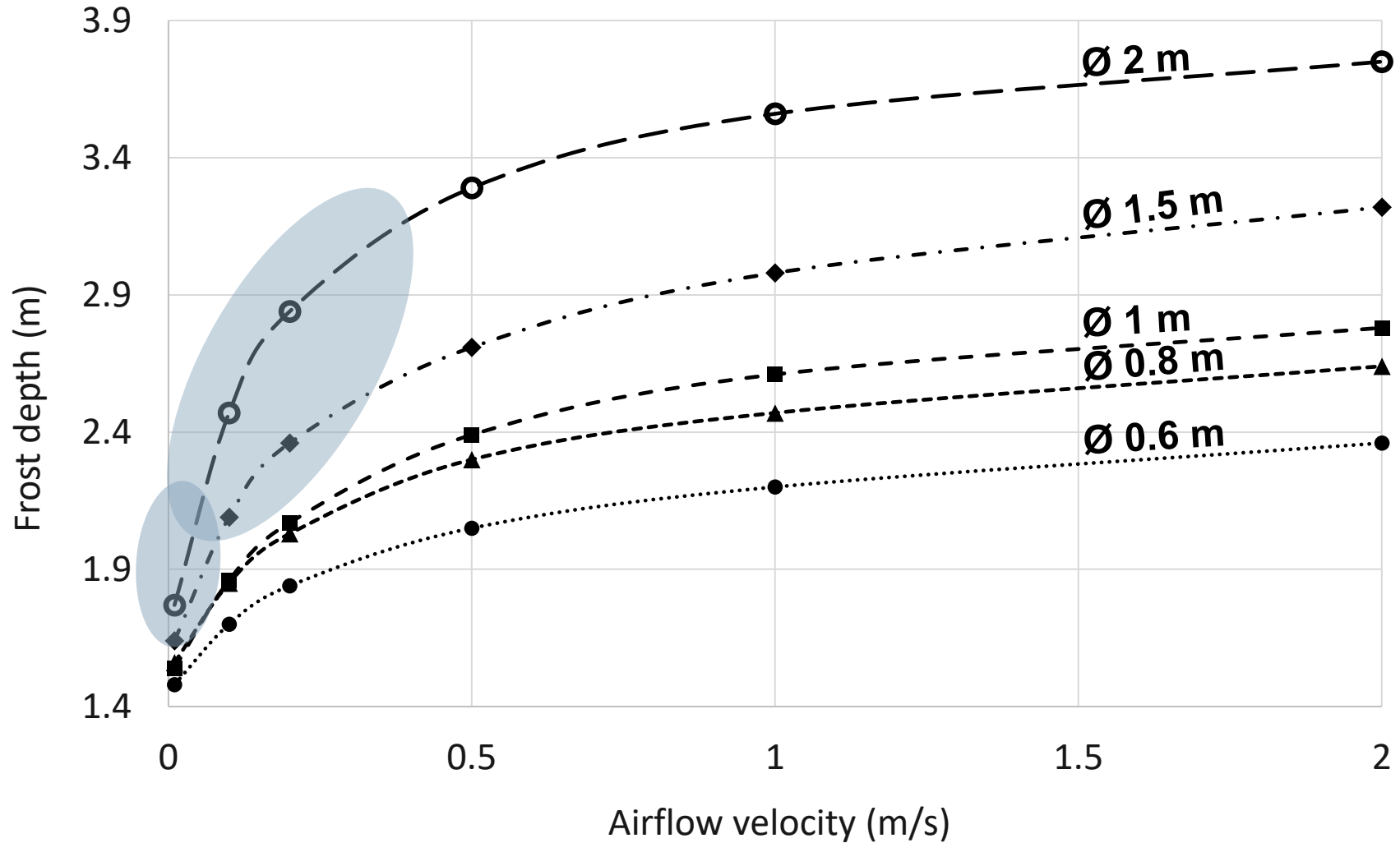
Parametric study

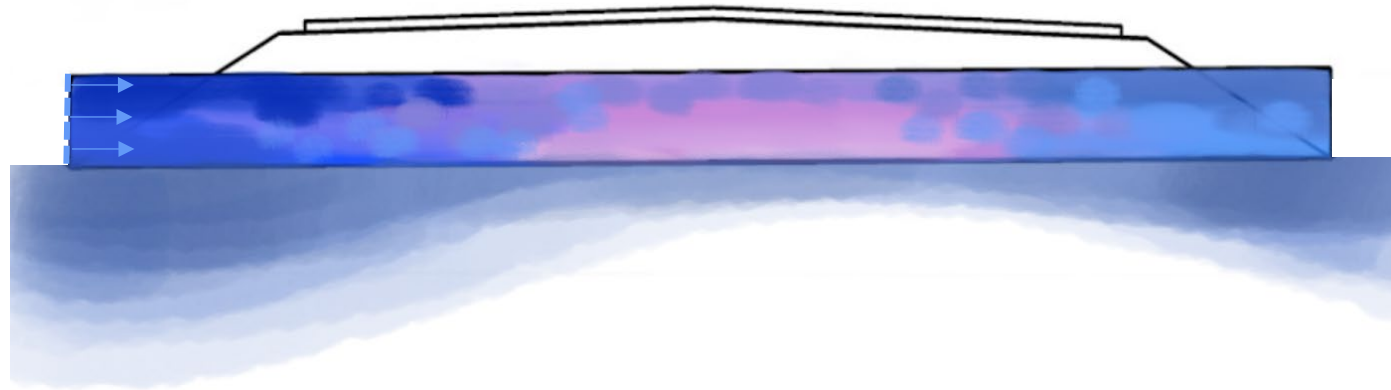
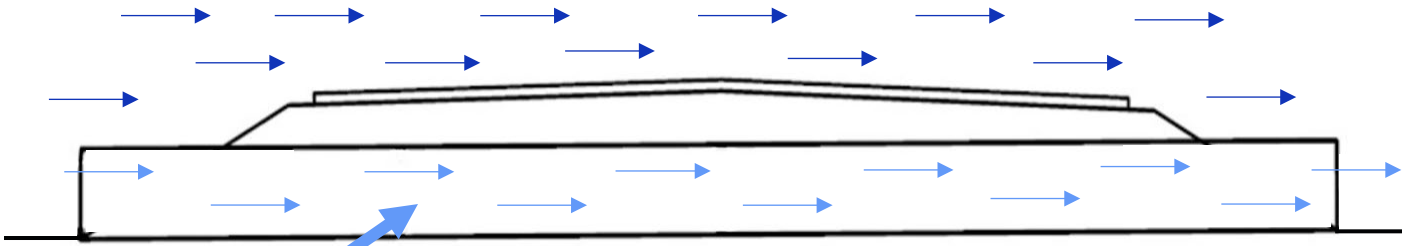
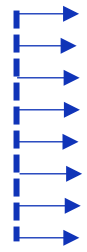
\varnothing (0.6); 0.8; 1; 1.5; 2 m

Inlet -6.9 °C
0.01; 0.1; 0.2; 0.5; 1; 1.5; 2 m/s

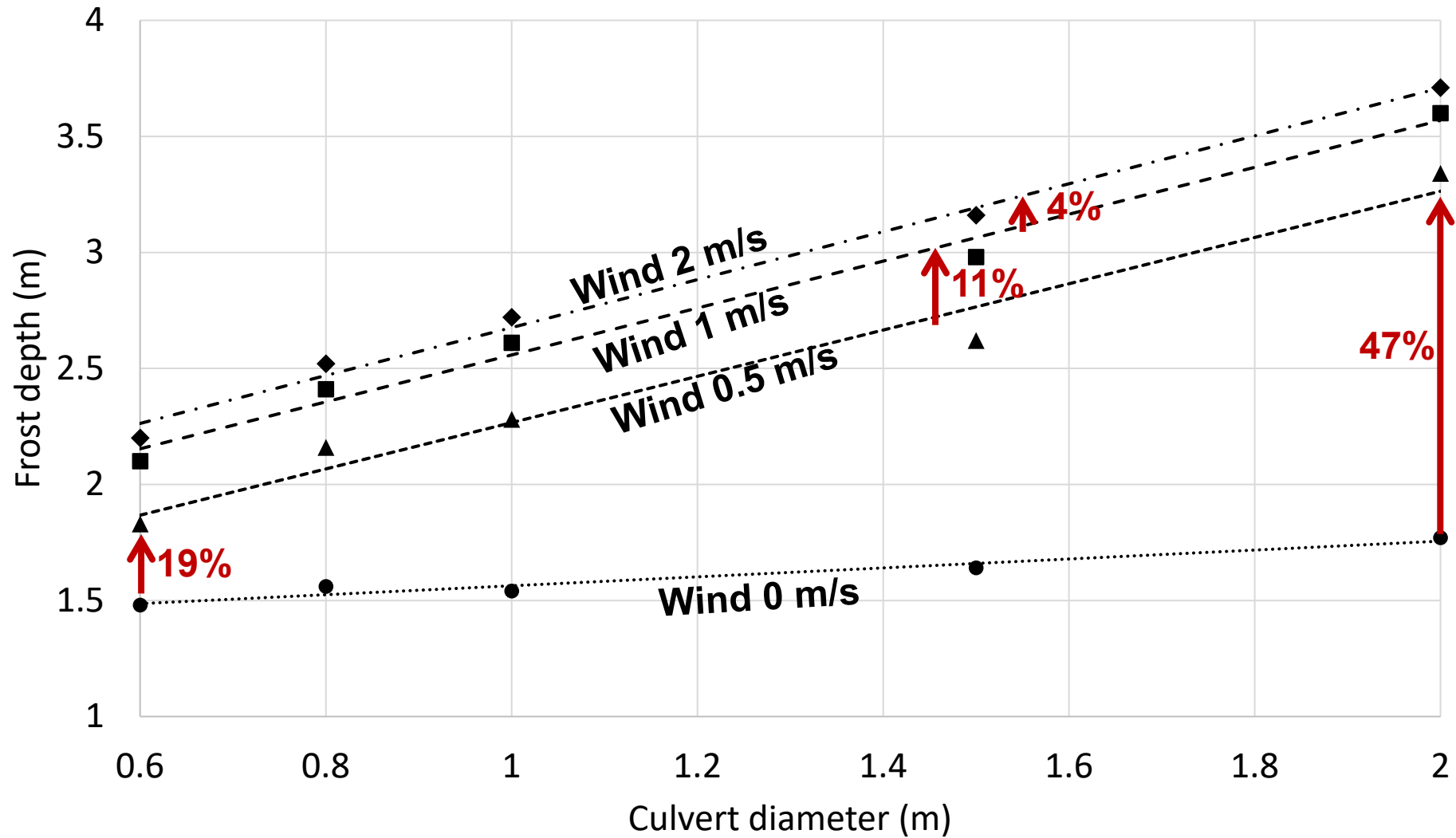


Numerical modelling- frost depth





Numerical modelling- frost depth

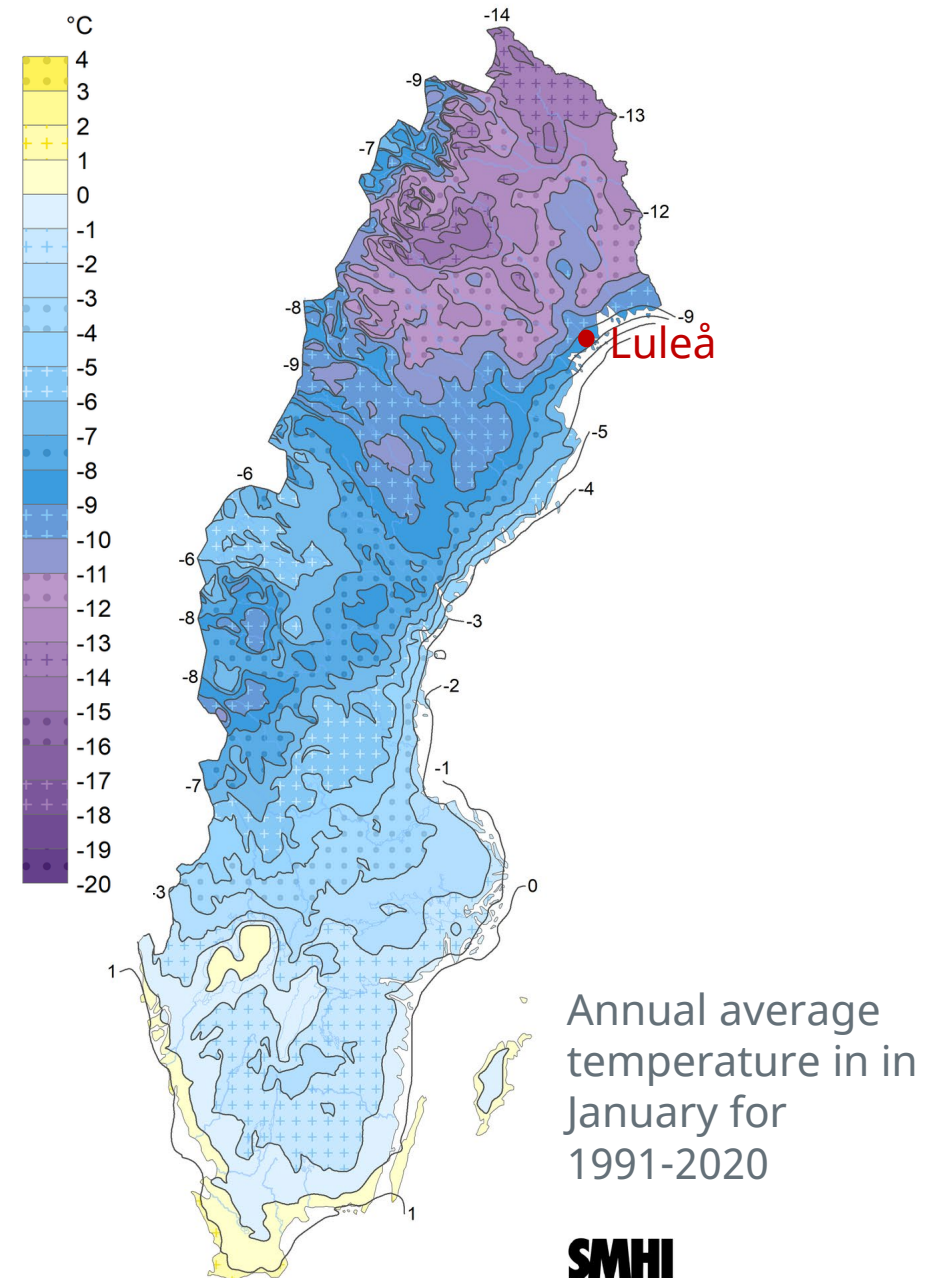


Conclusion

- Temperature inside culverts is not equal to outside temperature
- Two temperature distributions (airflow vs no airflow)
- Multiphysics models can be successfully used to model heat transfer within culverts
- Frost depth increases with culvert diameter and airflow (wind) velocity
 - Especially for larger culverts
- Frost penetration slows once ends of the culvert are covered by snow

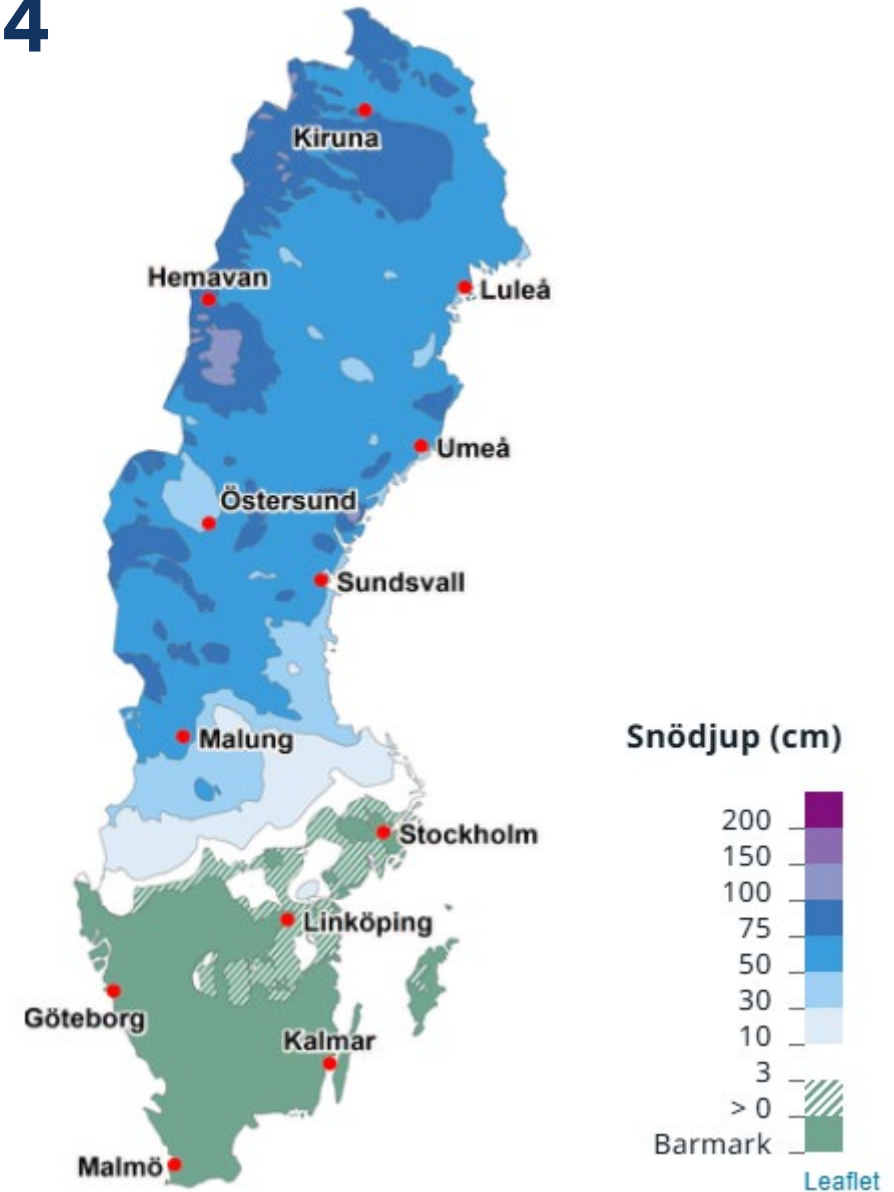
Future work

- Cross-validation of numerical models
 - More winters
 - Different locations
- Guidelines for non-frost susceptible design of culverts





Snow depth 1st of February 2024



1

0 cm

170 cm

184 cm

January

0 cm

178 cm

188 cm

Feb

0 cm

184 cm

193 cm

March

2

0 cm

133 145 149 cm

January

0 cm

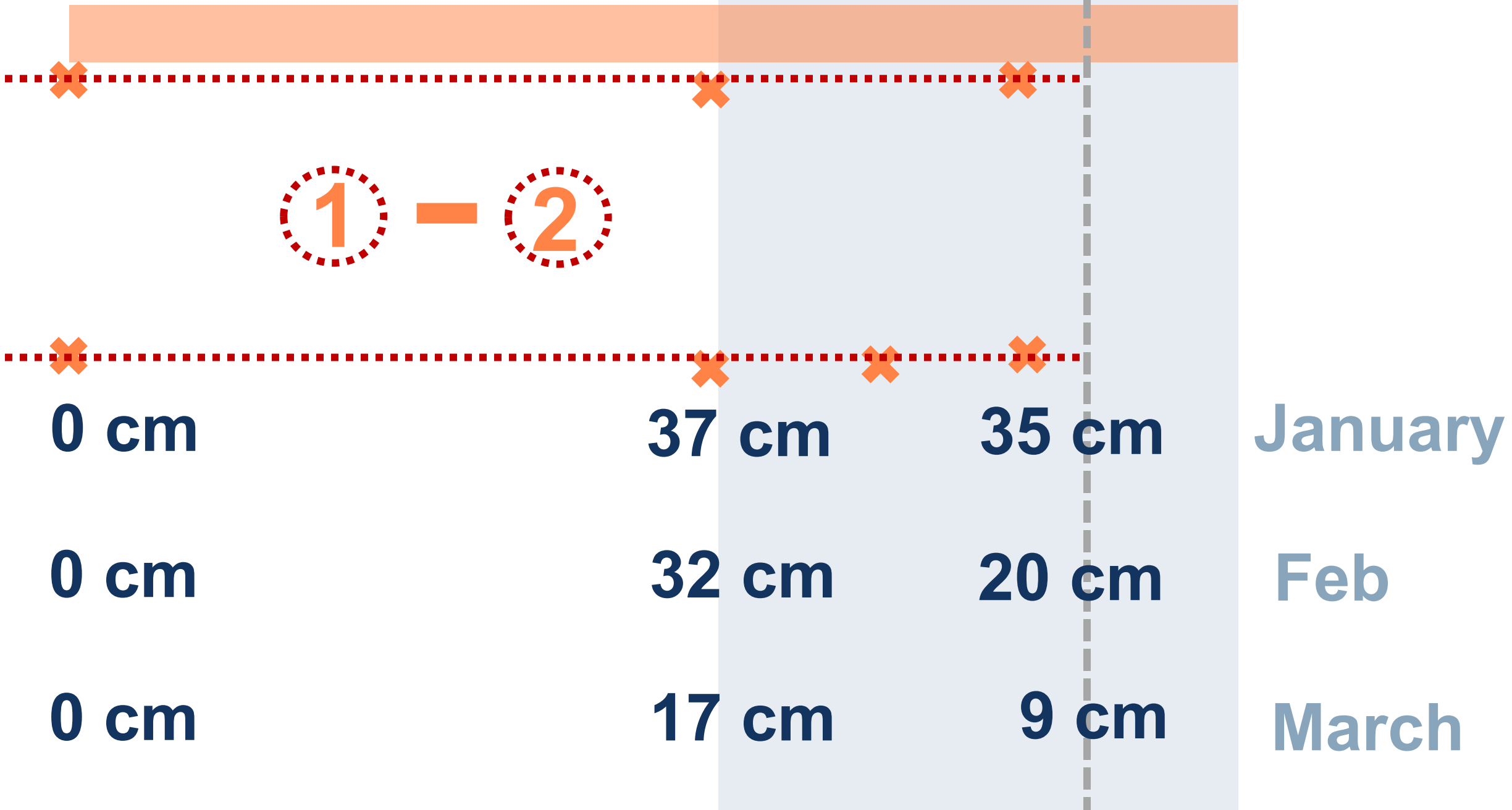
146 163 168 cm

Feb

0 cm

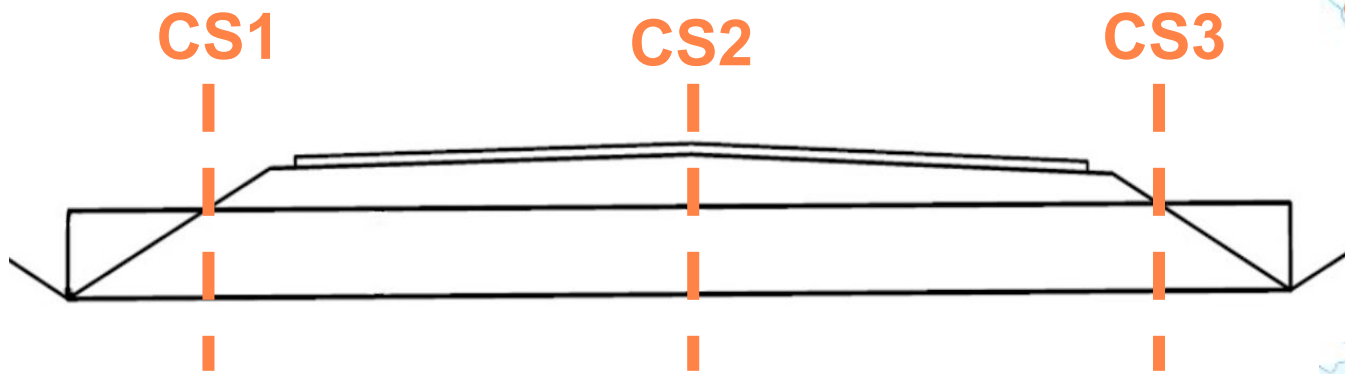
167 182 184 cm

March

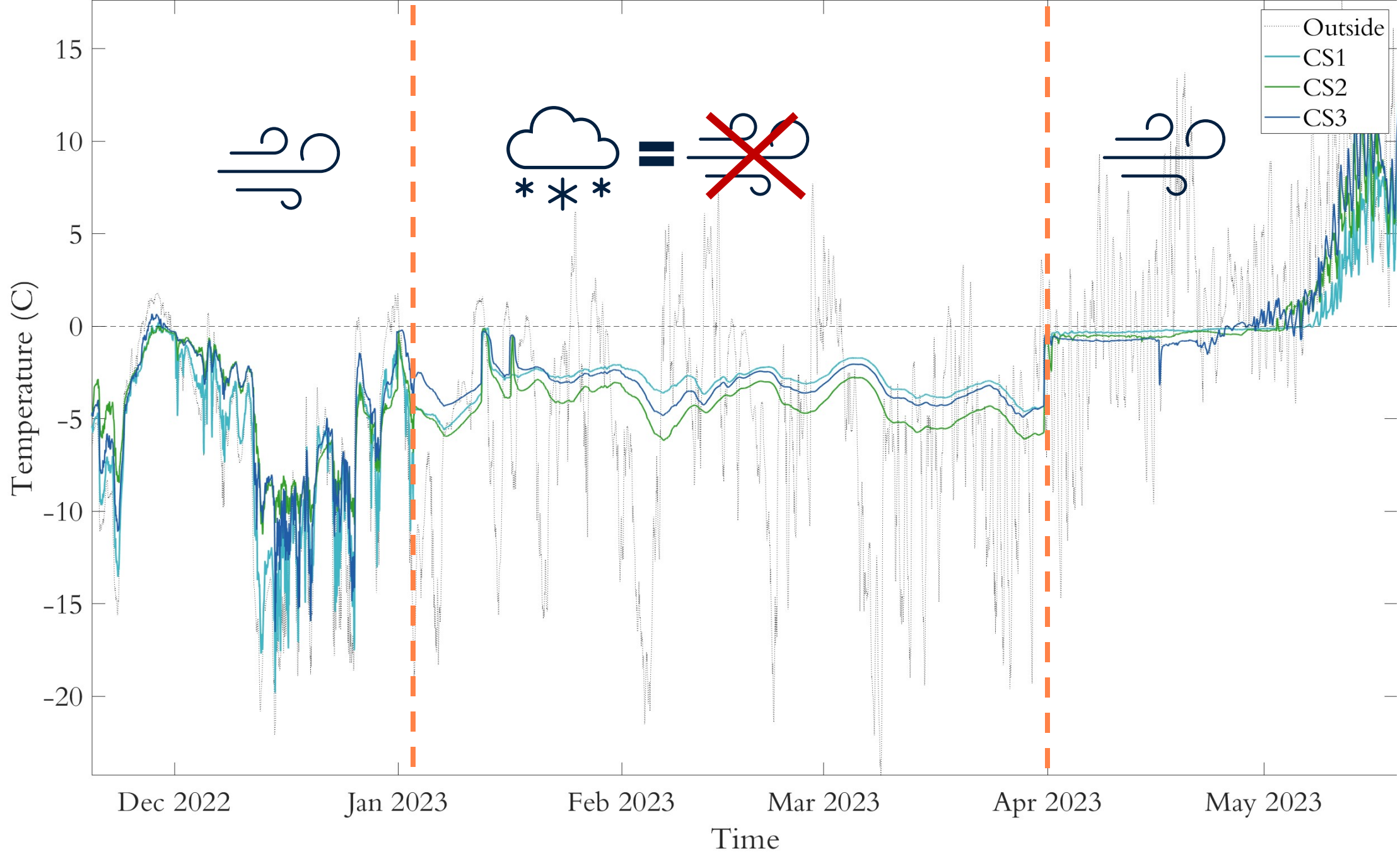


Field installation- up

- Air velocity
- Temperature inside the culvert + temperature probes under the road



Old Culvert Ø 0.6 m



Old Culvert Ø 0.6 m

