Assessing the effect of topography on the atmospheric flow over the Amazon Forest by means of Large Eddy Simulation and tower measurements

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Starting Question

What is the influence of the topography on the atmospheric flow above and within the Amazon Forest?

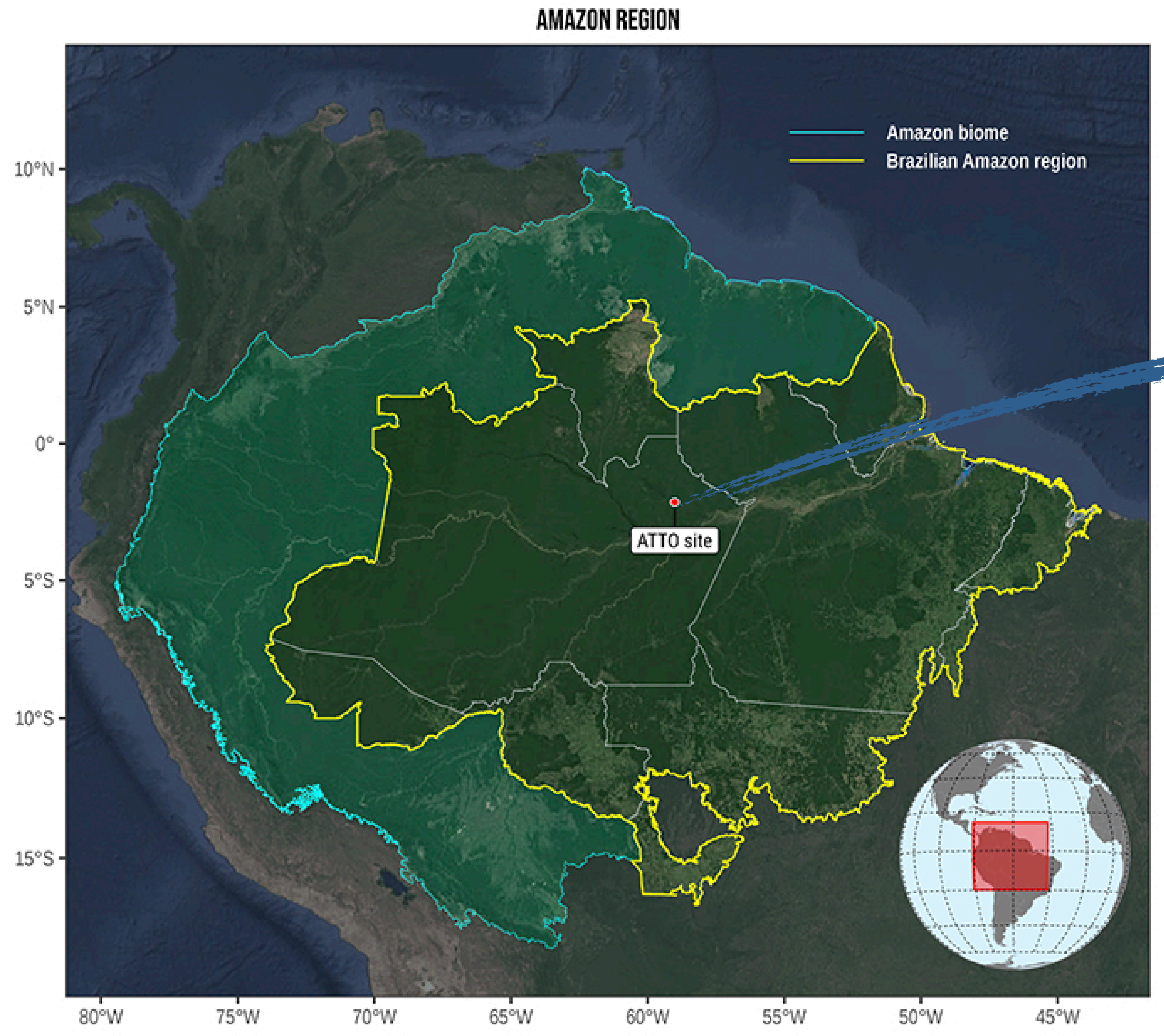
Contrary to our intuition forest are rarely situated on uniform and flat terrain in which the horizontally homogeneity of turbulence holds. But, at the same time, our estimates of the net ecosystem exchange and, in general, of the exchanges between the biosphere and the atmosphere are based on single point tower measurements of turbulent fluxes of scalars such as CO_2, CH_4, and $BVOC$ in which the horizontal redistribution of gases due to the influence of the topography is not considered.

To address this question in the present work, Large Eddy Simulation (PALM) is coupled with experimental data in a pristine area of the Amazon Forest

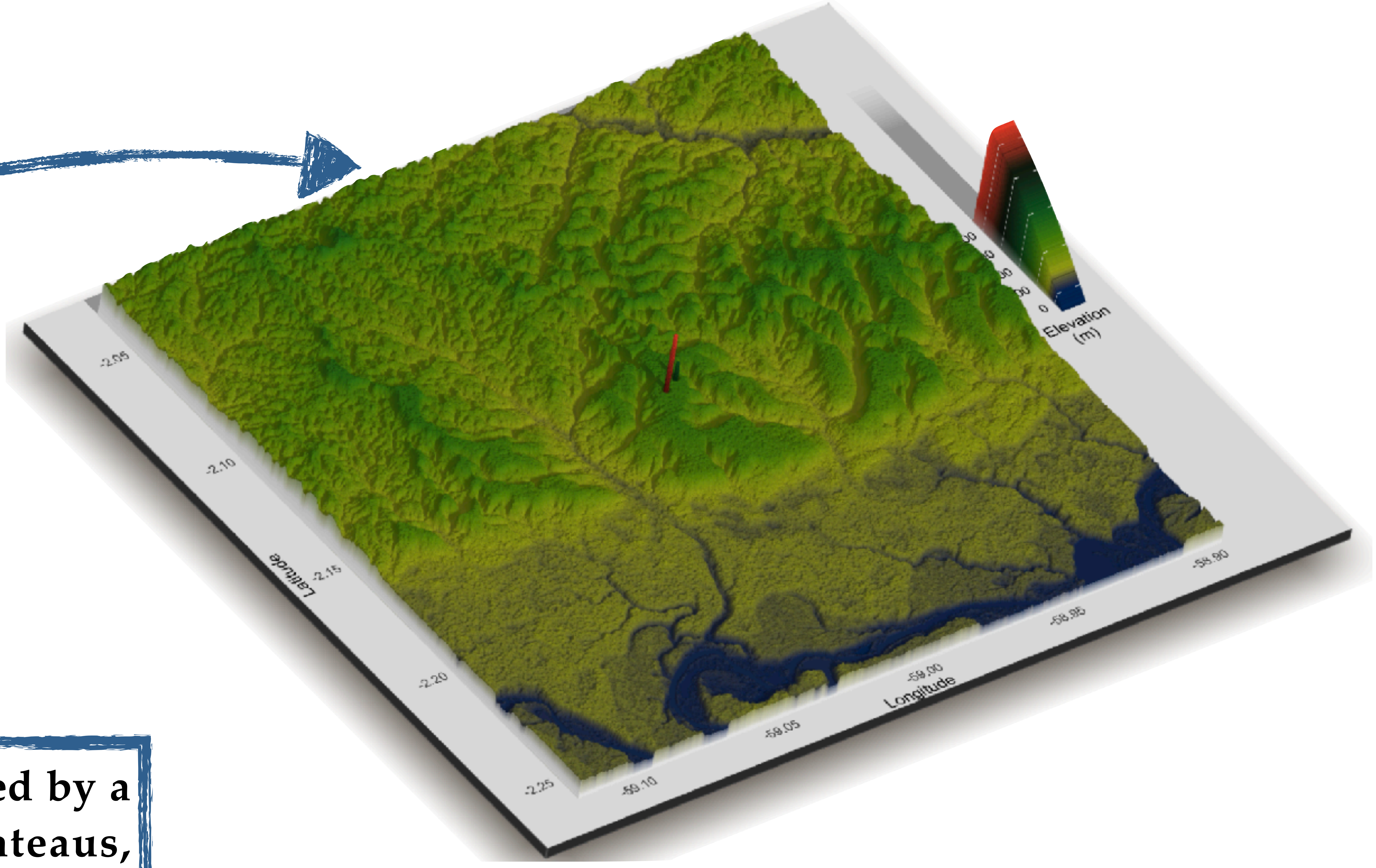
What does the Amazon forest look like?

Not so flat!

Amazon Forest Topography



The Brazilian Amazon



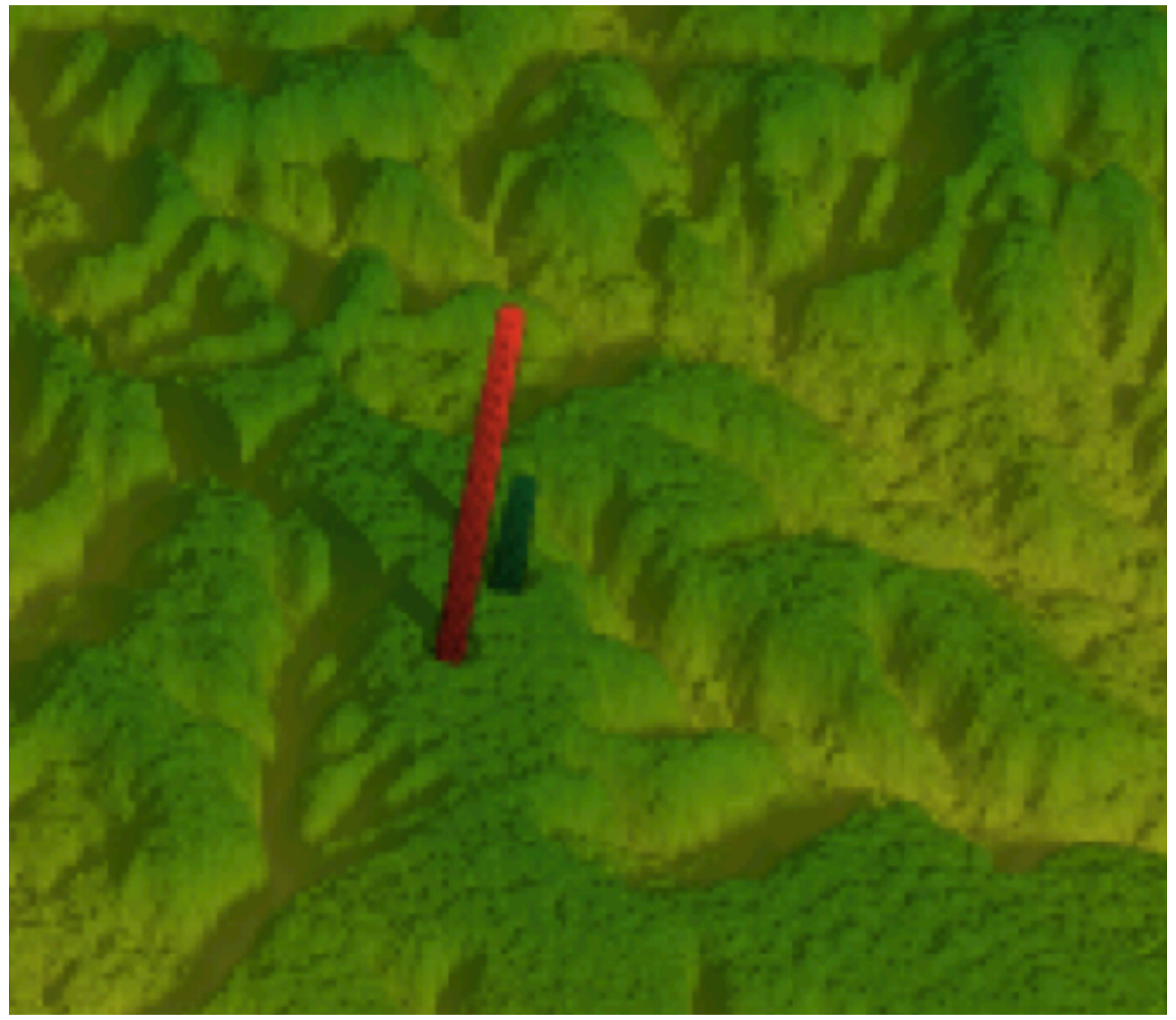
Digital elevation model of the selected study area in the Amazon Forest

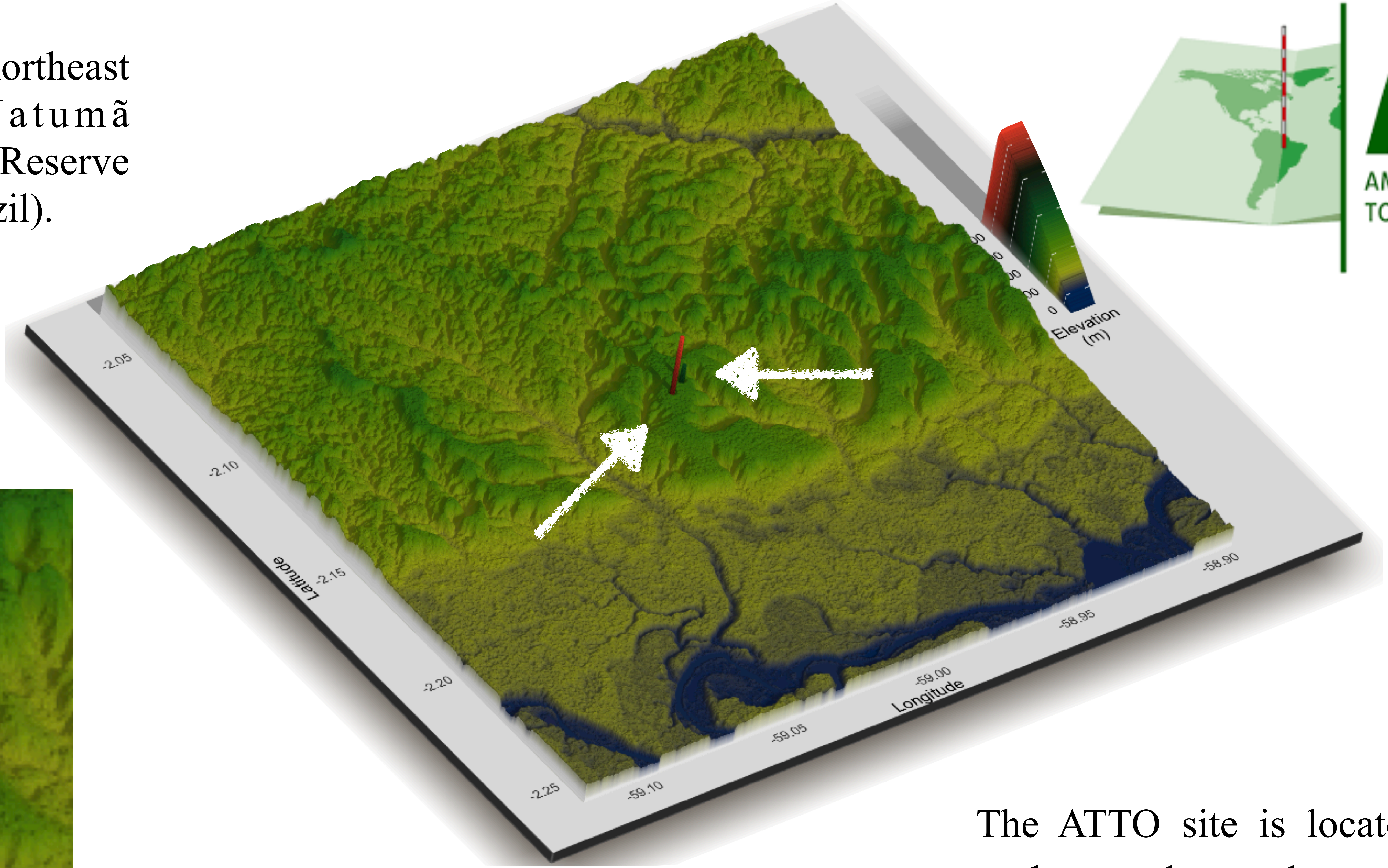
The Amazon forest is characterised by a continuous alternation of plateaus, ridges and valleys.

Amazon Tall Tower Observatory (ATTO)

ATTO
AMAZON TALL
TOWER OBSERVATORY

The ATTO site is 150 km northeast of Manaus in the Uatumã Sustainable Development Reserve in the central Amazon (Brazil).



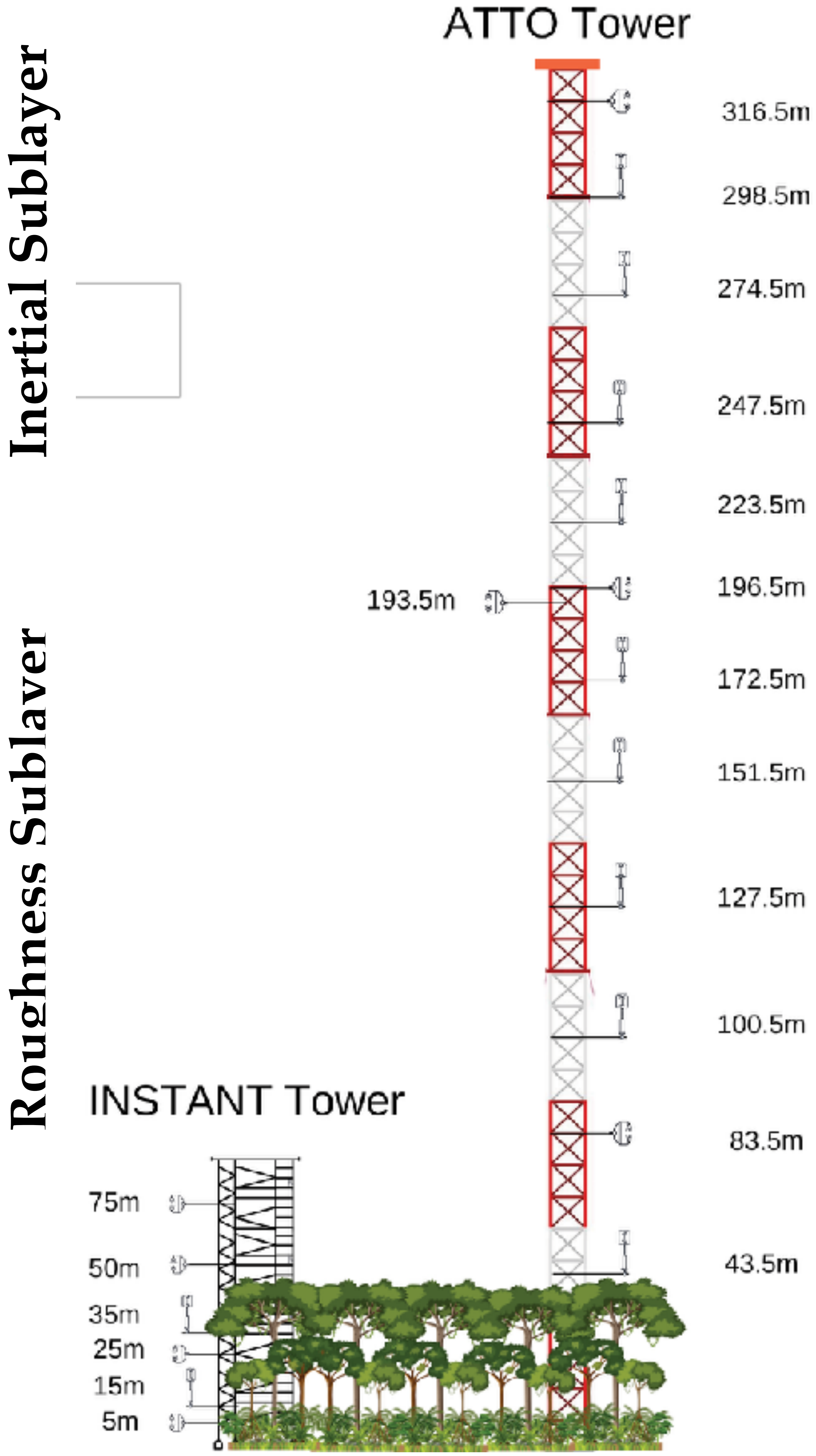


Digital elevation model around the ATTO site.

The ATTO site is located at 120 m a.s.l on a plateau that measures about 1.5km in NW-SE direction and about 5 km along the NE-SW axis.

Anemometric Measurements

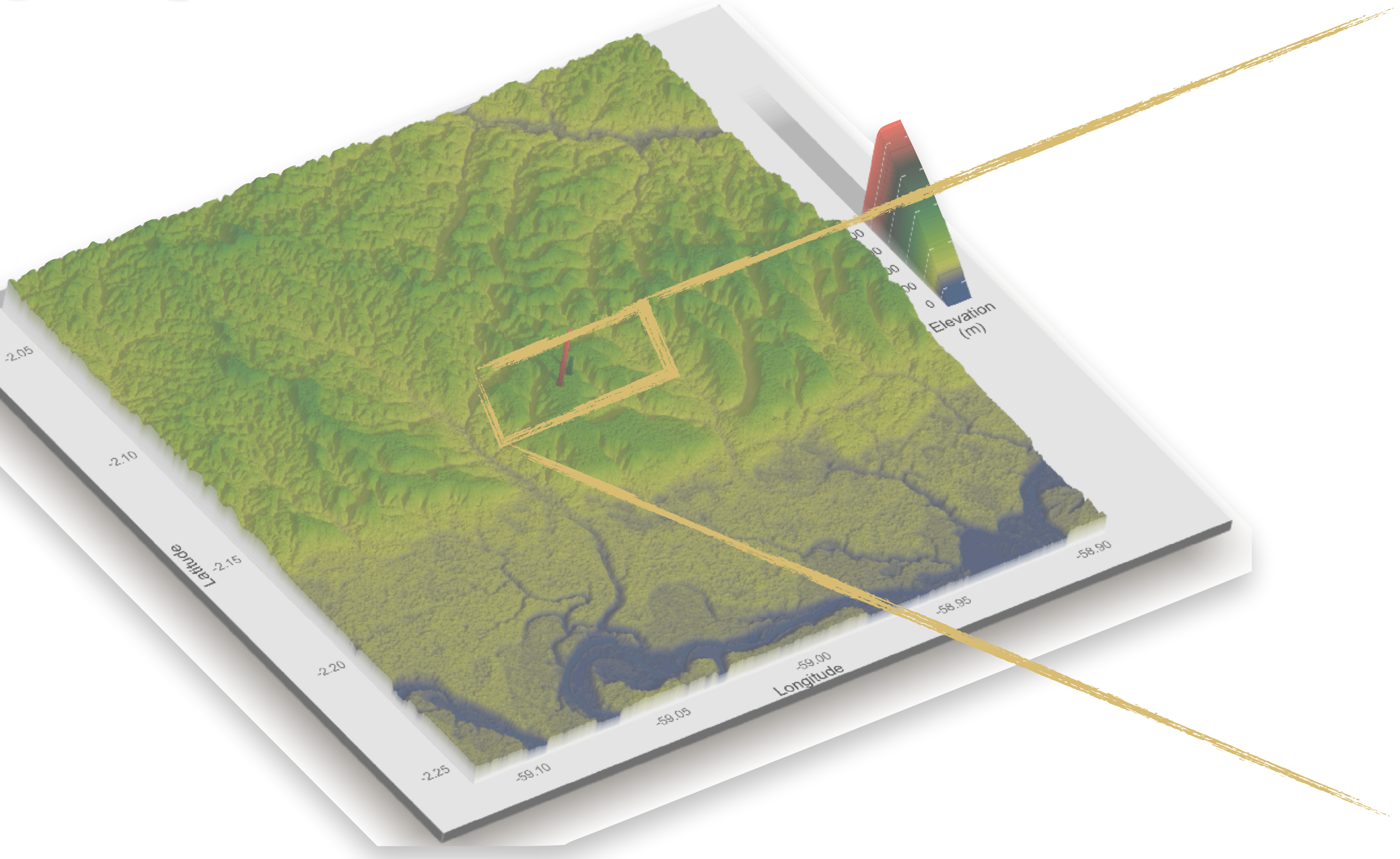
19 anemometers

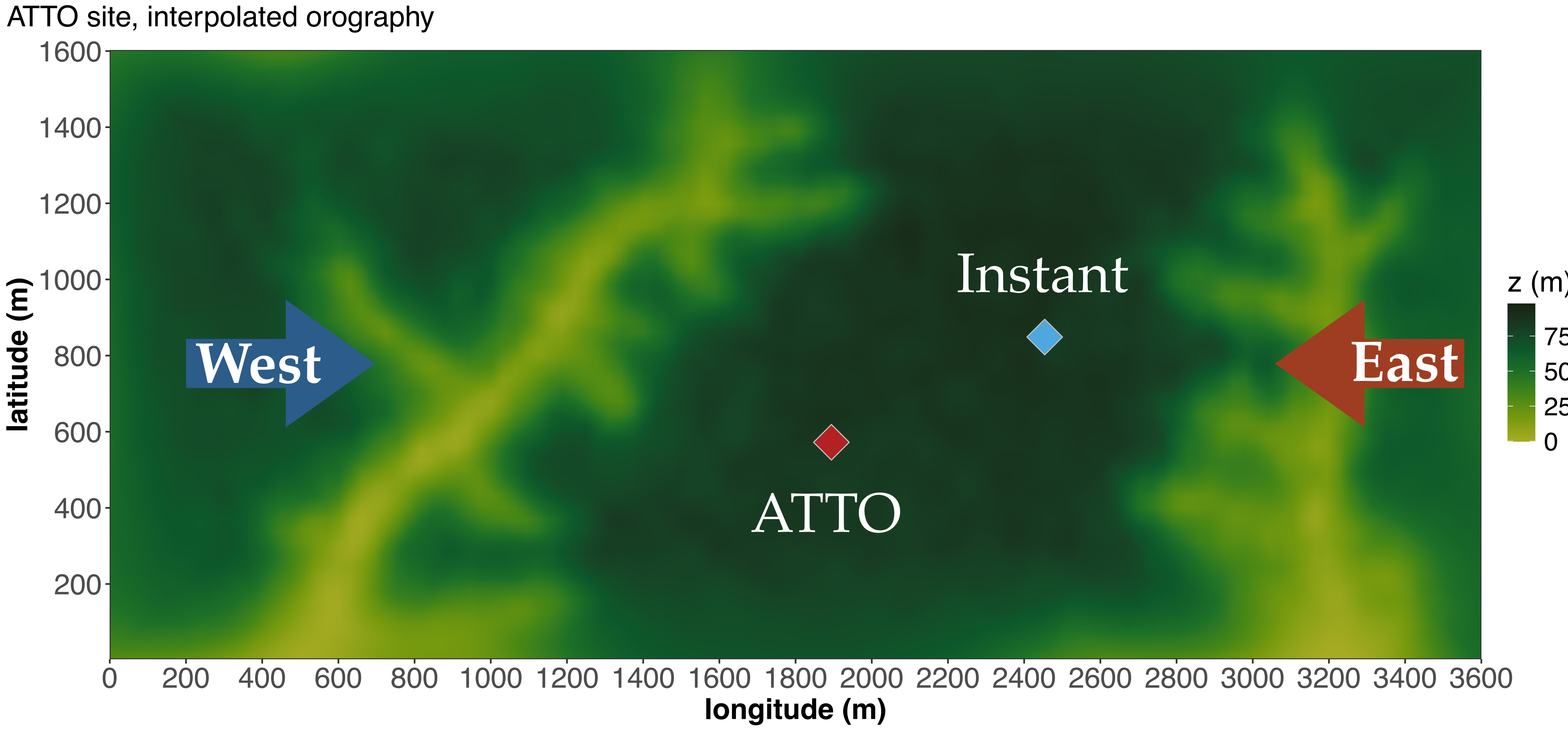


More than one year of high frequency data (2021-2022) from 3D sonic anemometer were thoroughly analysed (following Cava et al. 2022) to identify 20 30-min subsets from two opposite, cross-valleys wind directions. These subset provided the initial wind profile and the turbulent profiles used to compare the simulation outputs.

To totally ascribe the flow variability to spatial orography gradients, a horizontally homogeneous leaf area density and neutral atmospheric stratification will be considered.

Simulation set-up: PALM Model 23.10 version





ATTO site orography at 5 m resolution as seen by the PALM model.

Purely Neutral Simulations from two opposite wind directions

Model Setup

	Flat	With Topography
Streamwise domain size	1800	3600
Crosswise domain size	1600	1600
Vertical domain size	800	800
Horizontal grid	5	5
Vertical grid resolution	5	5

boundary conditions:

Lateral → periodic

Bottom: no-slip

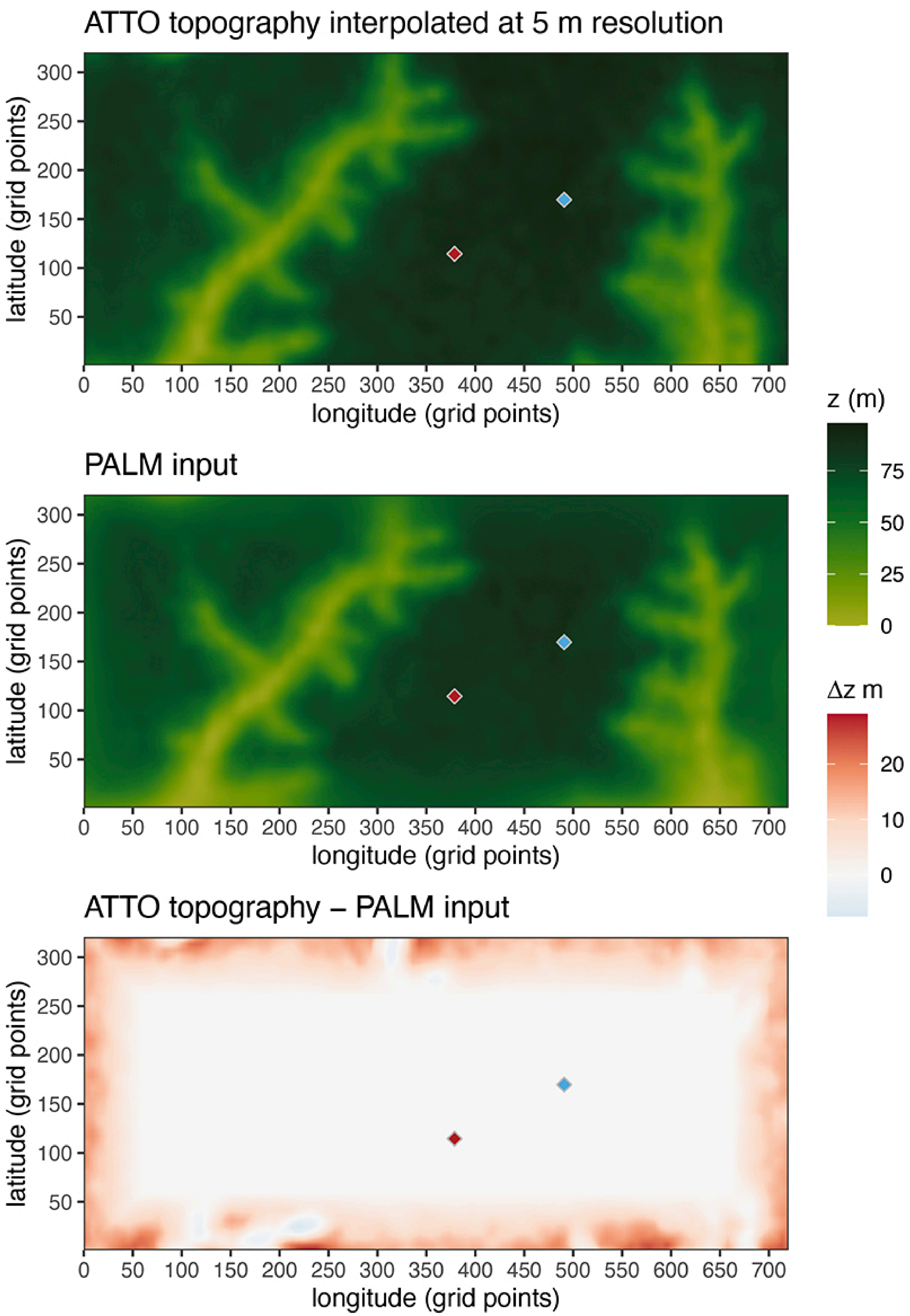
Top : free-slip

A gradient pressure of

$$\frac{1}{\rho}\frac{dx}{dy} = \pm 3 \cdot 10^{-4} m\ s^{-2}$$

Static Driver

Since cyclic boundary condition were considered on the frontier of the domain, a 2d gaussian smoothing was applied at the domain borders in order to guarantee continuity between the outflow and the inflow.

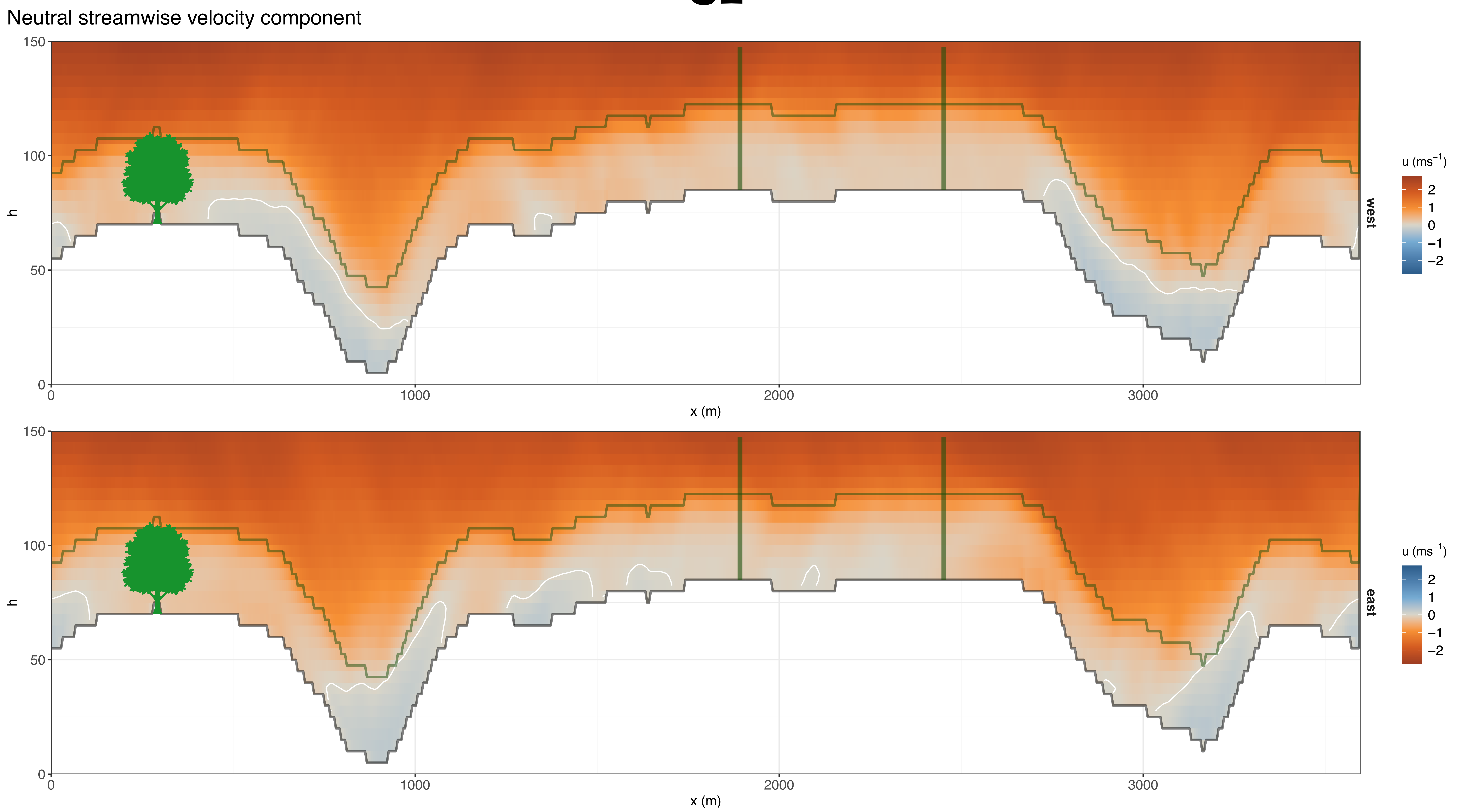


Preliminary results

wind coming from west

Canopy top

u



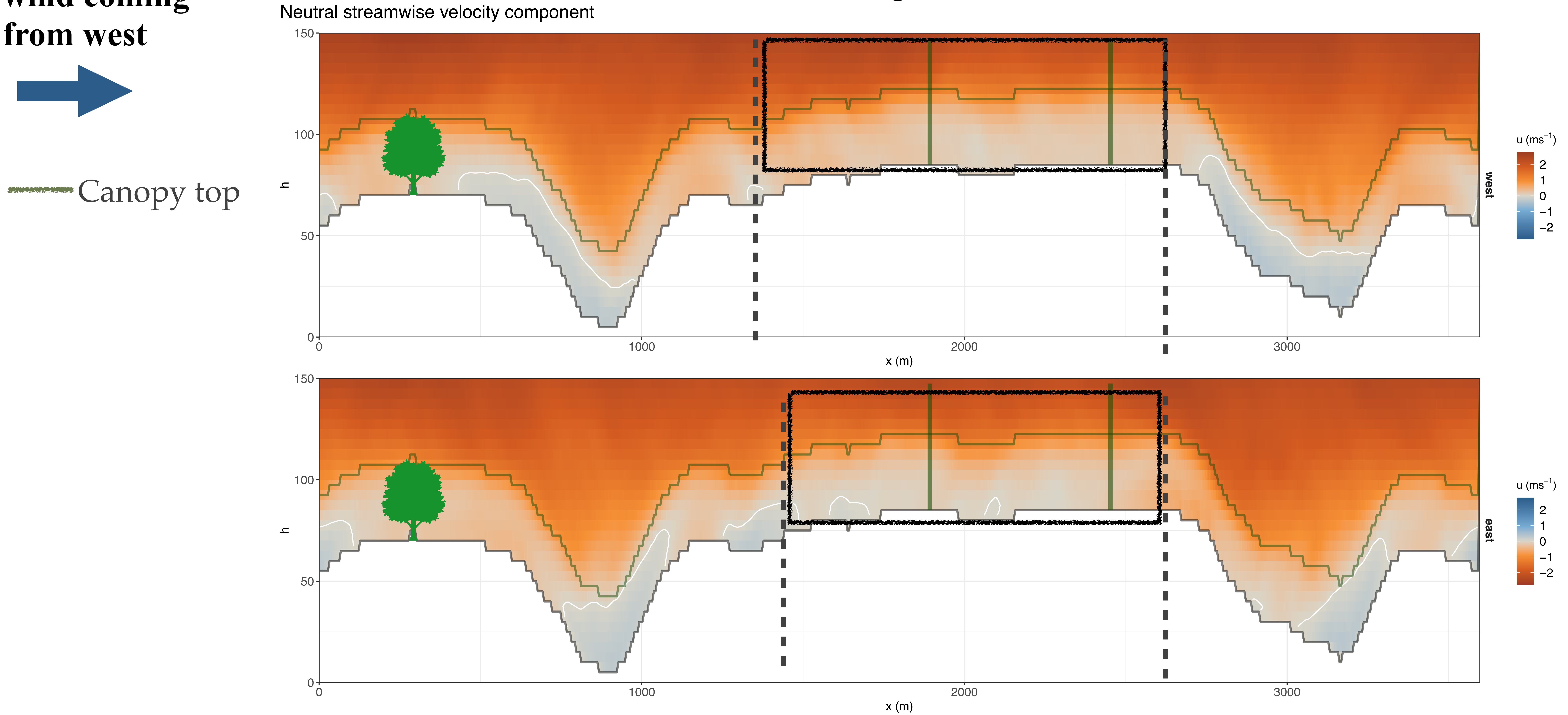
wind coming from east

XZ cross-section illustrating the stream-wise velocity component, u, for the west and east simulations for the y-ATTO position (dark green). The INSTANT tower is shown at its corresponding x-position (dark green).

Preliminary results

u

wind coming from west



wind coming from east

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Preliminary results

u

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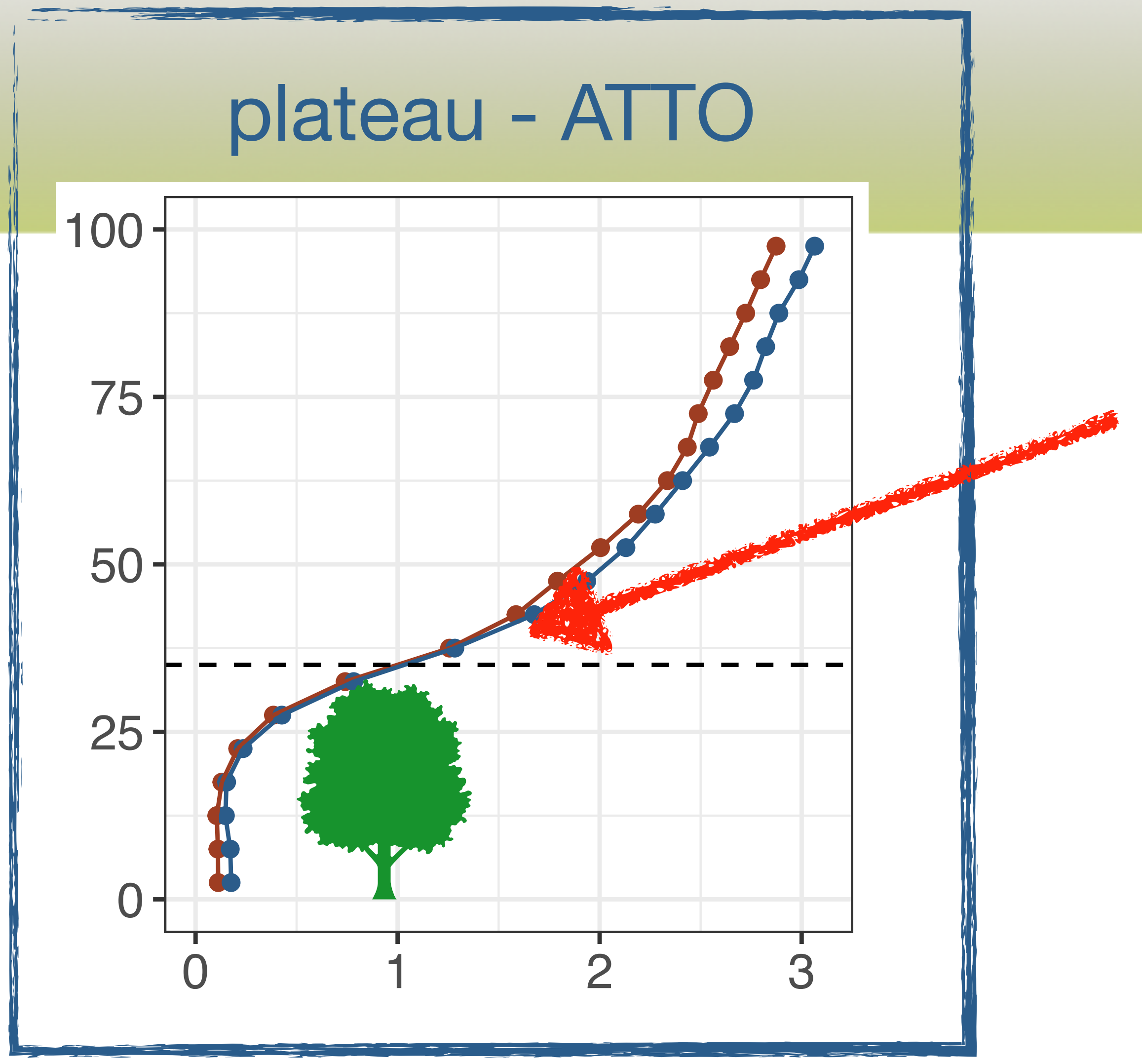
Wind-Speed

plateau - ATTO
u-component
Neutral streamwise velocity component
x (m)
h
u (ms^{-1})
west
east

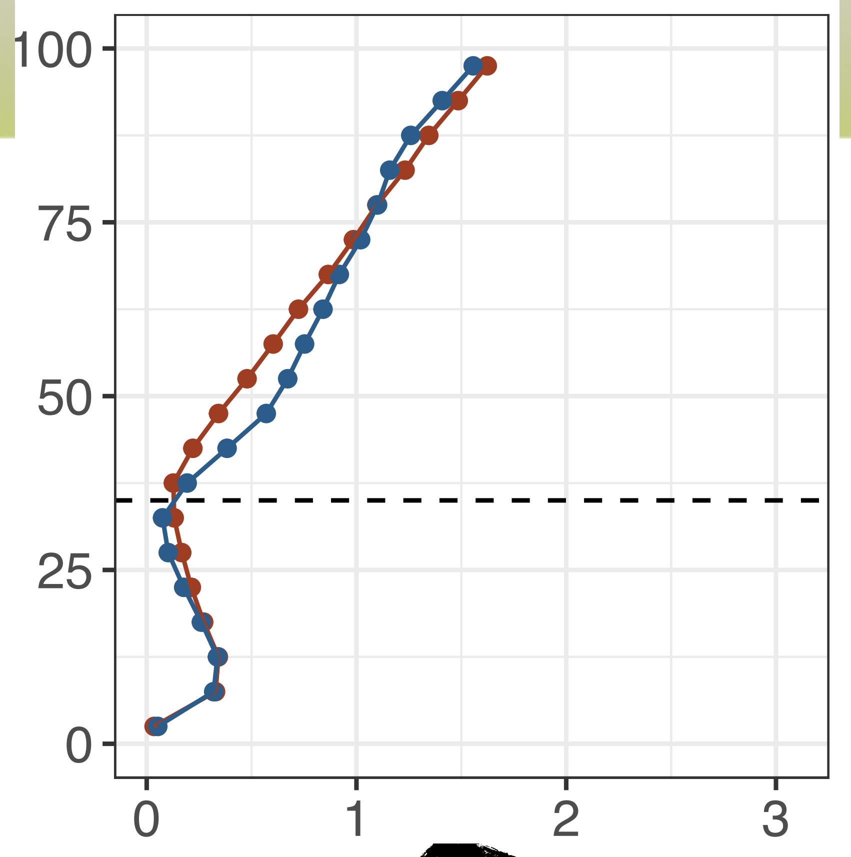
Wind-Speed

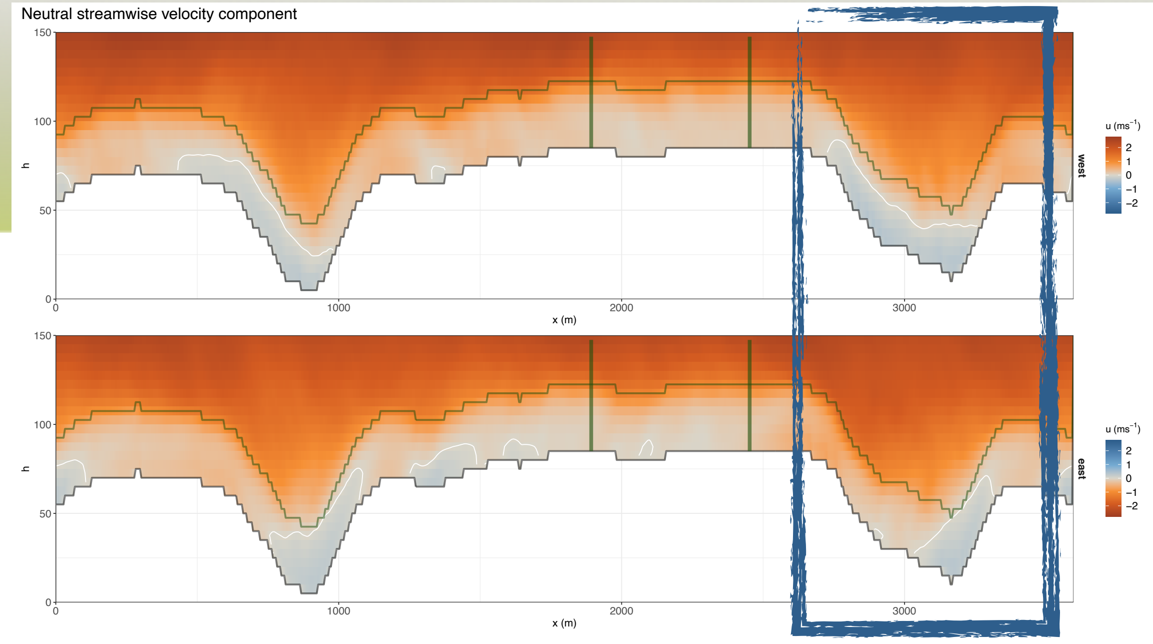
plateau - ATTO
Inflection point
u-component
Neutral streamwise velocity component
x (m)
h
u (ms^{-1})
west
east
east
west

Wind-Speed



Inflection point

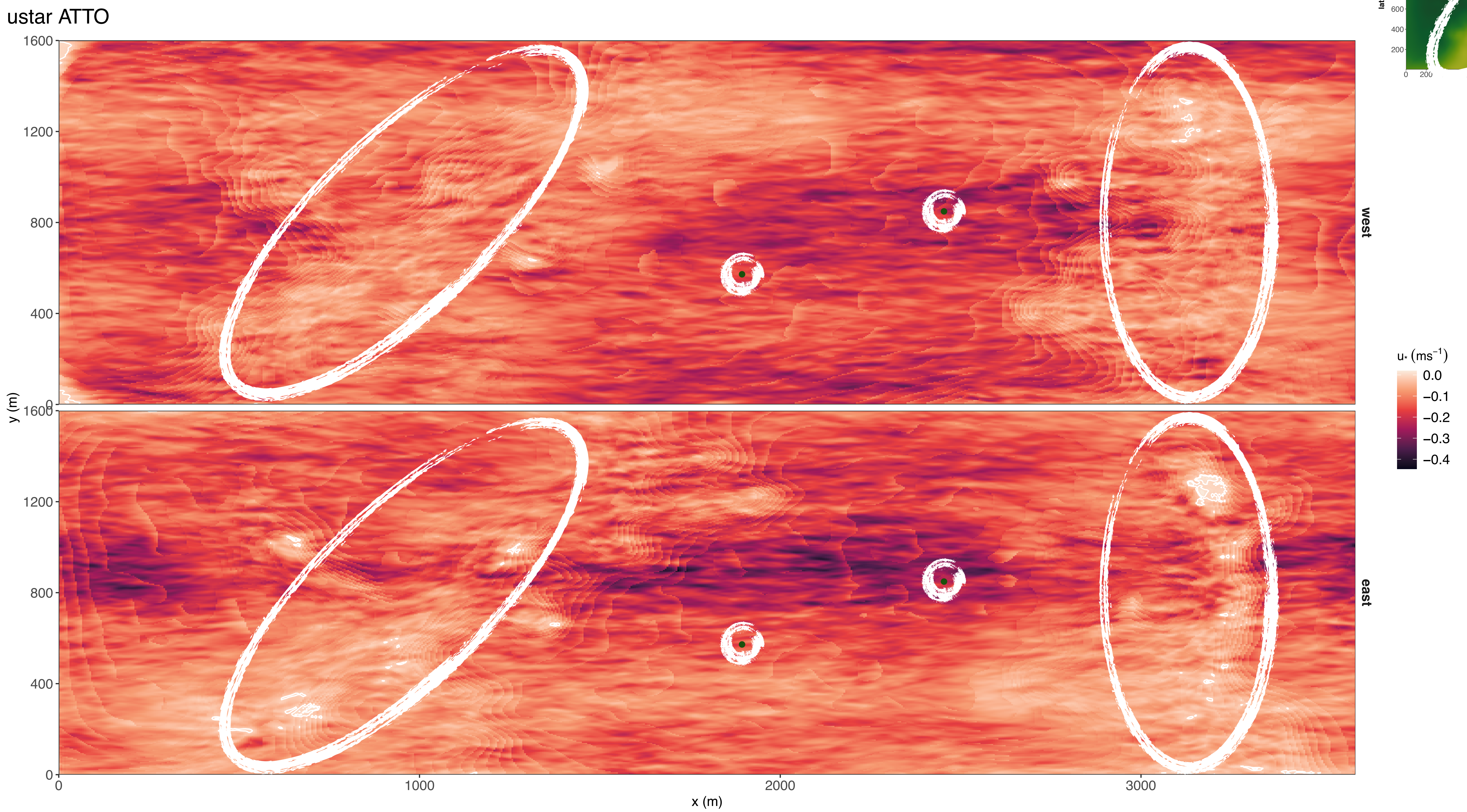


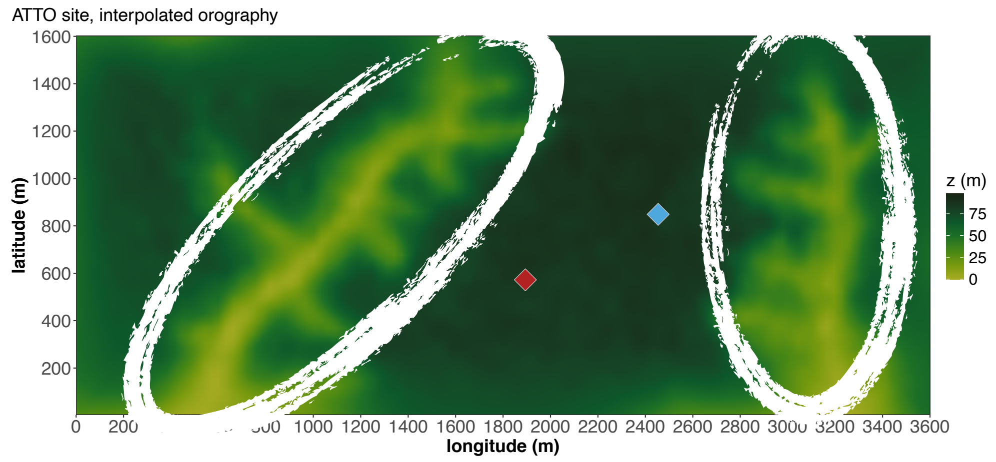


Preliminary results

u_*

wind coming from west

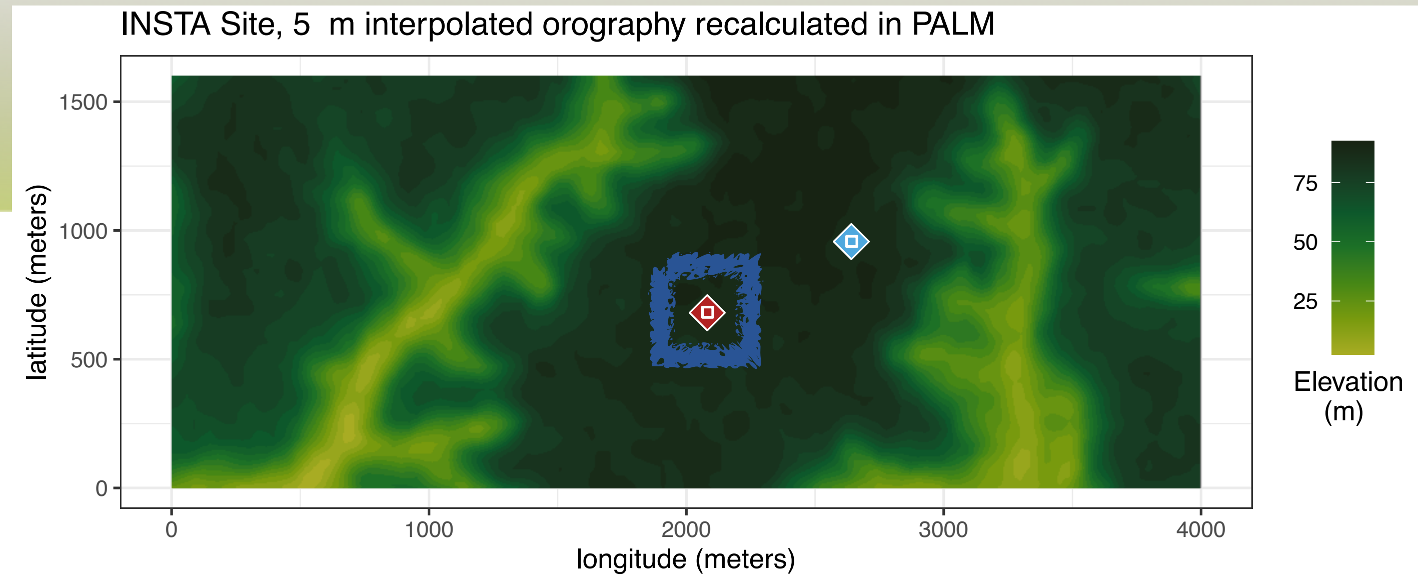




wind coming from east

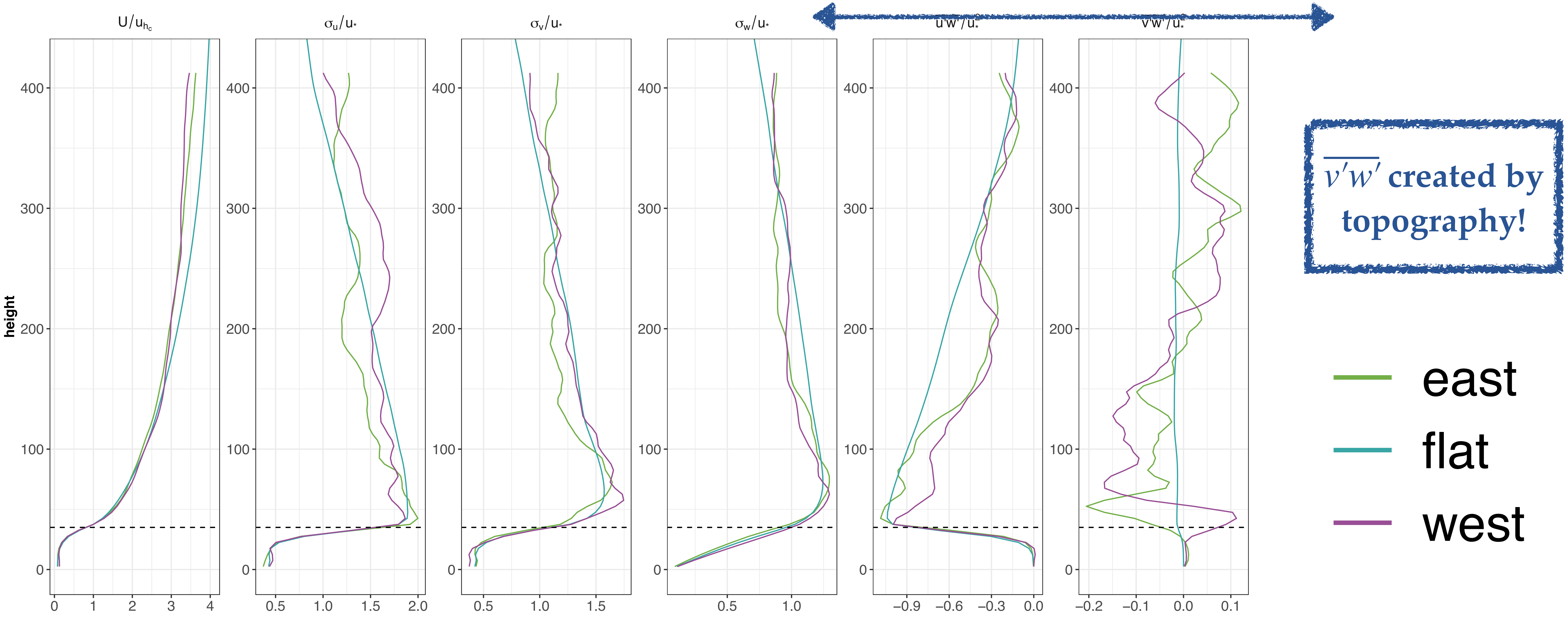
XY cross-section illustrating friction velocity for west and east simulations. The INSTANT tower is shown at its corresponding x-position (light green).

Preliminary results: comparison between east, west and flat simulations



Normalised turbulent profiles

PALM – ATTO SITE



Mean values calculated over and area of 45 m x 45 m (81 grid points) wind speed, stream-wise variance, spanwise variance, vertical variance, downward vertical momentum flux, crosswind-vertical turbulent momentum transport.

Take Home

Forest are not situated on uniform, flat, homogeneous terrain.

This implies that theories that rely on horizontal homogeneity do not hold, and new ones have to be developed both for modeling purposes and for experimental data interpretation purposes.

Our preliminary results show a profound influence of topography on the wind speed vertical profile, suggesting a disruption of the mixing layer analogy inside valleys. This may have a strong impact on biosphere-atmosphere interaction.

Thank you!

This work was partially conducted within the framework of the National Biodiversity Future Center (NBFC) at the National Research Council, Institute of Atmospheric Sciences and Climate (ISAC), Lecce. The project was funded by the European Union - Next Generation EU by PNRR, Spoke 4: "Potenziamento strutture di ricerca e creazione di campioni Nazionale di R&S", Project CN00000033.

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