Global, consistent, and efficient production of transient permafrost ensemble simulations for investigating climatic influences on slope failures

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Carleton University

PermafrostNet
NSERC | CRSNG

Landslide around Dawson City, Yukon. Credit: V. Pozsgay

Permafrost landslides

Landslide around Dawson City, Yukon.
Credit: V. Pozsgay

Permafrost landslides are increasingly affecting mountain communities!

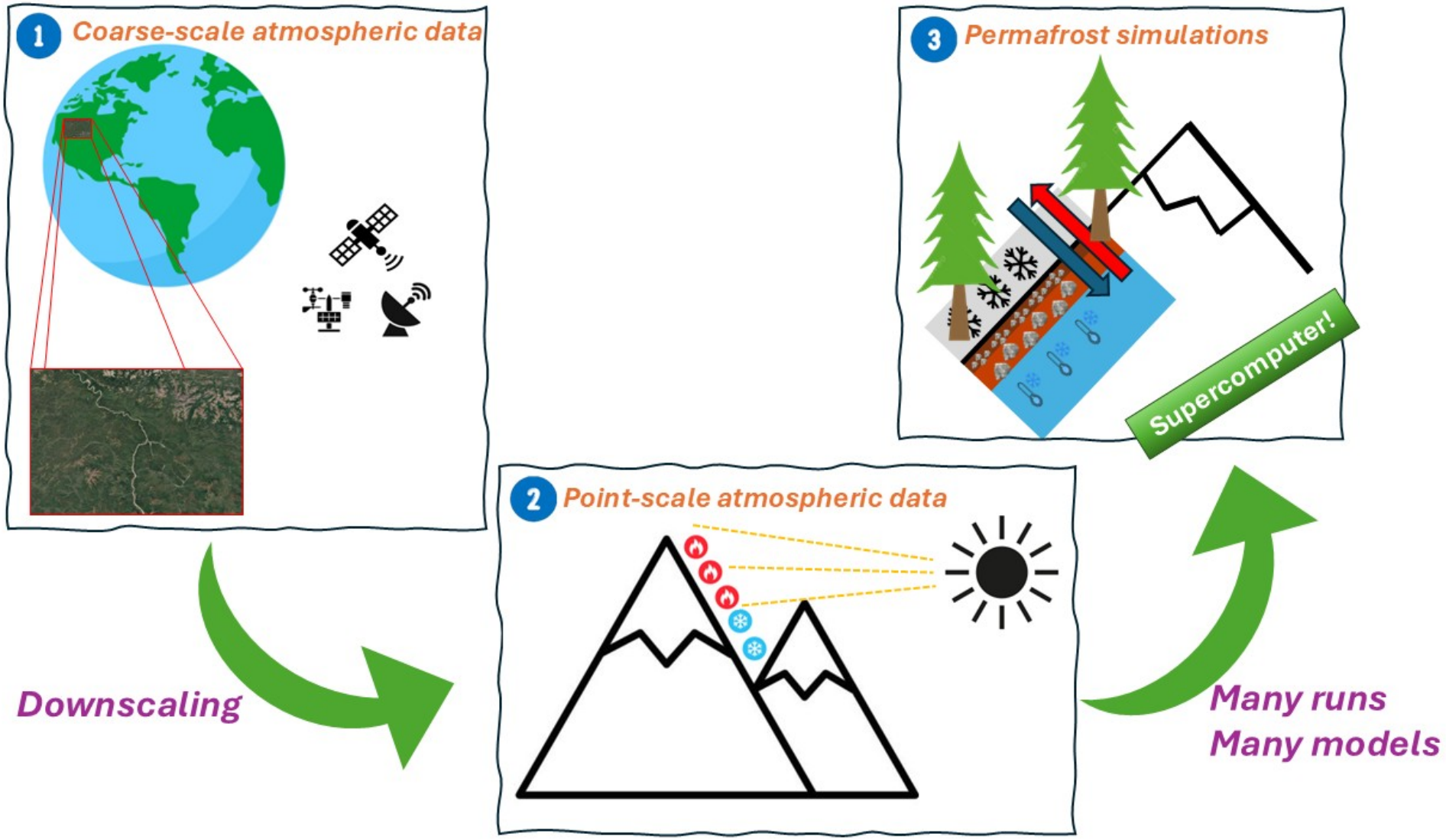
Permafrost landslides

Landslide around Dawson City, Yukon.
Credit: V. Pozsgay

Research project

Can we estimate their **temporal** and **spatial** likelihood?

Method


1 Coarse-scale atmospheric data
2 Point-scale atmospheric data
3 Permafrost simulations
Supercomputer!
Downscaling
Many runs
Many models

How reliable is this?

Problem	Solution	Implemented?

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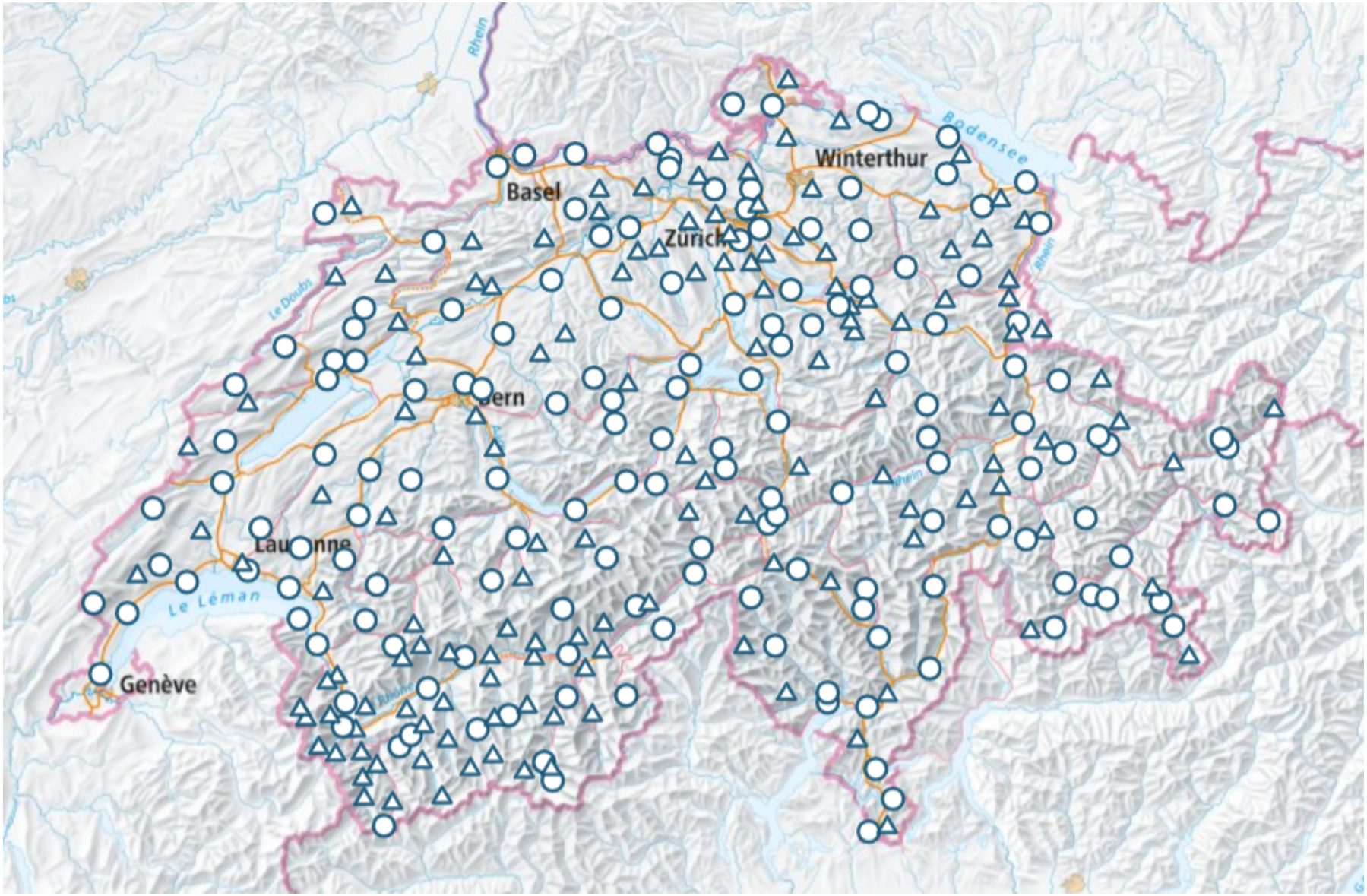
Why not just use weather stations?



Source: [MeteoSwiss/SwissMetNet]

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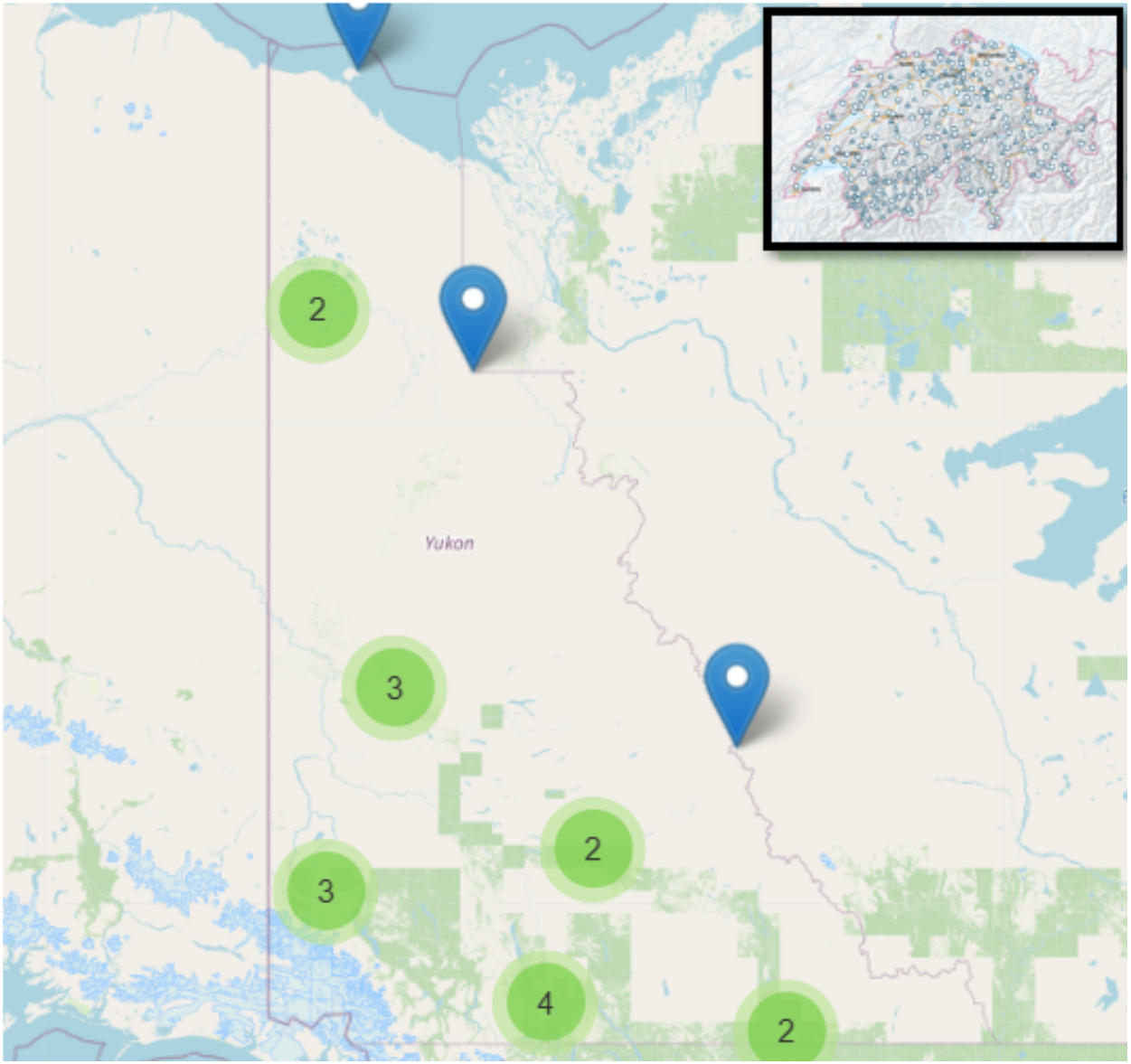
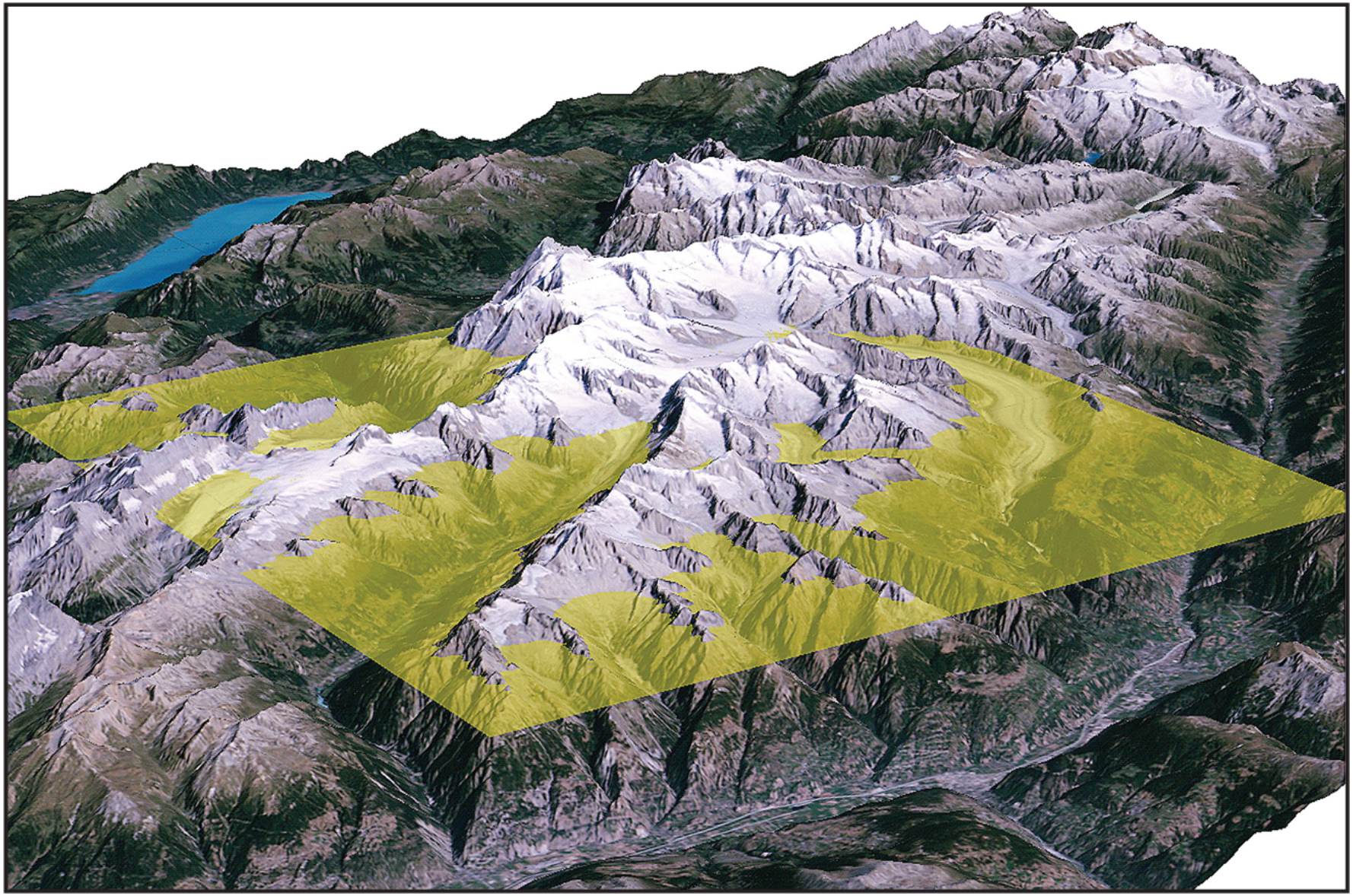


Source: [Environment and Climate Change Canada; MeteoSwiss/SwissMetNet]

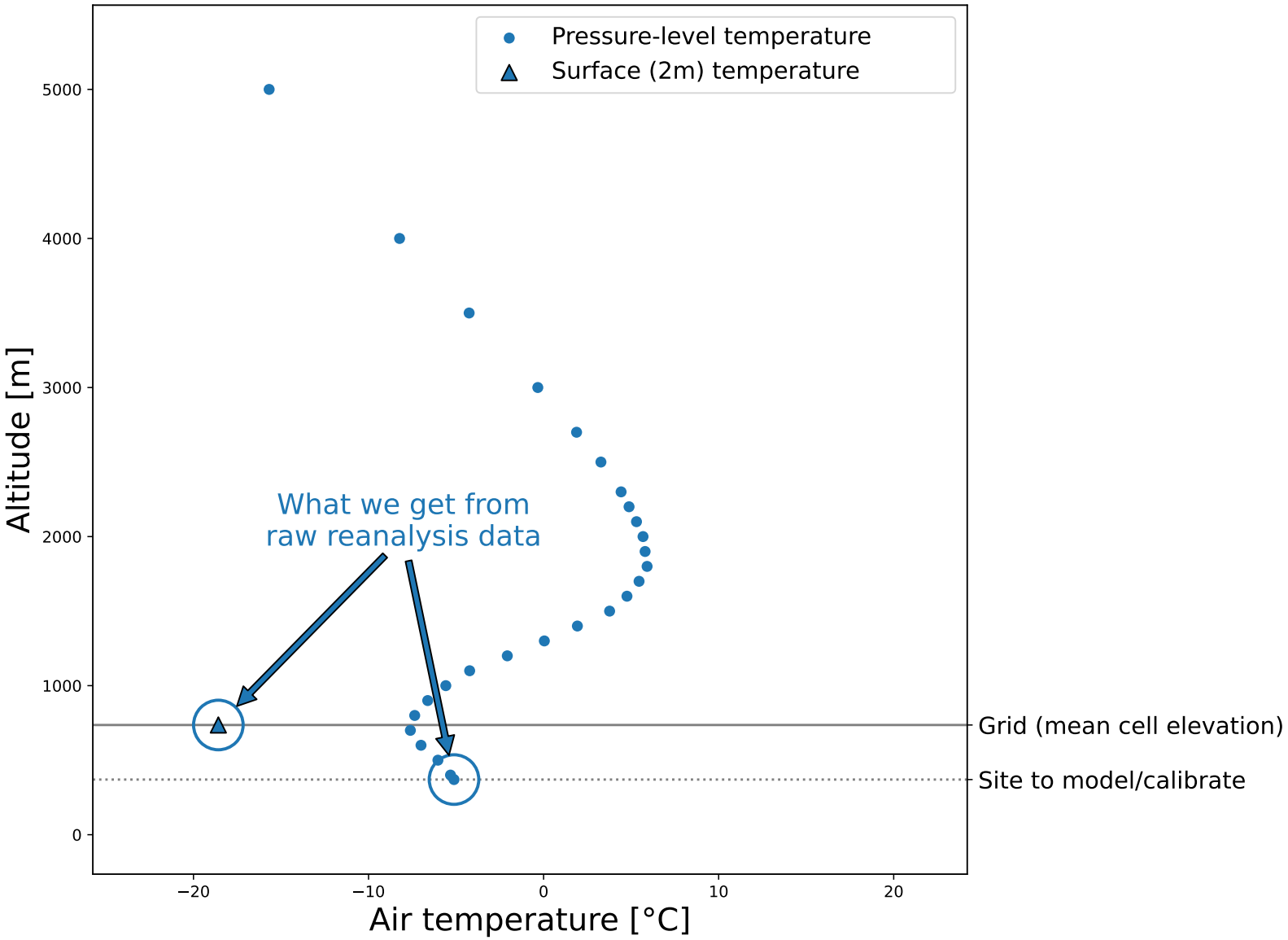
Why not just use reanalysis data?



Source: [S. Gruber. Derivation and analysis of a high-resolution estimate of global permafrost zonation, 2012.]

Temperature inversion model [in review]

Dynamic & instantaneous: hourly update! (Here: Feb. 1, 2007)



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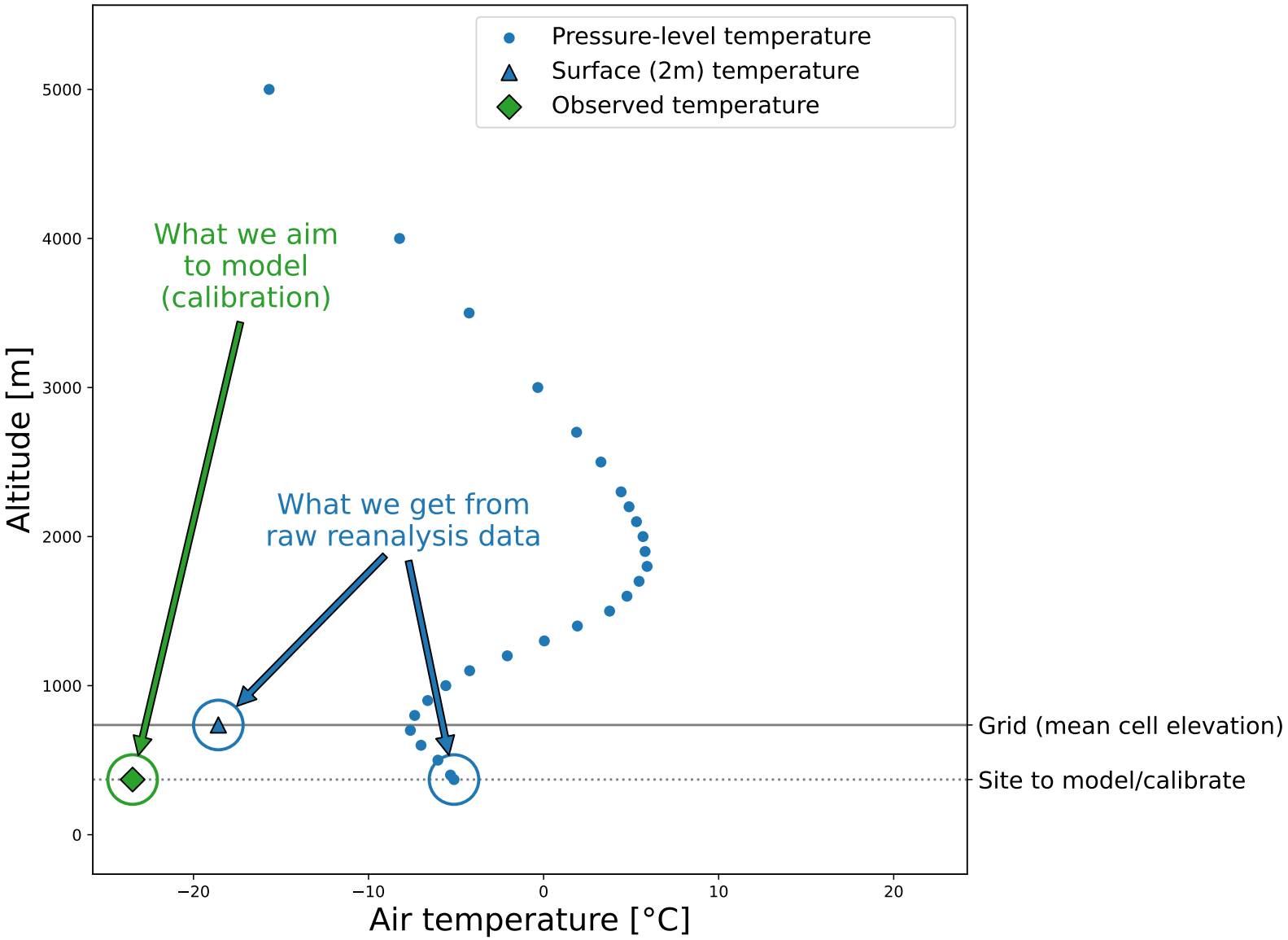

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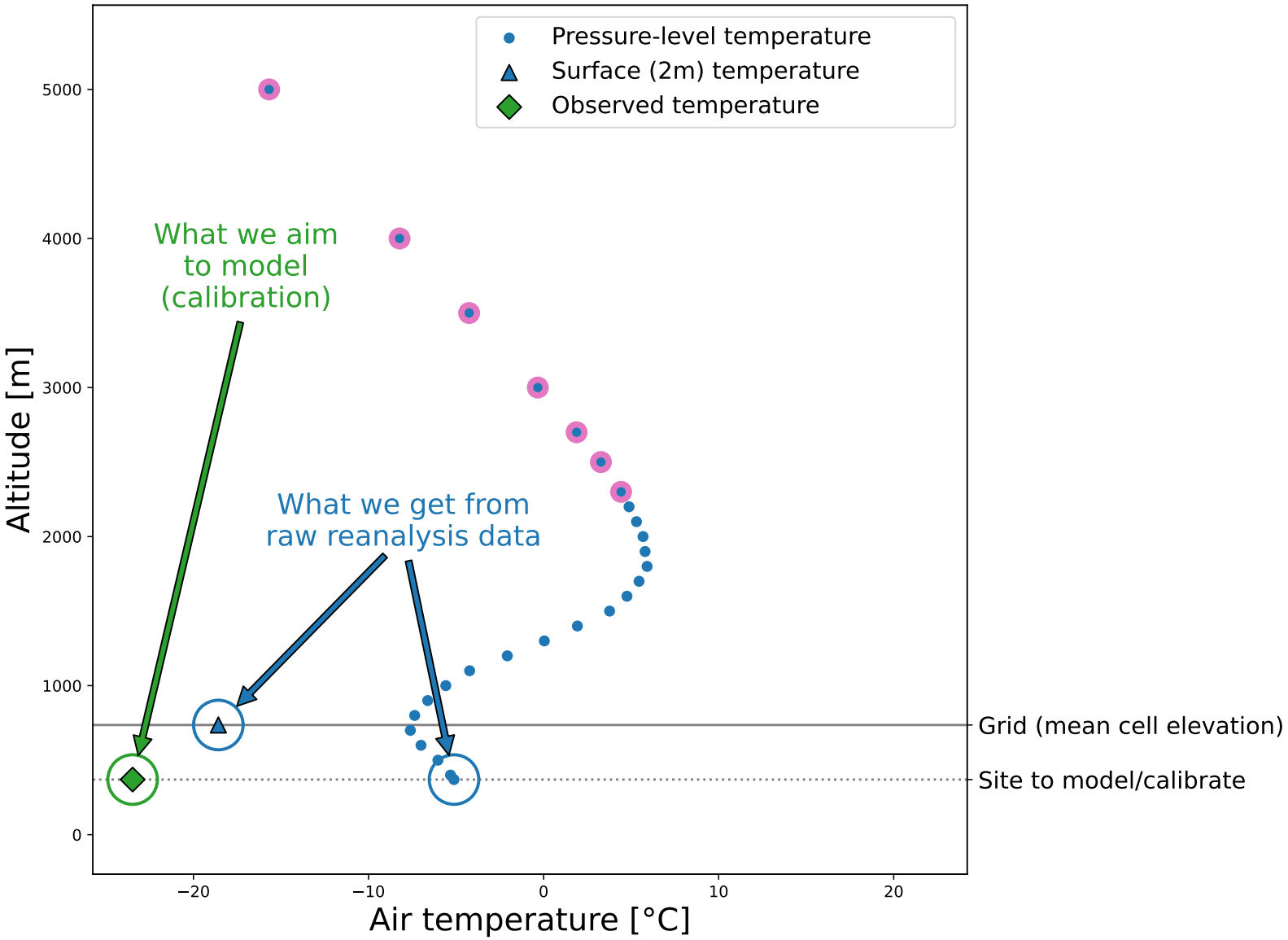

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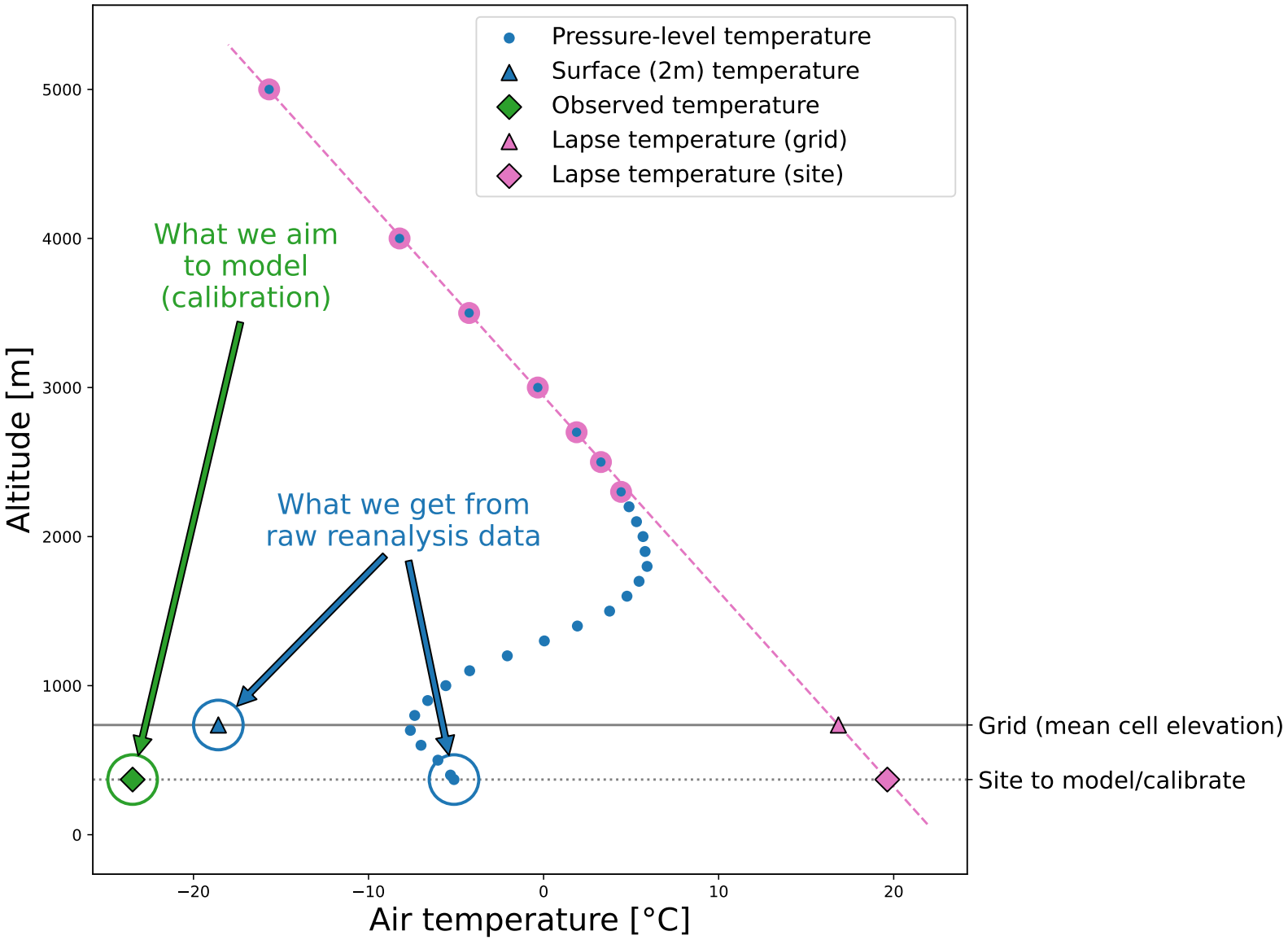

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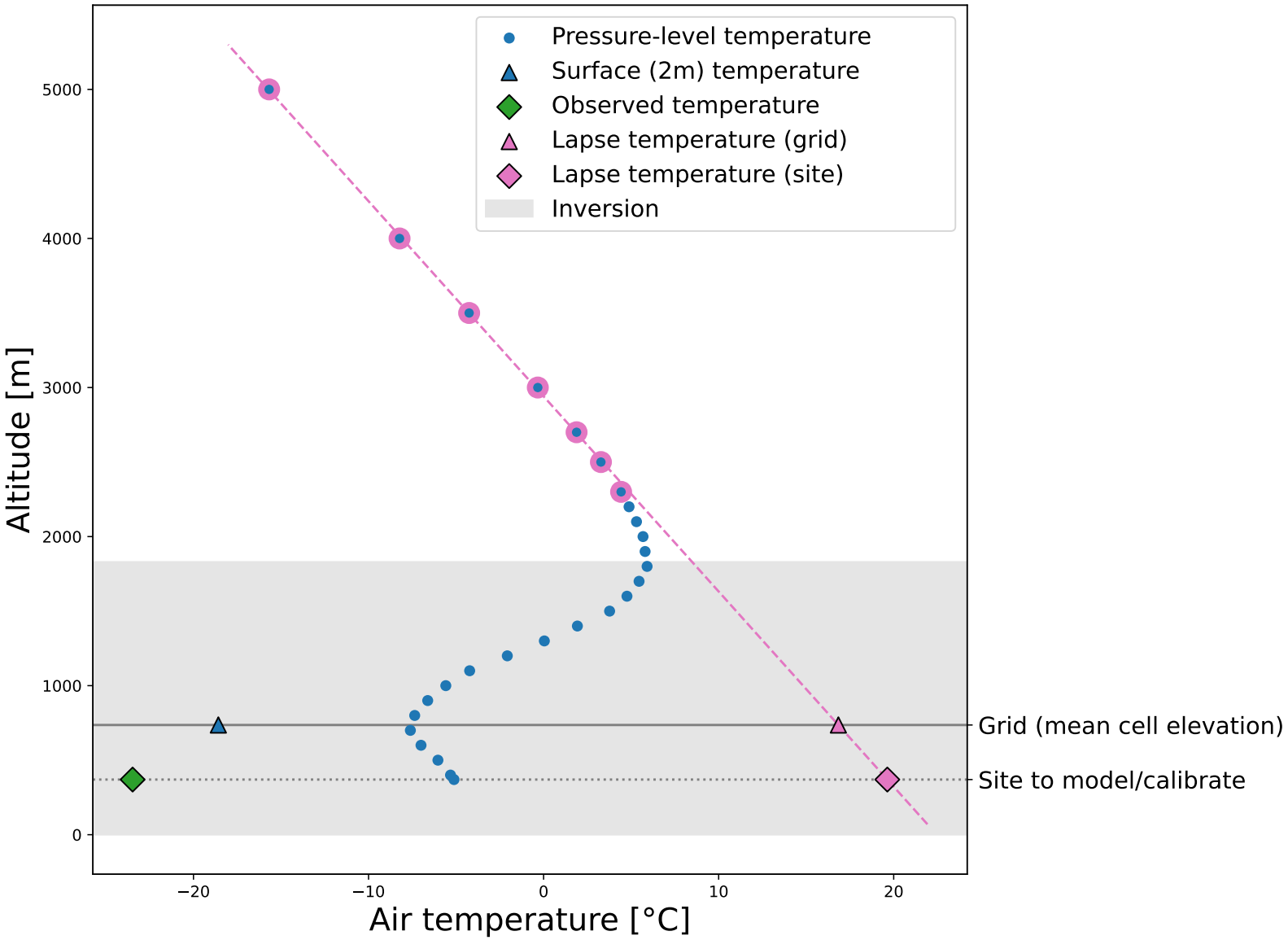

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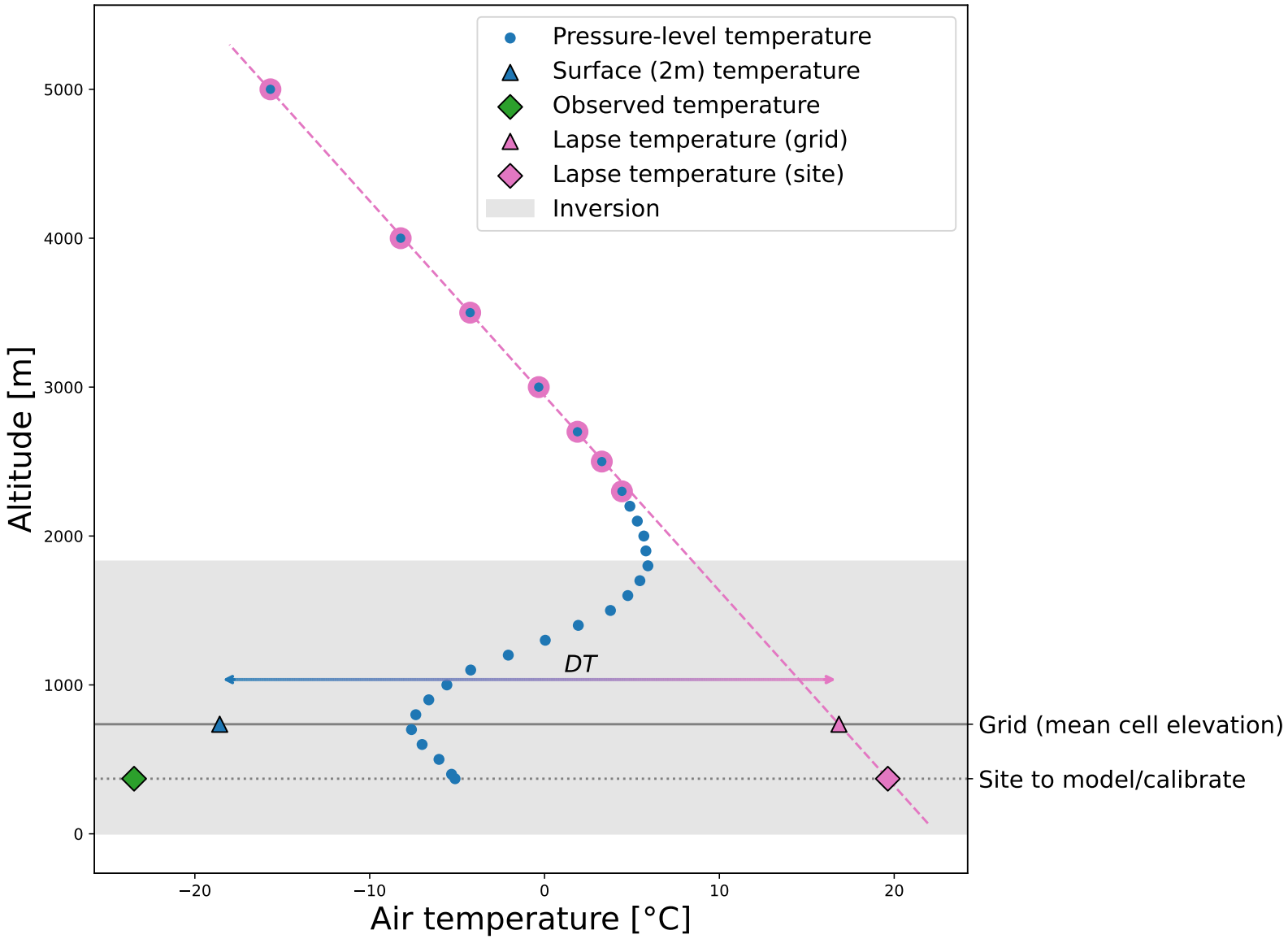

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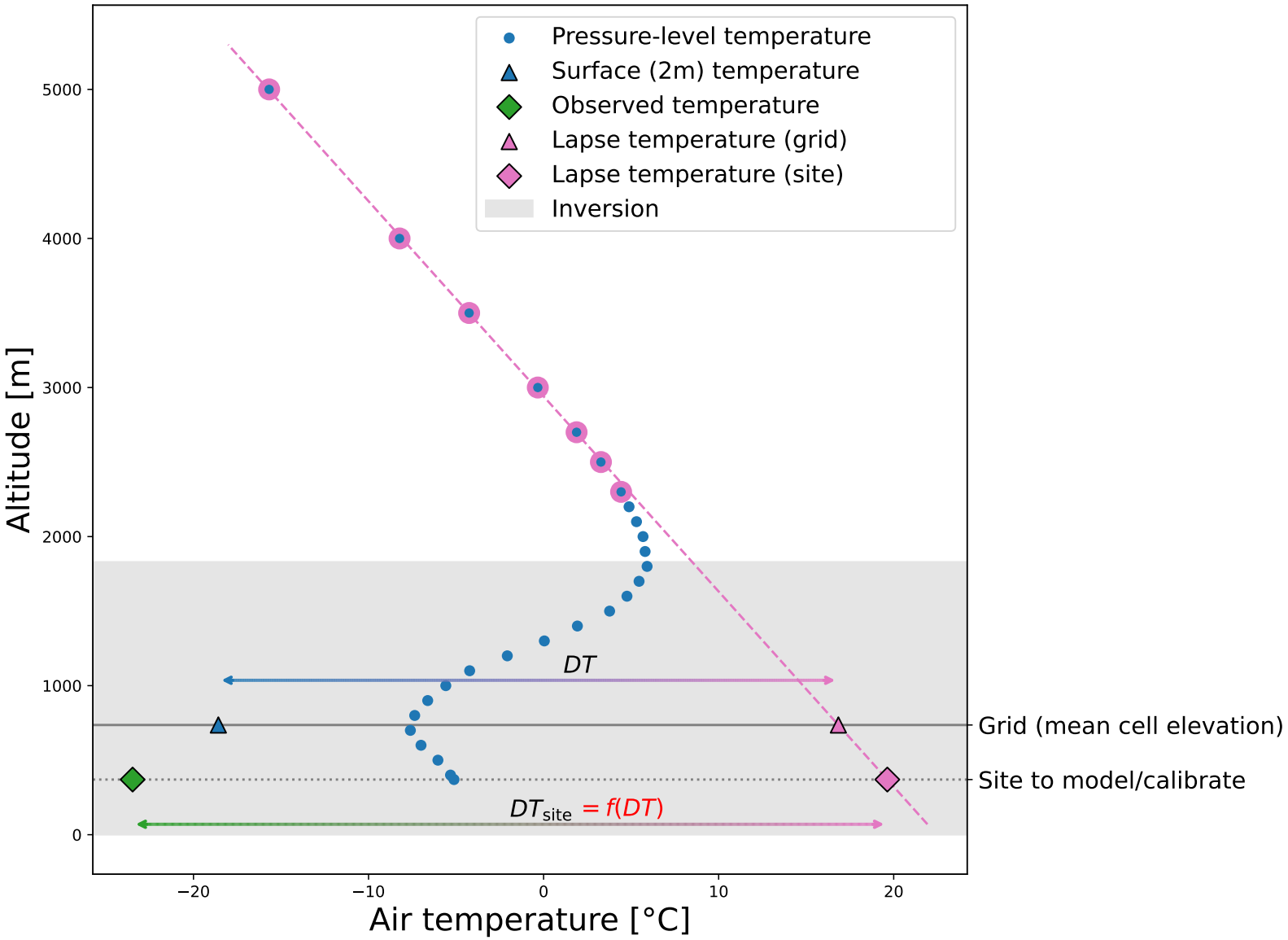


Temperature inversion model [in review]

Main technical novelty: **dynamic** upper atmosphere background lapse rate (updated at every time step), **calibrated** with 5 stations

$$DT_{\text{site}} = \alpha(z) \cdot DT + \beta(t)$$

with

$\alpha(z)$: linear geometric factor

z : elevation

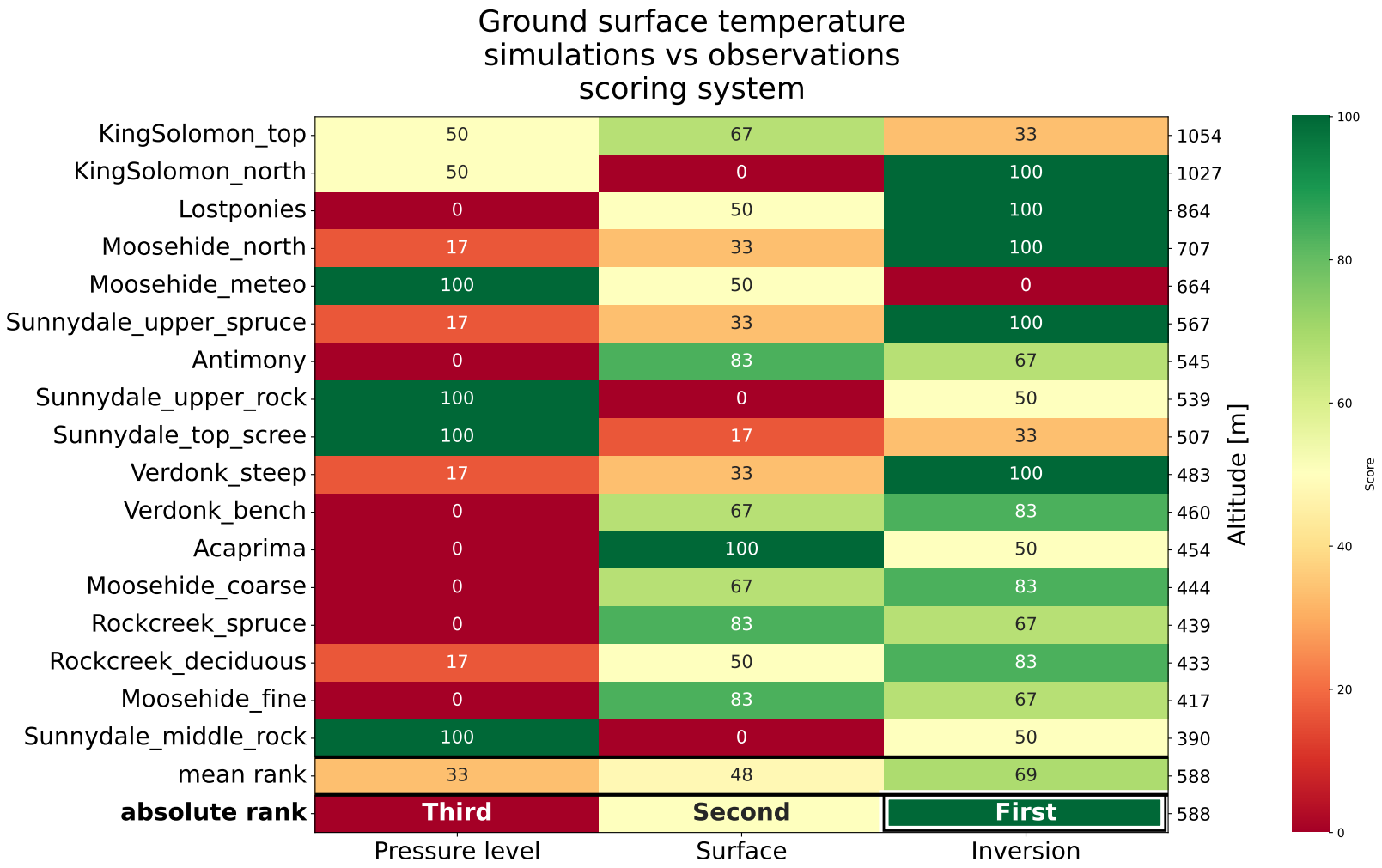
$\beta(t)$: annual oscillations of the reanalysis bias

t : time

Formulation

$$\alpha(z) = \alpha_0 \cdot z + \alpha_1 + (\text{trends}),$$
$$\beta(t) = \beta_0 \cdot \cos(2\pi(t - t_*)) + \beta_1 + (\text{trends}).$$

Results: Dawson City case study [preliminary]



Key take away

The inversion model performs better (across all reanalyses)

Conclusions

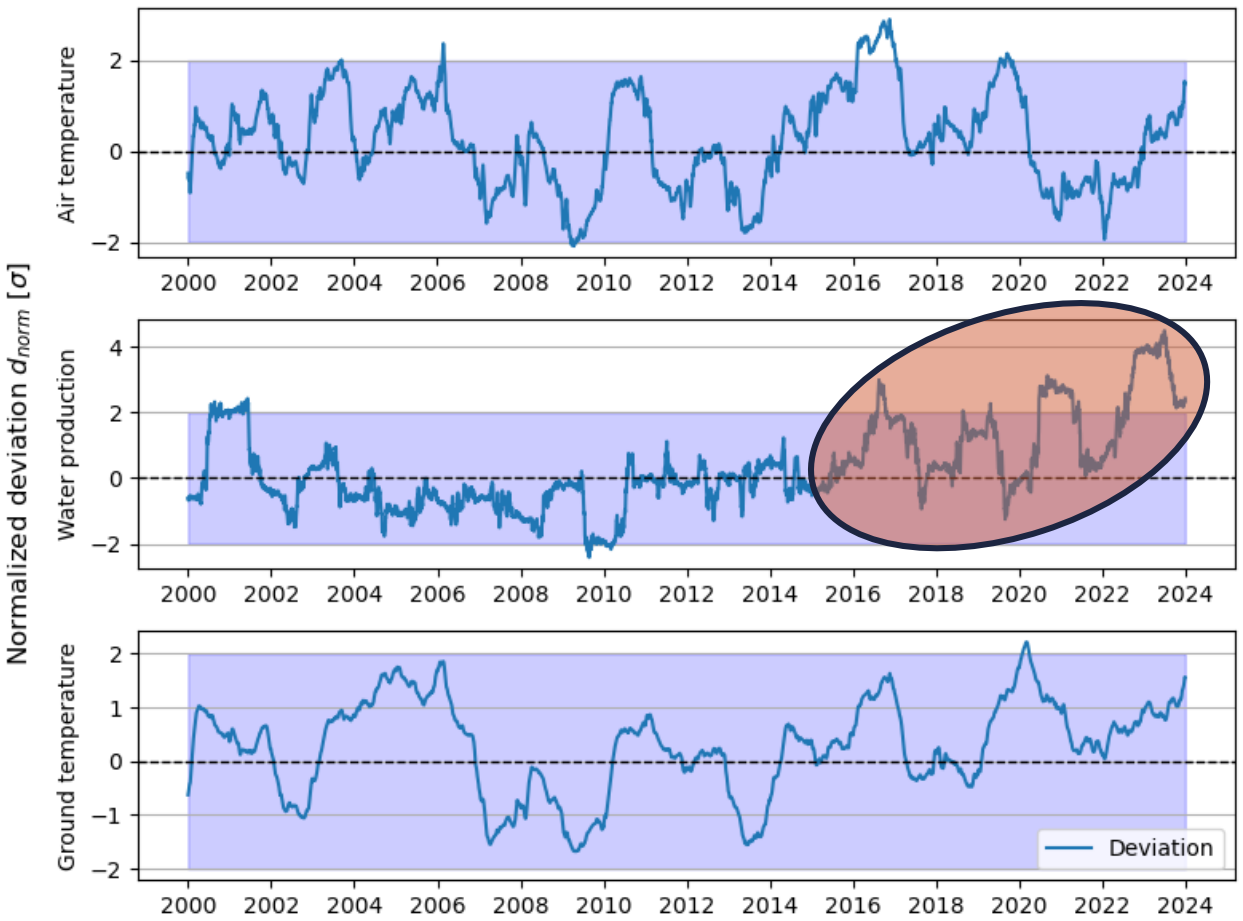
Successful implementation of a **dynamic** model of temperature inversions into our permafrost simulation workflow:

- produces **reliable** time series for air temperature in **complex terrain with strong and frequent inversions**,
- **performs consistently better** than bare reanalysis products,
- uses ever-improving physically-based data, making it **future-proof** and **versatile** in its regional applications.

Future improvements:

- automatic **snow pack calibration** with MODIS satellite data,
- correlate permafrost metric evolution with **slope movement**.

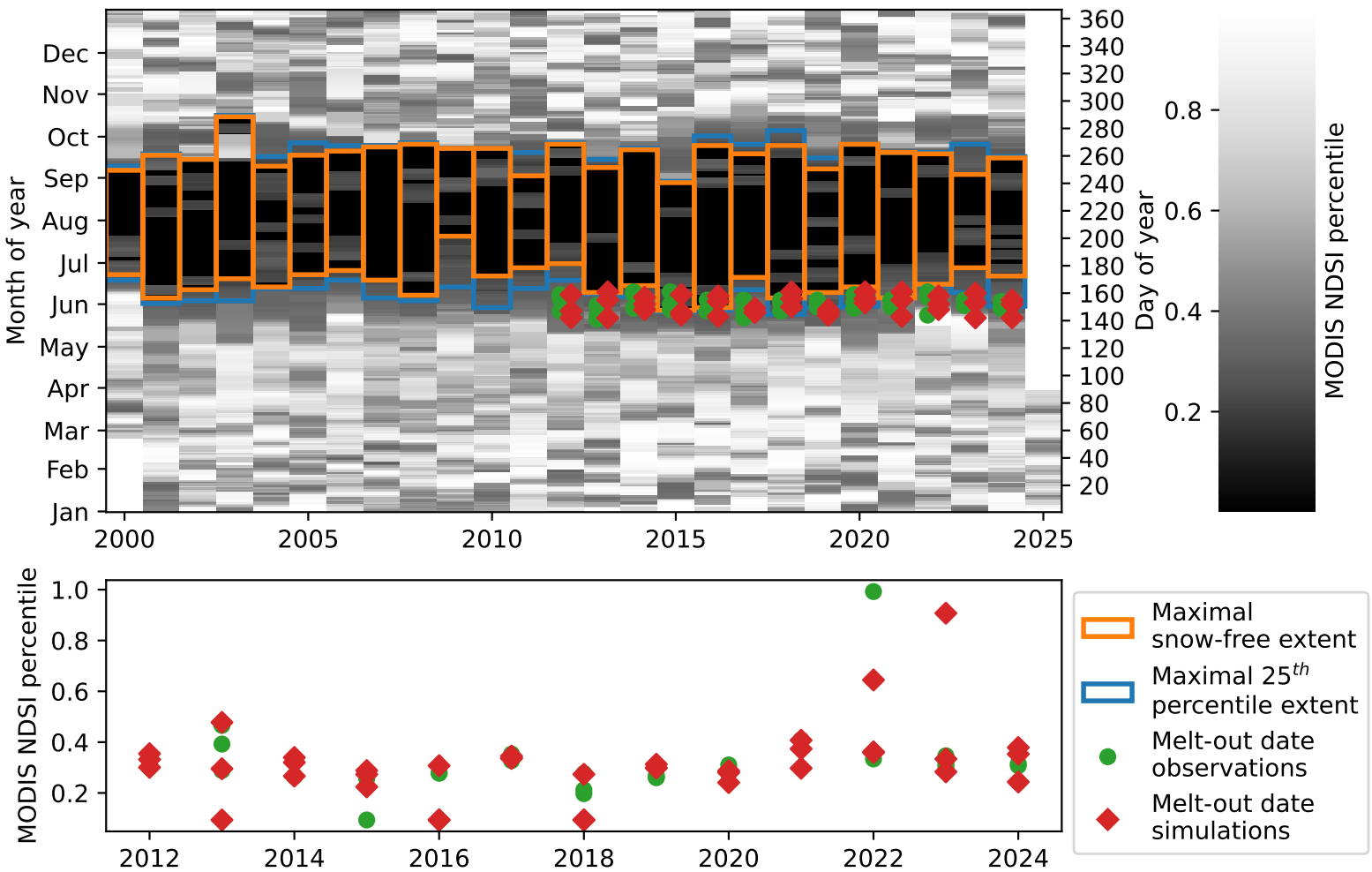
Putting this in context [SuPerSim package]



Dimensionless measure of extreme simulated values for the Sunnydale Slide near Dawson City, Yukon, Canada.

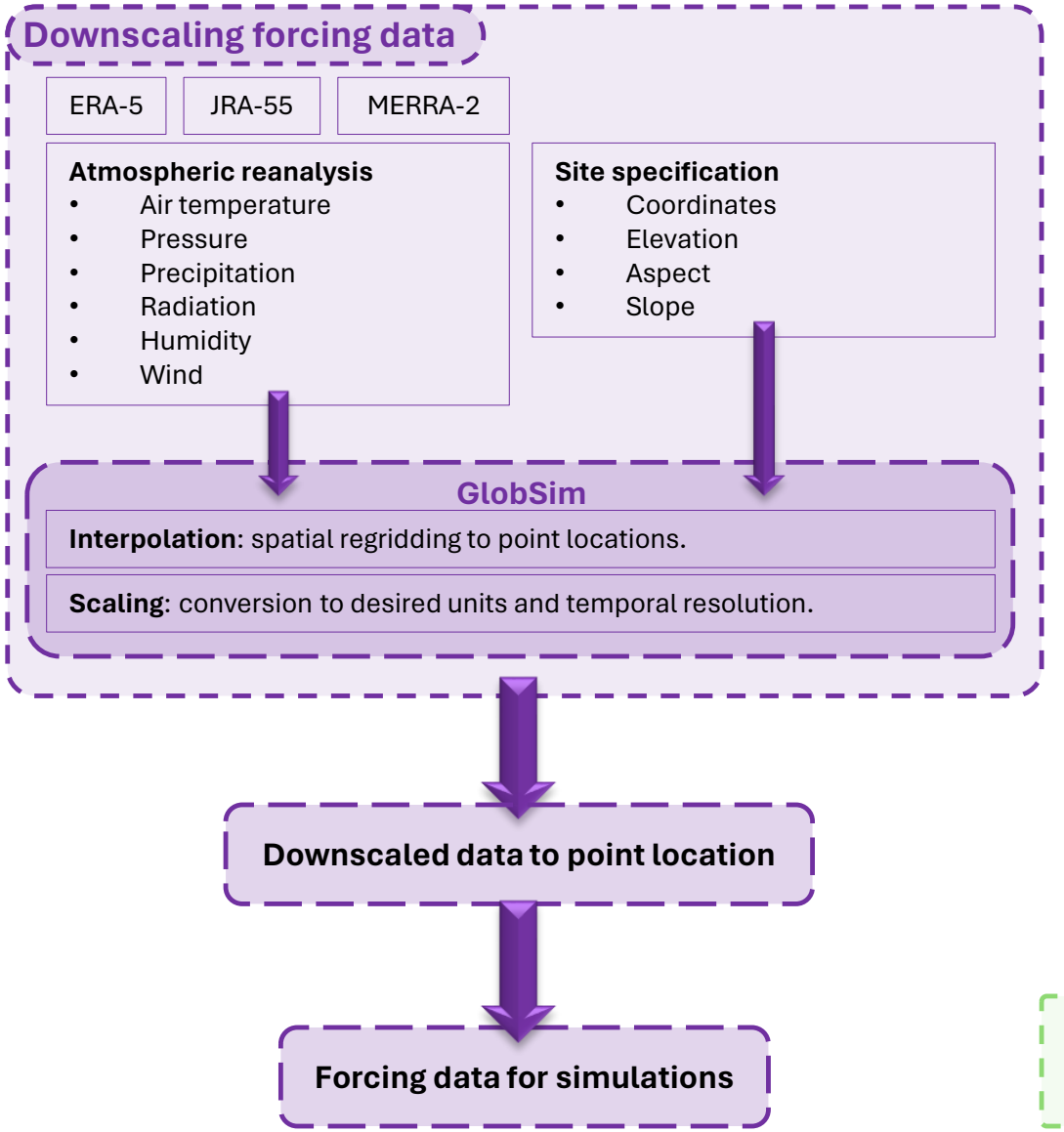
MODIS snow data [current work]

Comparison of observed and simulated melt-out dates with MODIS snow data



Simulation workflow

Step 1: Downscaling to point location

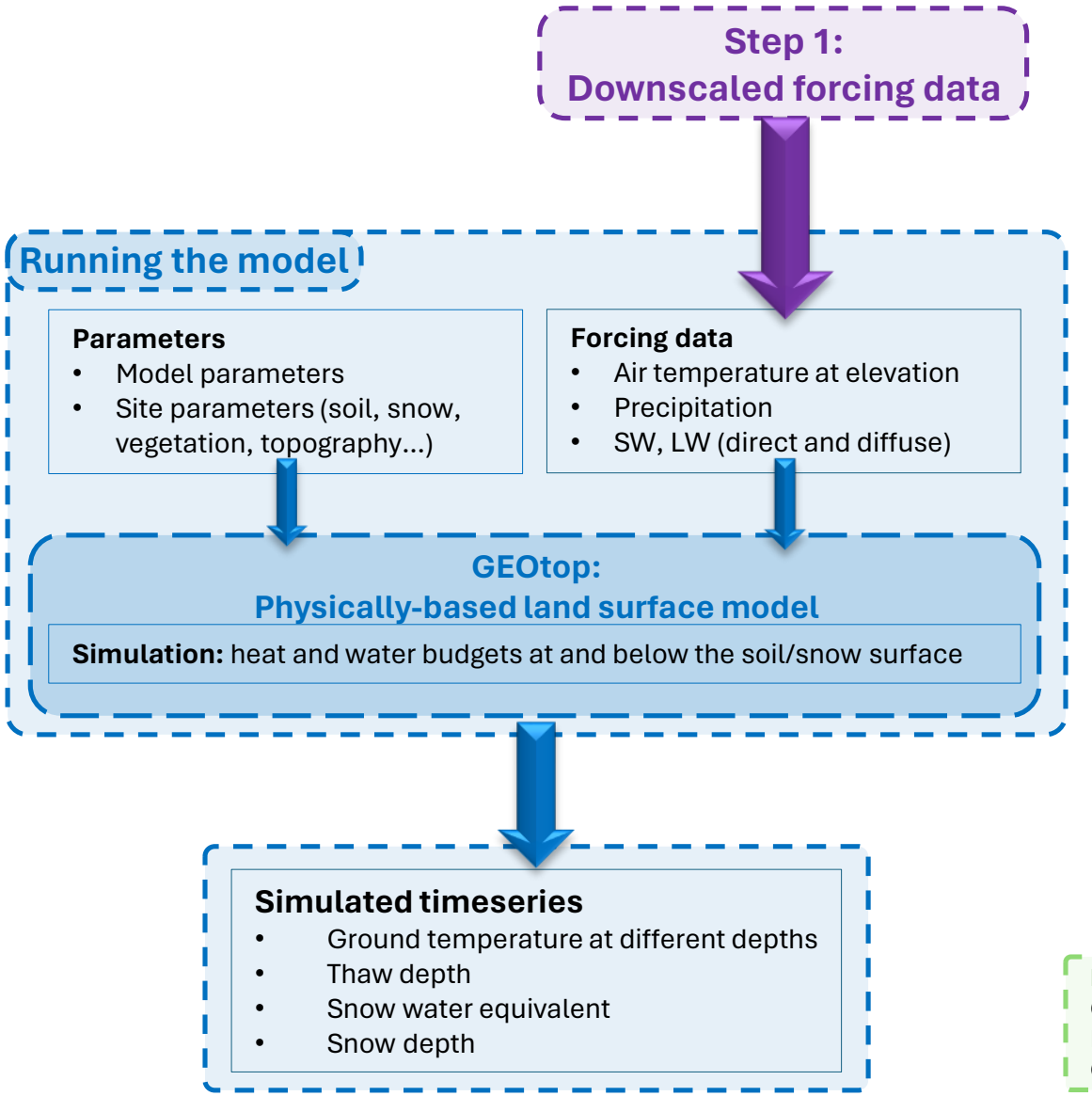


References

GlobSim: B. Cao, X. Quan, N. Brown, E. Stewart-Jones, S. Gruber

Simulation workflow

Step 2: Producing simulated time series



References

GEOtop: S. Endrizzi, S. Gruber, M. Dall'Amico, R. Rigon

GTPEM: N. Brown