From past to the future: temporal interpolations and predictions

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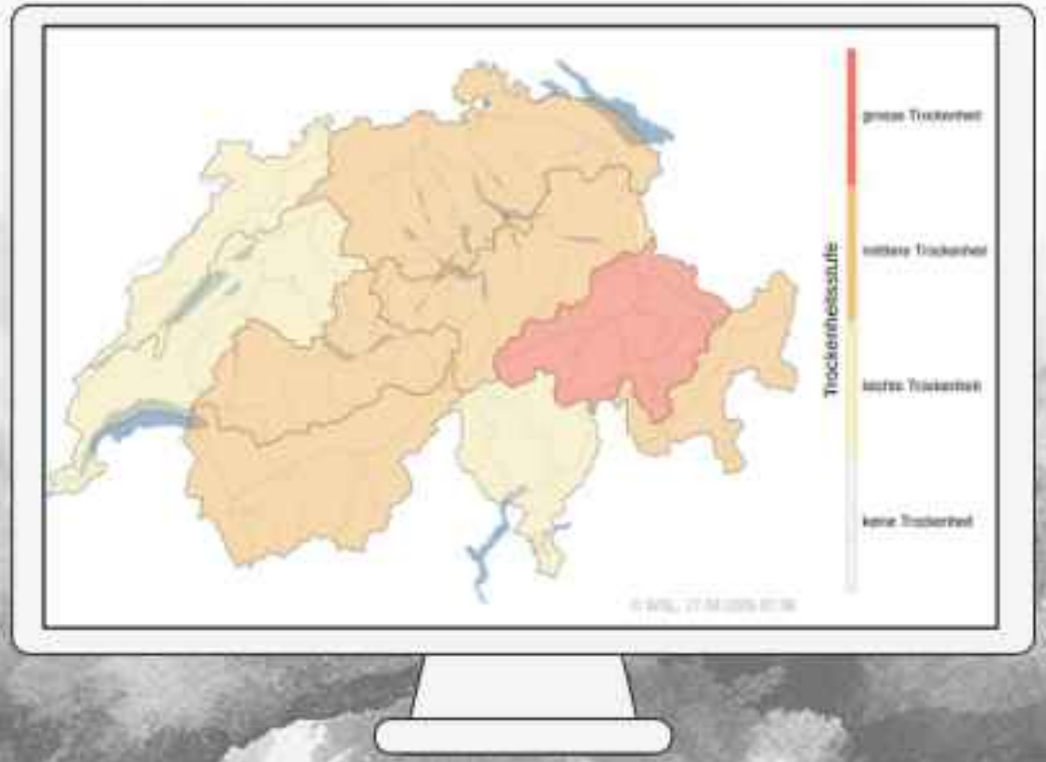
Machine Learning Scientist @ WSL

Development of National drought platform

TreeNet from WSL should contribute biological drought indicators to the national drought platform.

drought.ch



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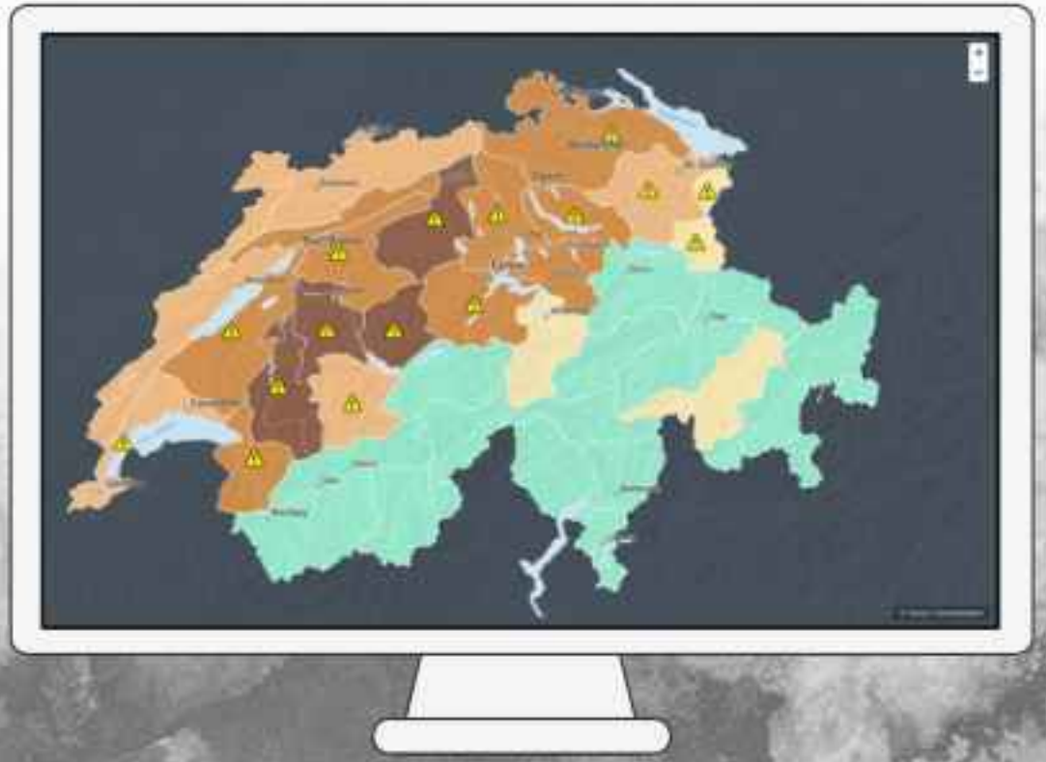
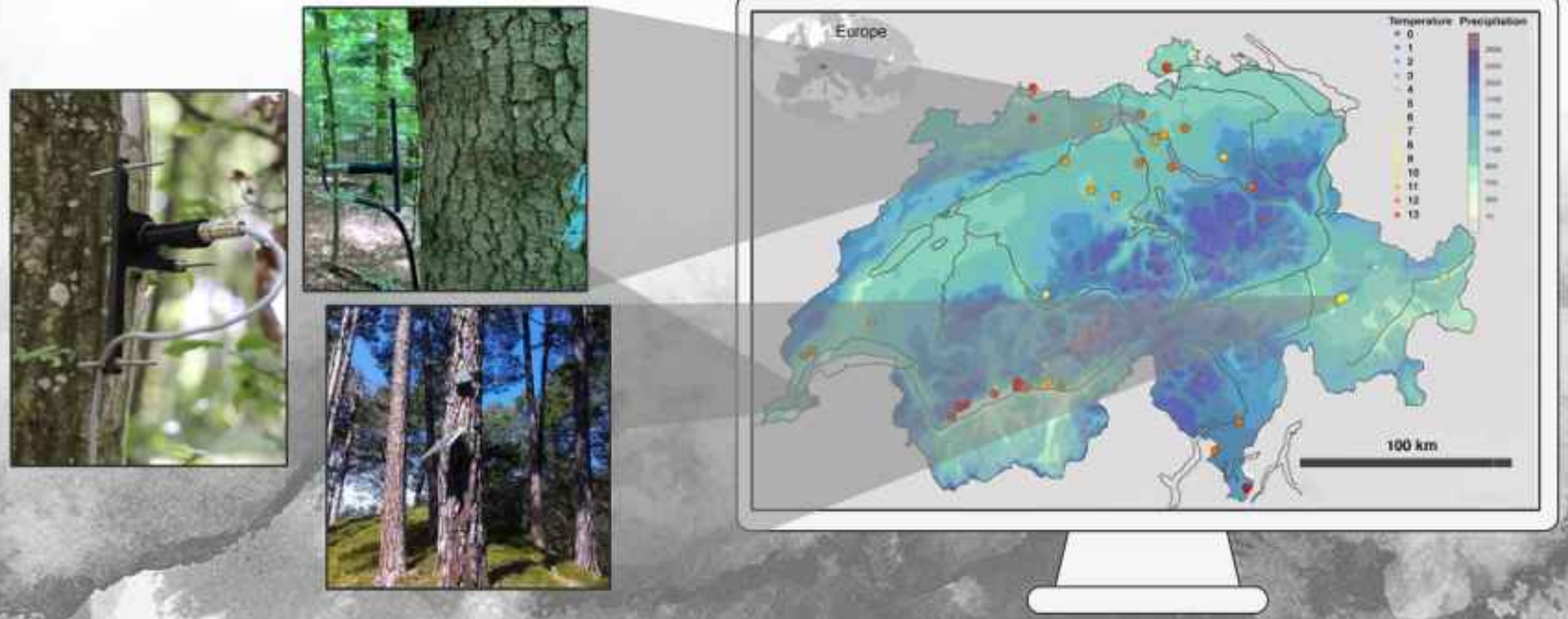


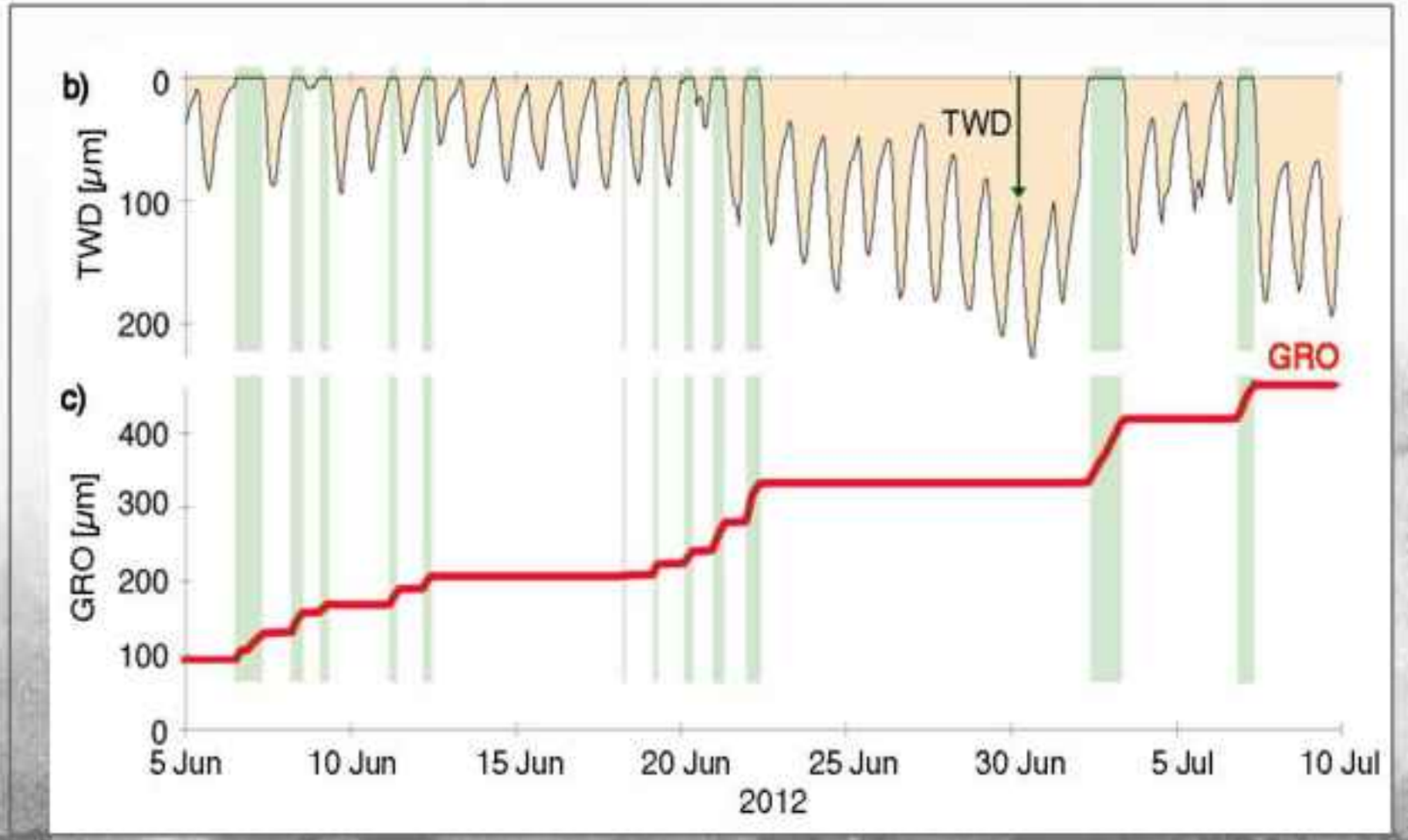
TreeNet

The biological drought and growth indicator network.

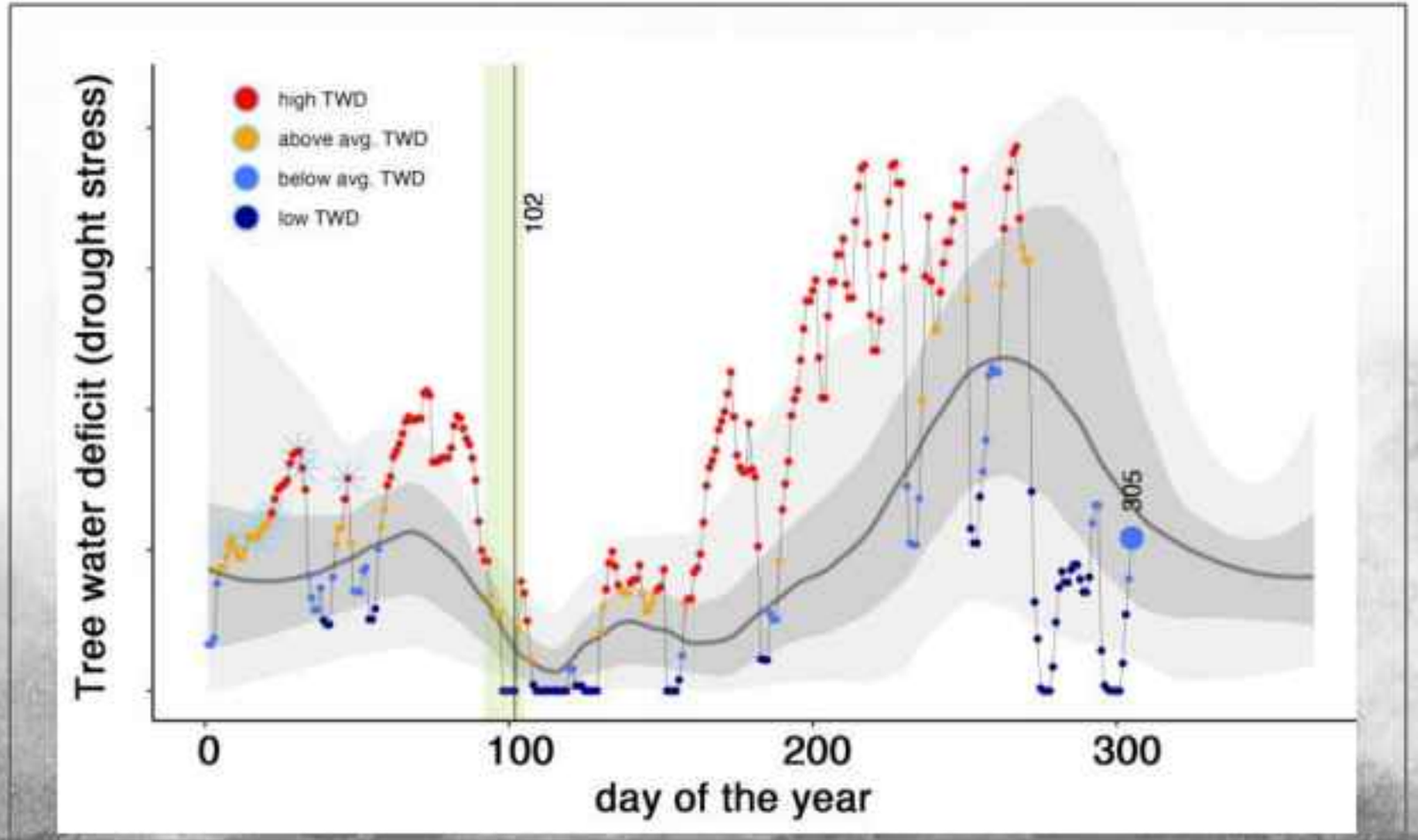
Tree measurements acquired through point dendrometers.



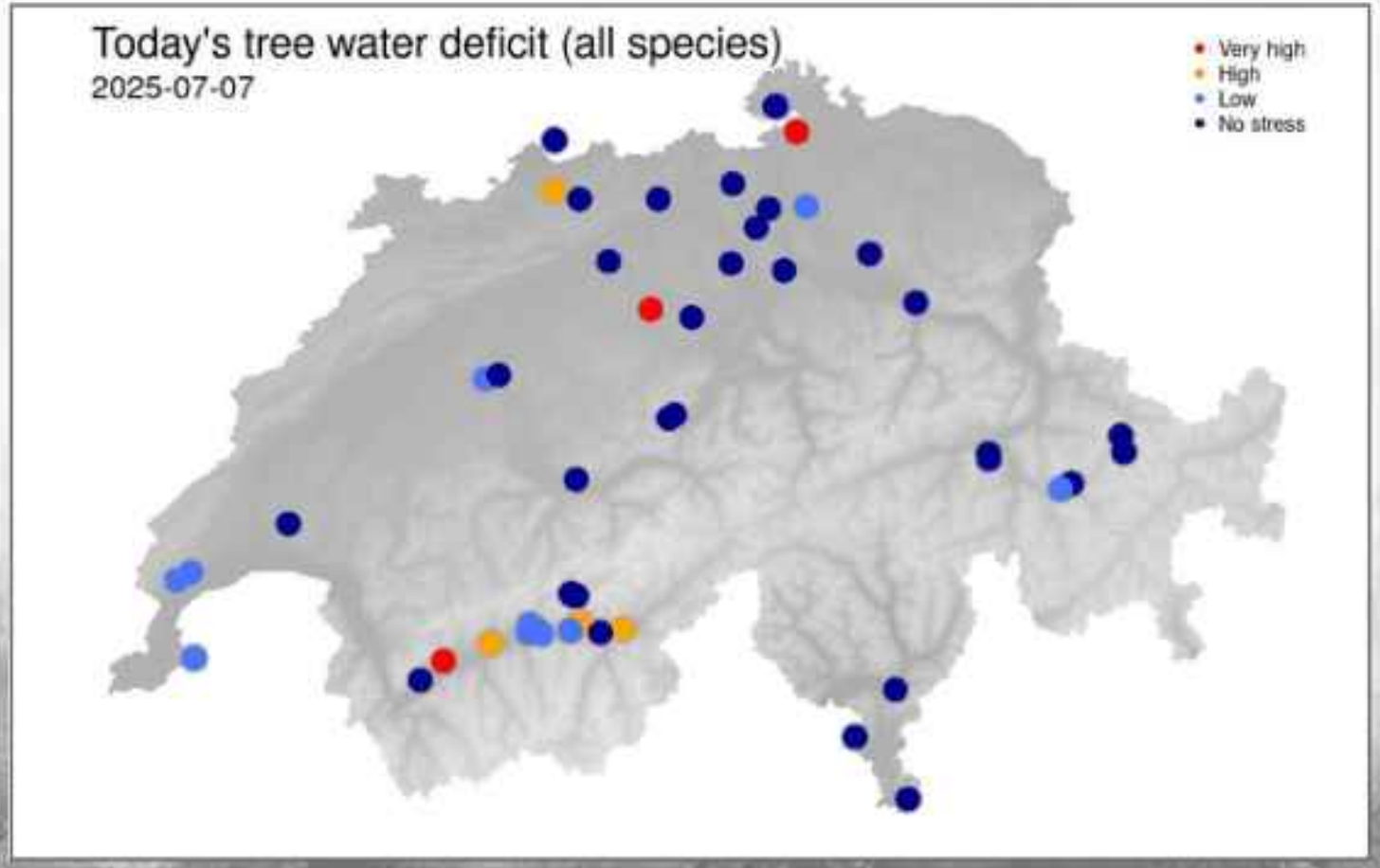
Measuring pulse of trees



Biological drought stress indicator



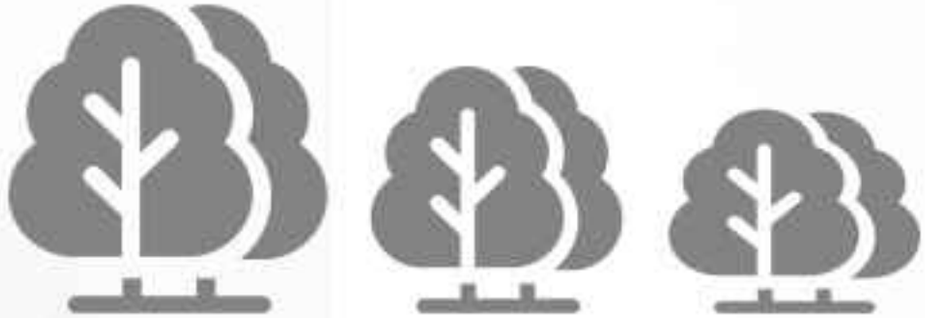
Biological drought stress indicator



What about other regions?

Spatially interpolating biological drought indicator

… stay tuned for William’s talk!



What about the future?

Forecasting of biological drought indicator

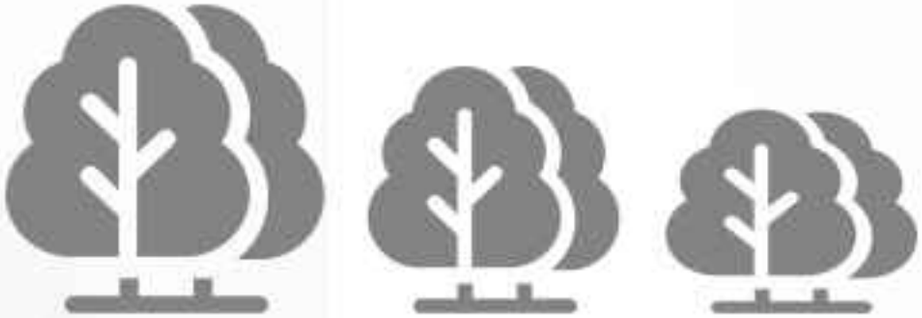
… focus of this presentation

The original research idea

How much water fills a TWD?
… very difficult to answer from the data we have.

Every time there is a different amount of precipitation needed.

How do we know how much precipitation brought TWD to 0 and how much was extra?



Let’s forecast TWD instead…

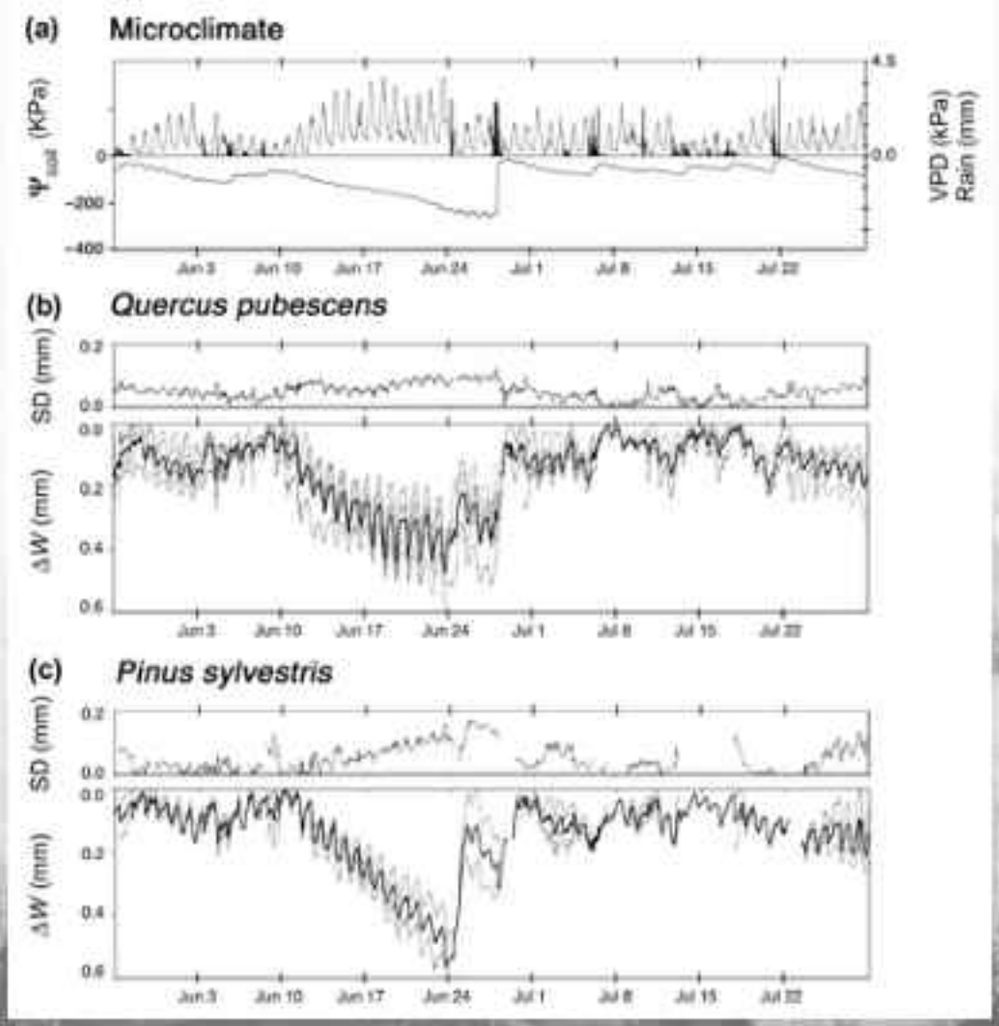
Tree Water Deficit (TWD)

Zweifel etal. [2005] showed that TWD can be to a certain extent modelled from microclimate variables Vapor Pressure Deficit (VPD) and Soil Water Potential (SWP).

$$\Delta W_E = \left\{ VPD - \frac{\Psi_{soil}}{k_1} \right\} k_2$$

treenet.info

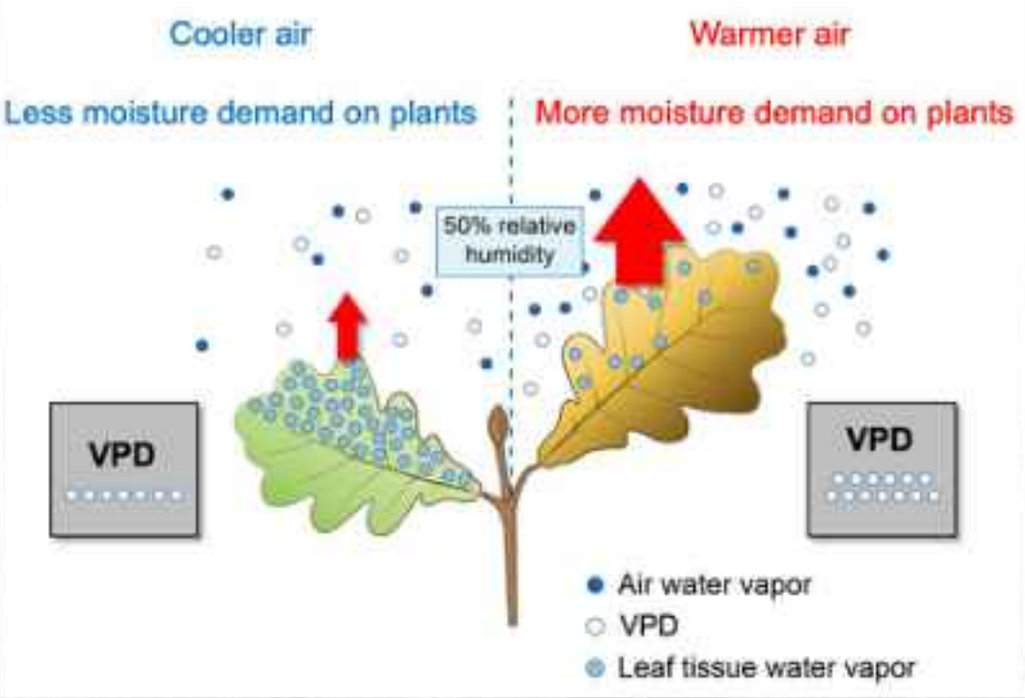
Zweifel et al., 2021

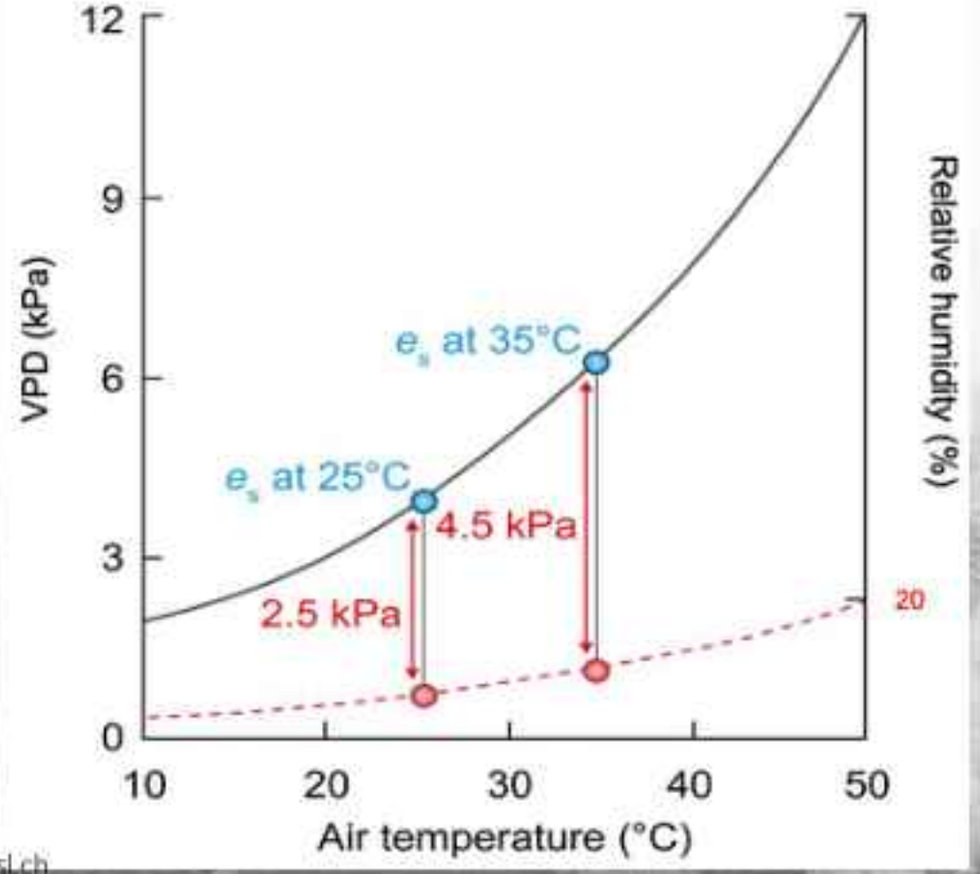


Zweifel et al., 2005

Vapor Pressure Deficit (VPD)

The difference between the amount of moisture in the air at saturation (RH = 100%) and the actual amount of moisture in the air at a given temperature.



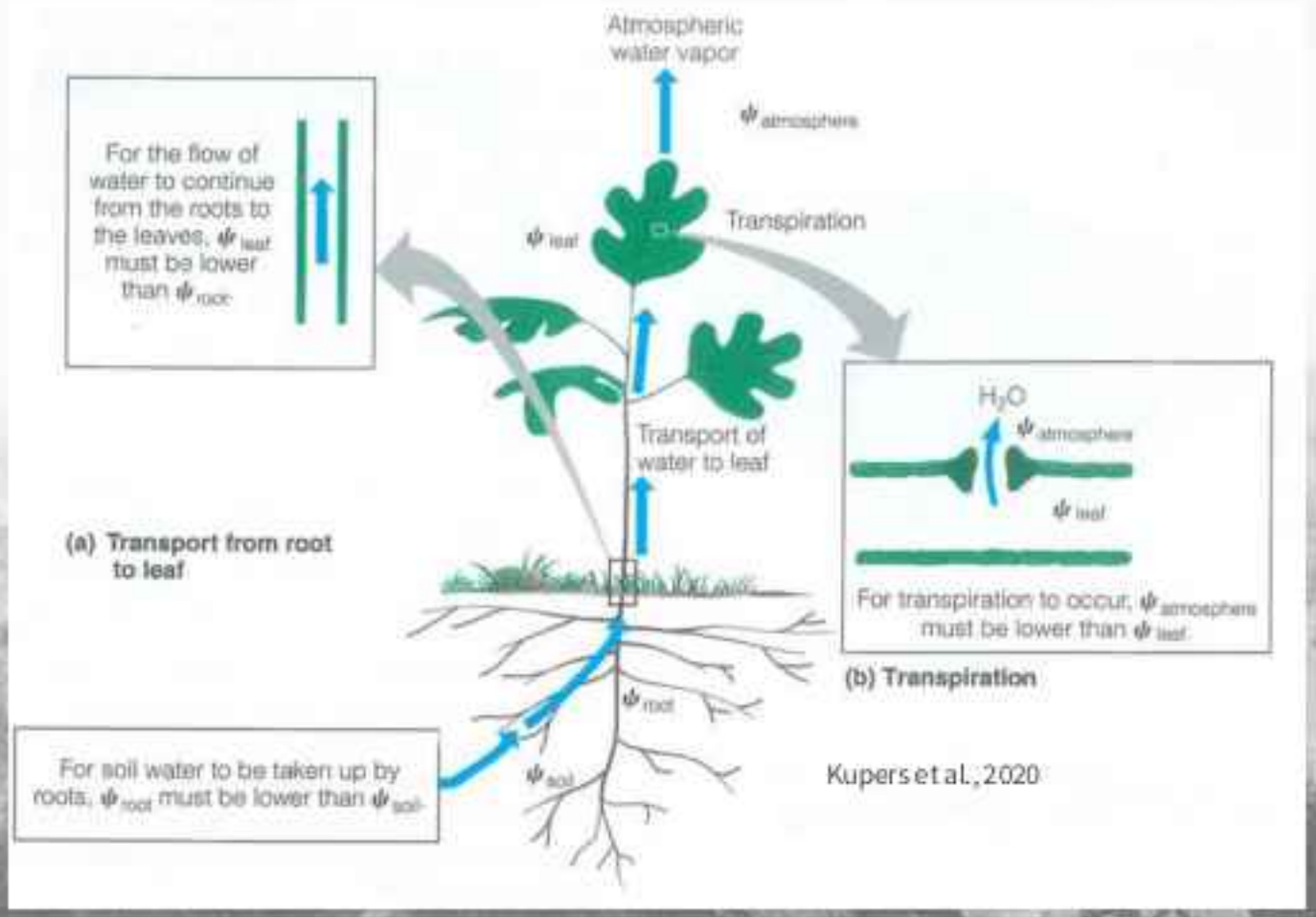


Soil Water Potential (SWP)

Potential energy of water in the soil, which indicates how strongly the water is held by the soil and its tendency to move.

SWP is heavily influence by rain, which increases the soil water content.

Solar radiation is a primary driver of evaporation and transpiration from the soil and plants, and therefore indirectly affects also SWP.



Kupers et al., 2020

Forecasting TWD from climate variables

We assume that we can model TWD from:

- precipitation [mm]
- relative humidity [%]
- air temperature [°C]
- solar radiation [W/m^2]
- vapor pressure deficit [kPa]
- soil water potential [kPa]

Soil water potential is only available and the TreeNet measurement sites.

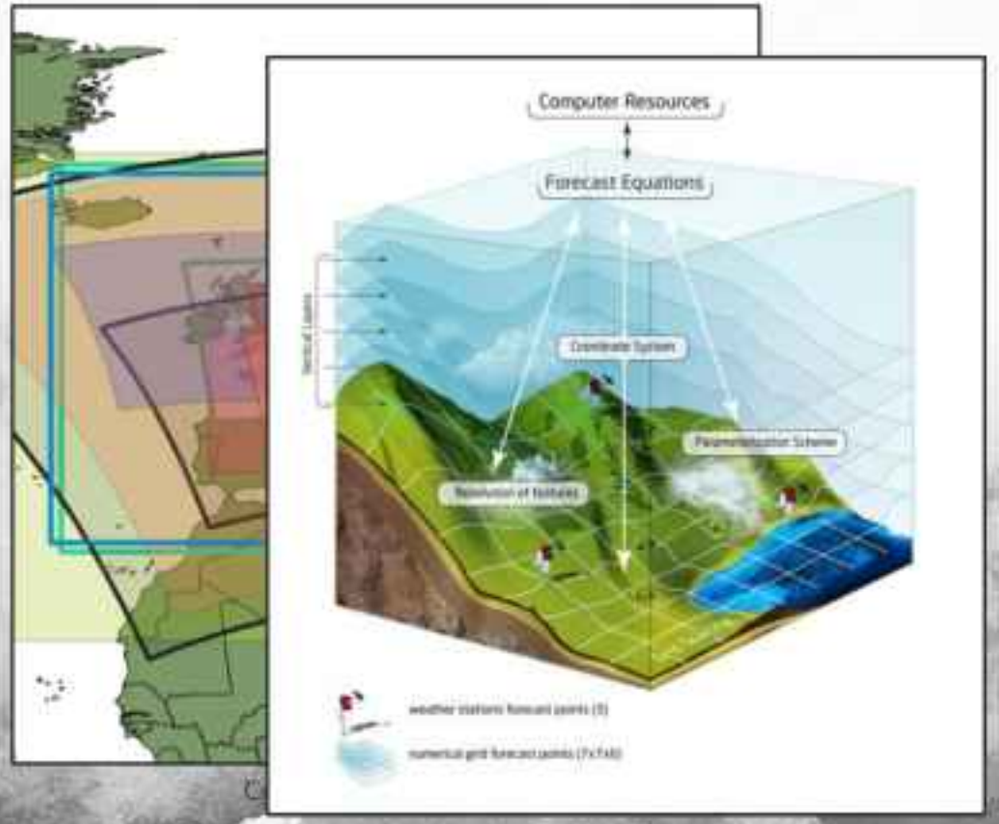
Vapor pressure deficit is computed from air temperature and relative humidity.

The remaining variables are available from the meteorological forecasts.

Availability of meteorological forecasts

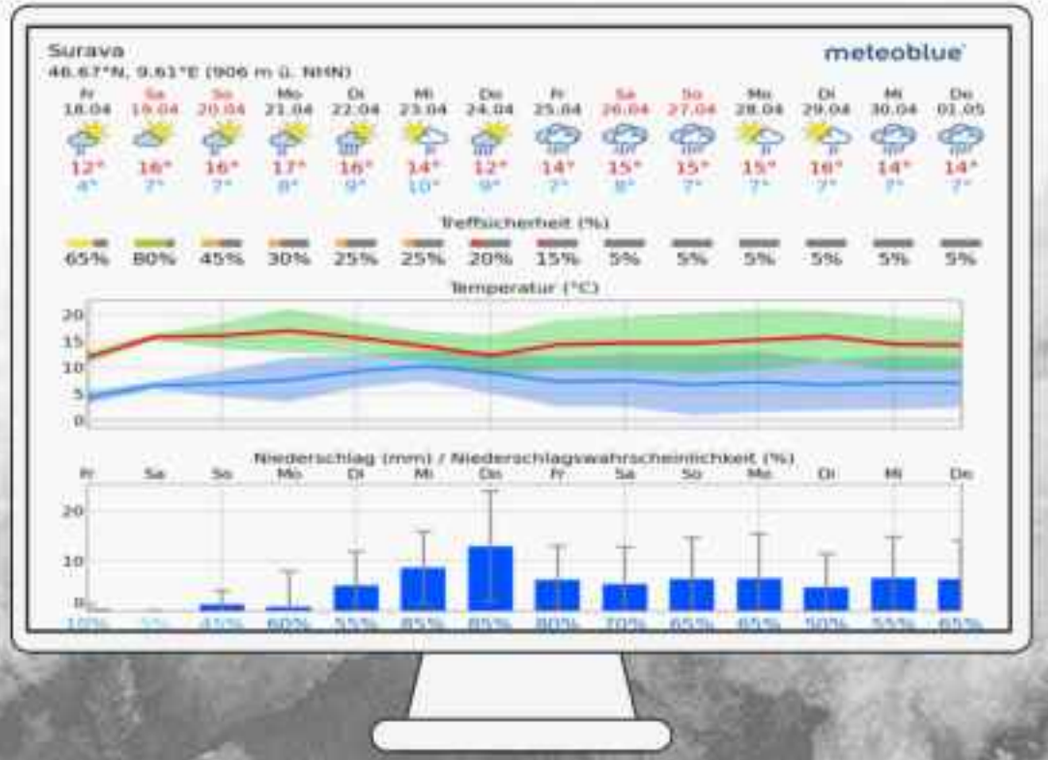
Provides a forecast of the development of climate variables.

Climate forecast is important for understanding of the development of Tree Water Deficit in trees.



Credit: meteoblue.com

meteoblue.com



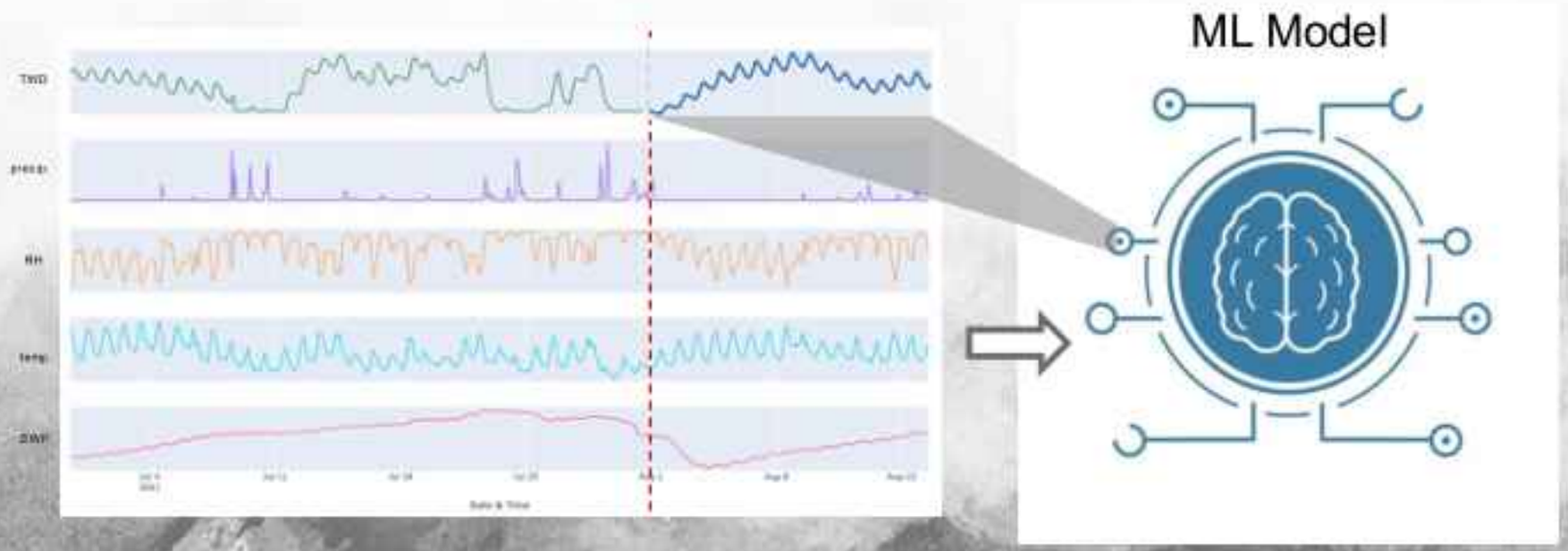
Proof of concept

Use directly the microclimate measurements.

Using microclimate to forecast TWD

Assuming we have the microclimate measurements and forecast.

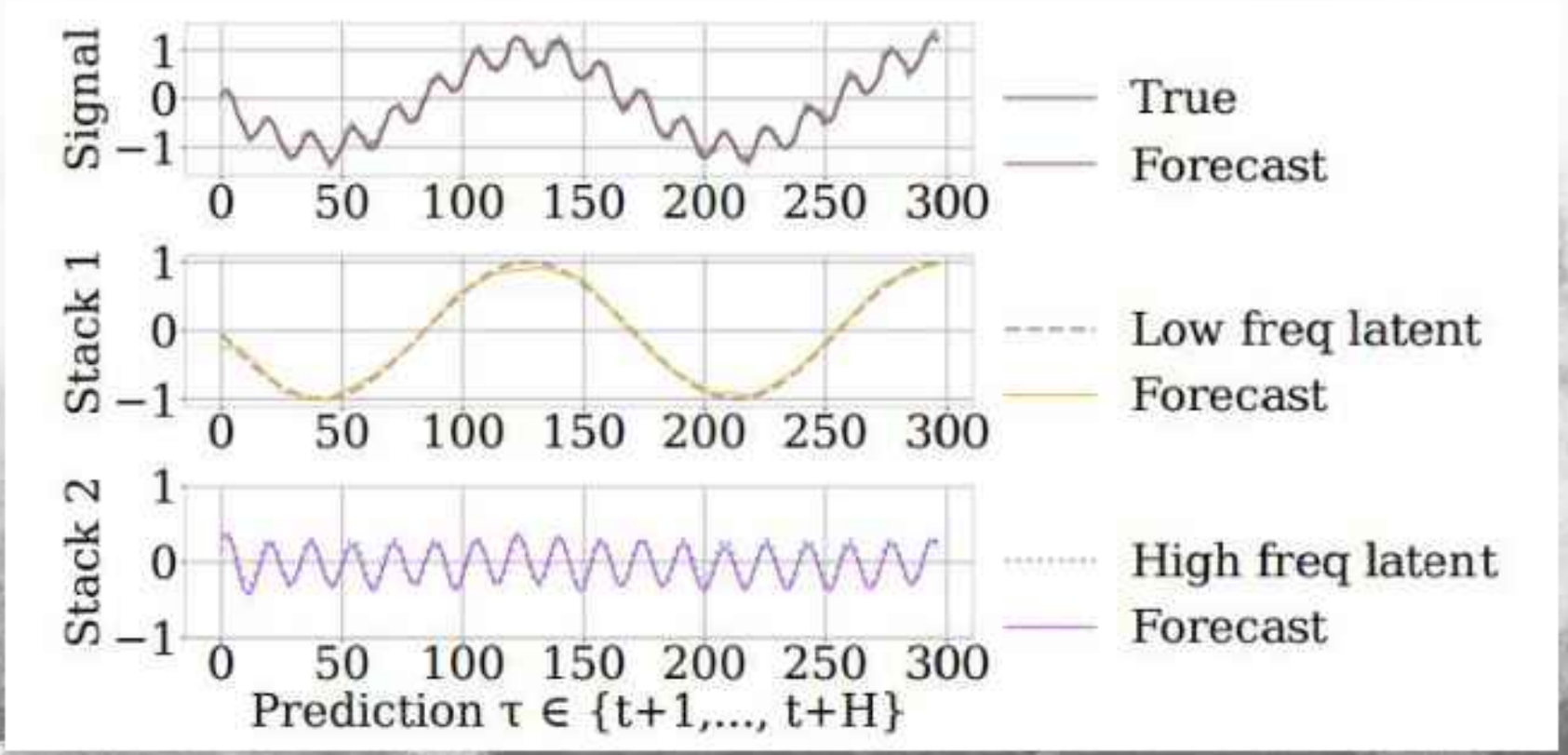
We take the TWD history and try to forecast its future development.



Using microclimate to forecast TWD

N-HITS – one of the SOTA models for time-series forecasting (Challu etal. 2023)

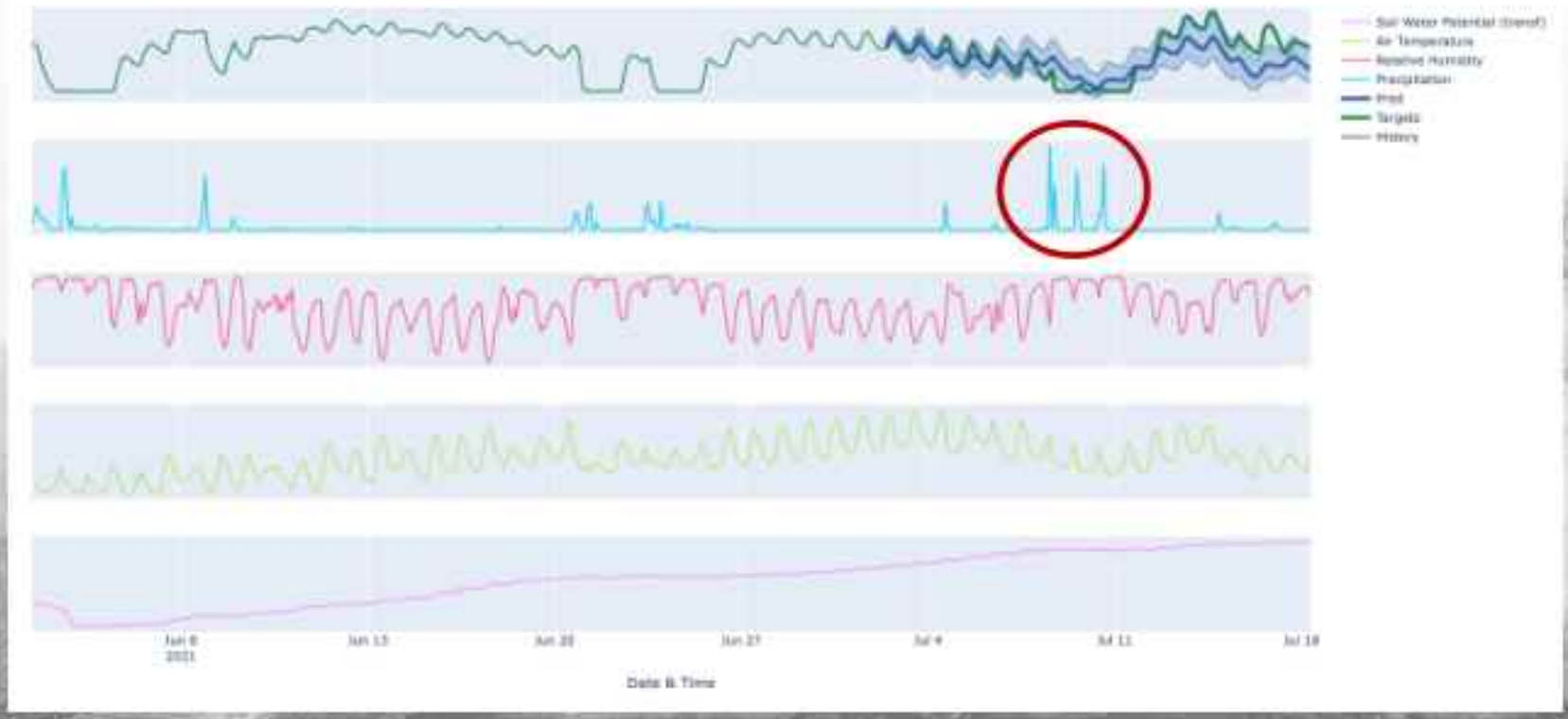
Takes inspiration from harmonic analysis – signal expressed as composition of harmonics.



Using microclimate to forecast TWD

Our models look 32 days in the past and forecast 16 days in the future.

Probabilistic forecasts with confidence intervals.



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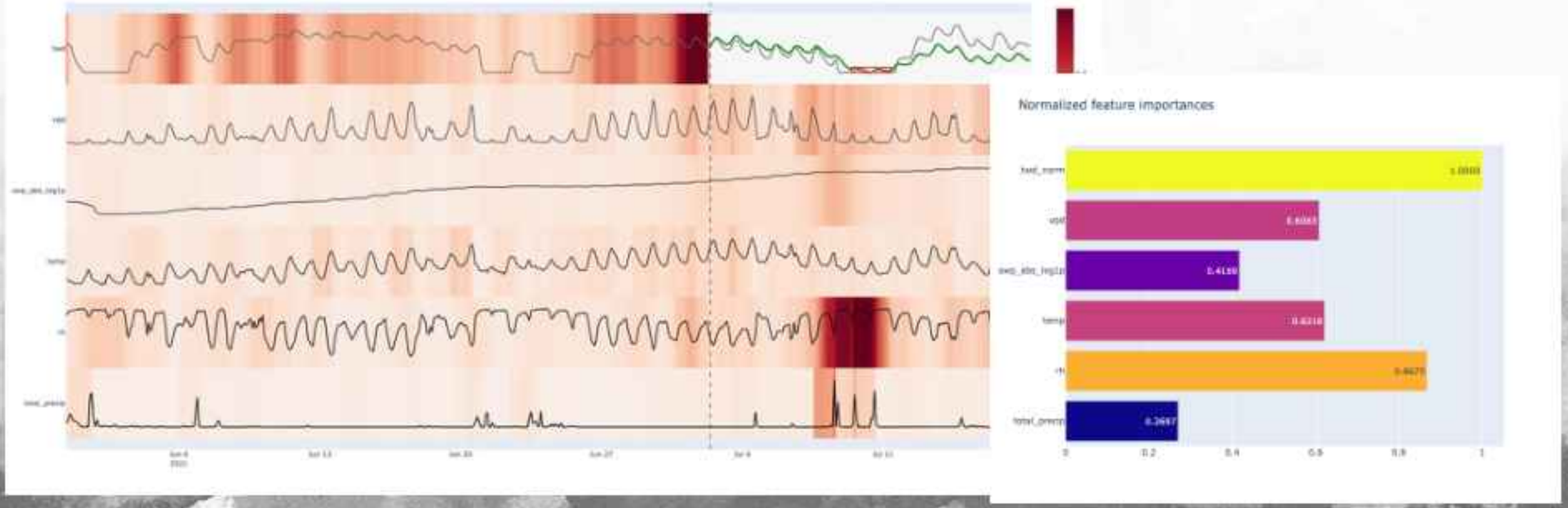
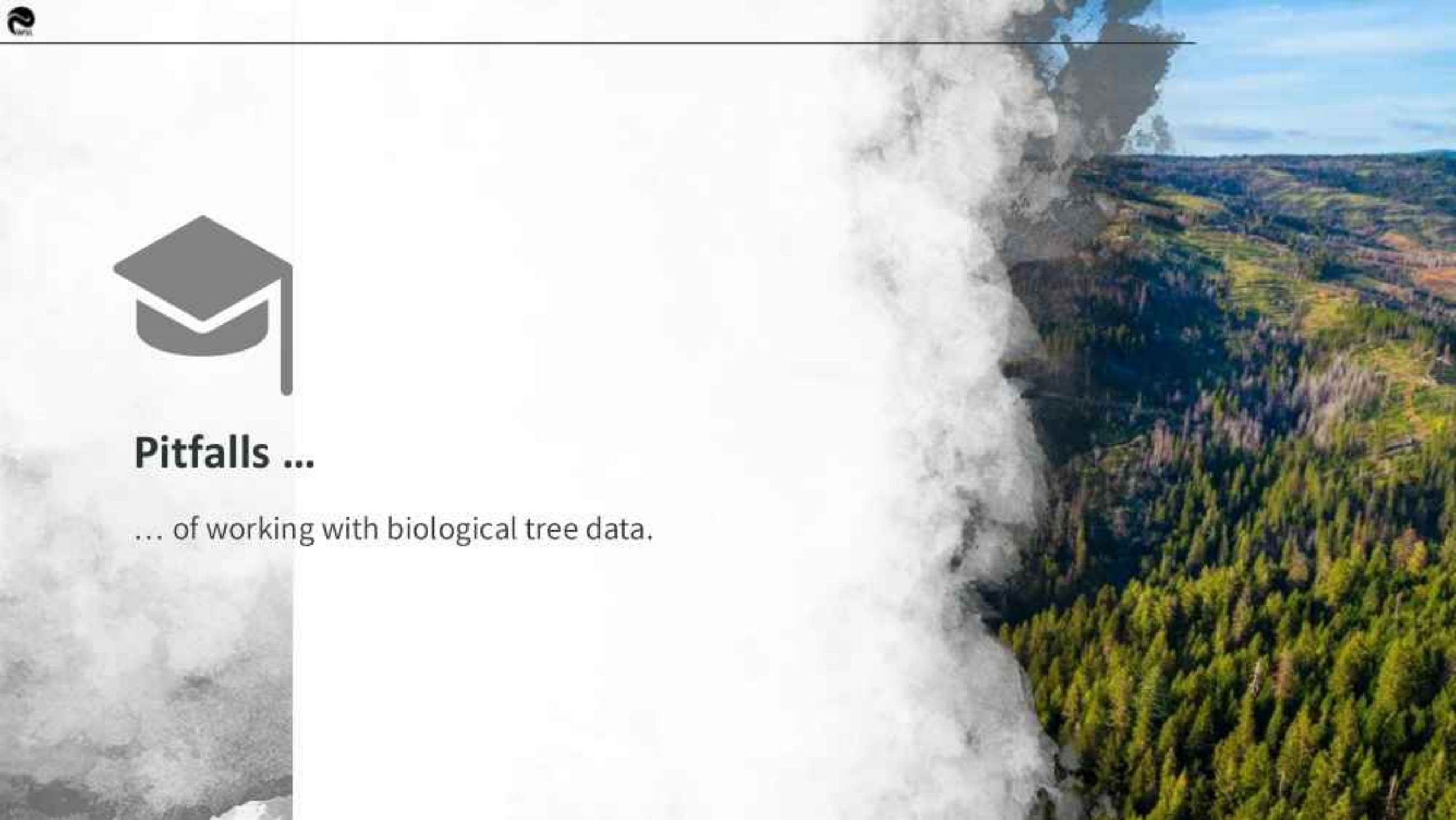
Using microclimate to forecast TWD

Explainability of predictions made by our models (based on Integrated Gradients method).

Could be used also to better understand what drives different behaviors in trees.





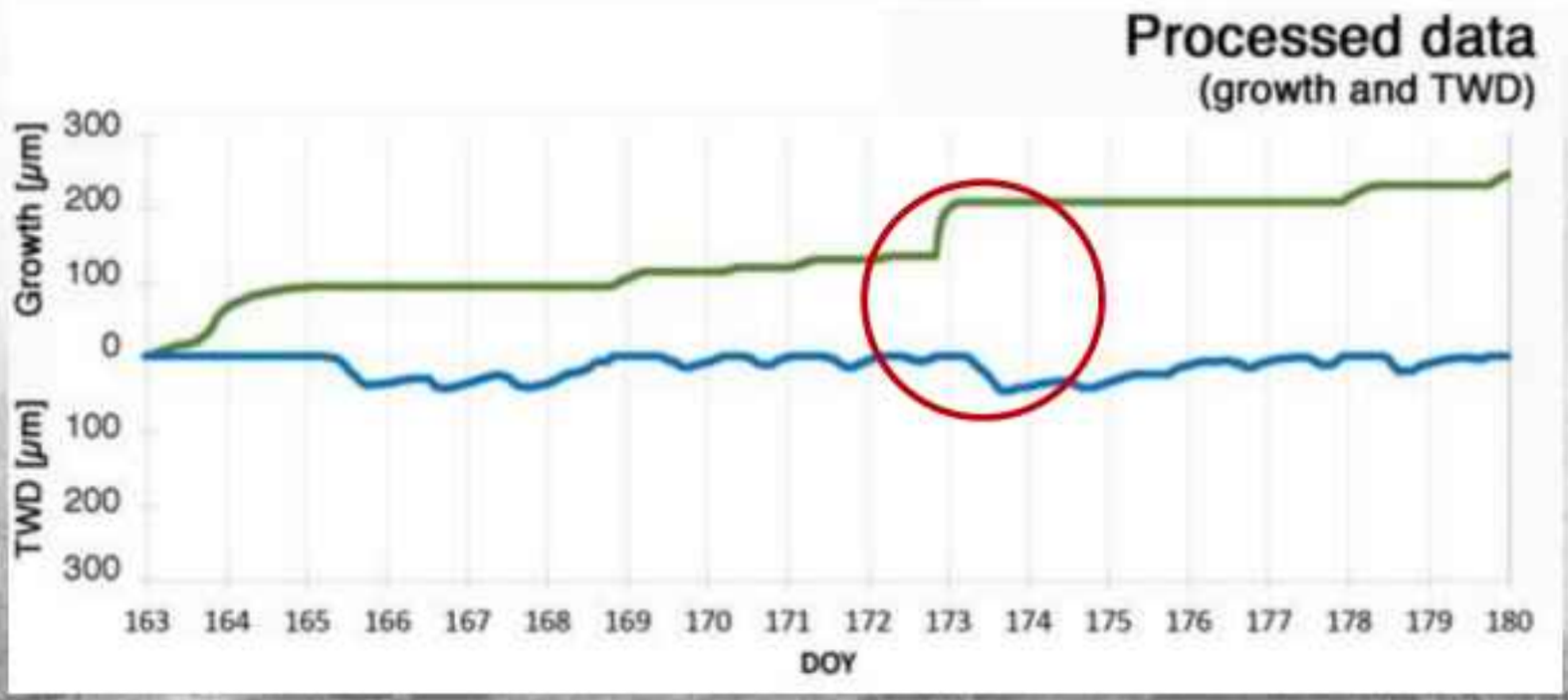
Pitfalls ...

… of working with biological tree data.

Real-world sensors are prone to errors

No guarantee that what is measured actually corresponds to the reality.

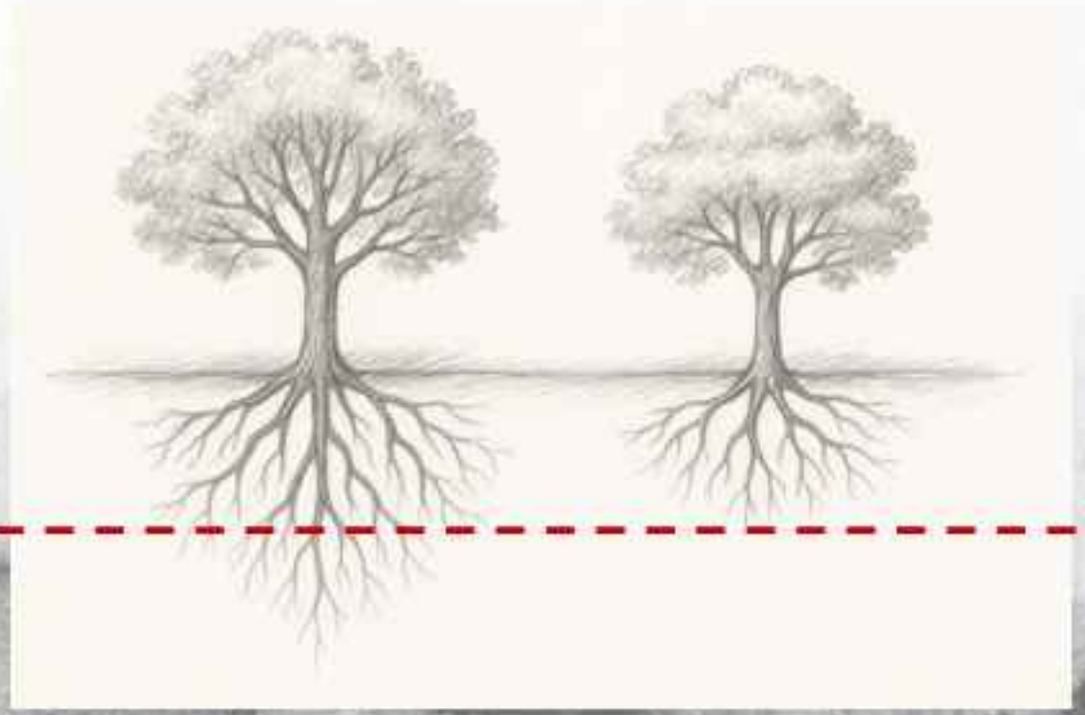
Data preprocessing pipelines heavily influence dataset quality.



Not everything can be measured

Not everything that matters can be measured – e.g. root depth of trees.

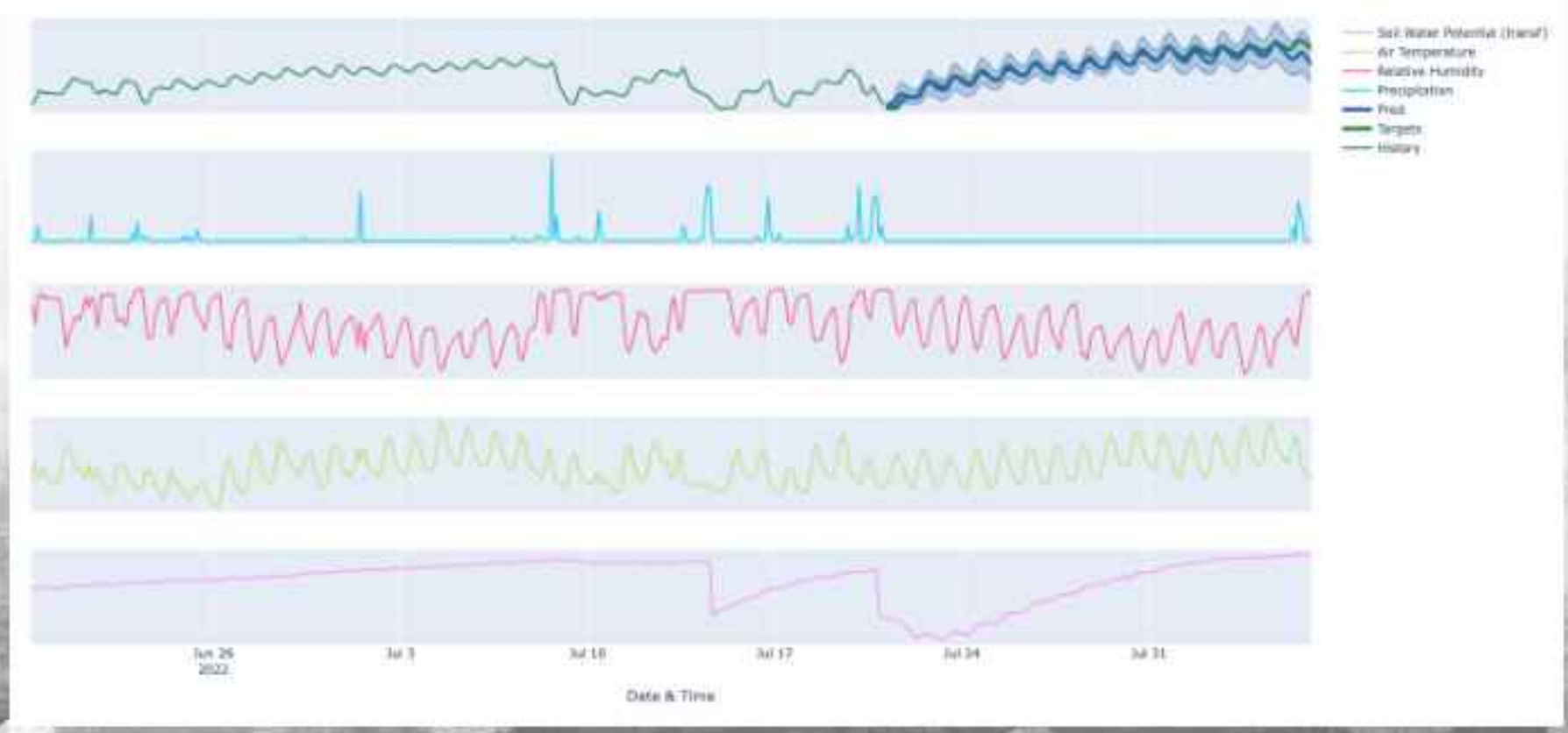
Trees are living organisms – undeterministic behaviors, competition within an ecosystem.



What impacts forecastability?

What information is necessary to produce the forecast one desires.

Need to have realistic expectations about what one wants to forecast.

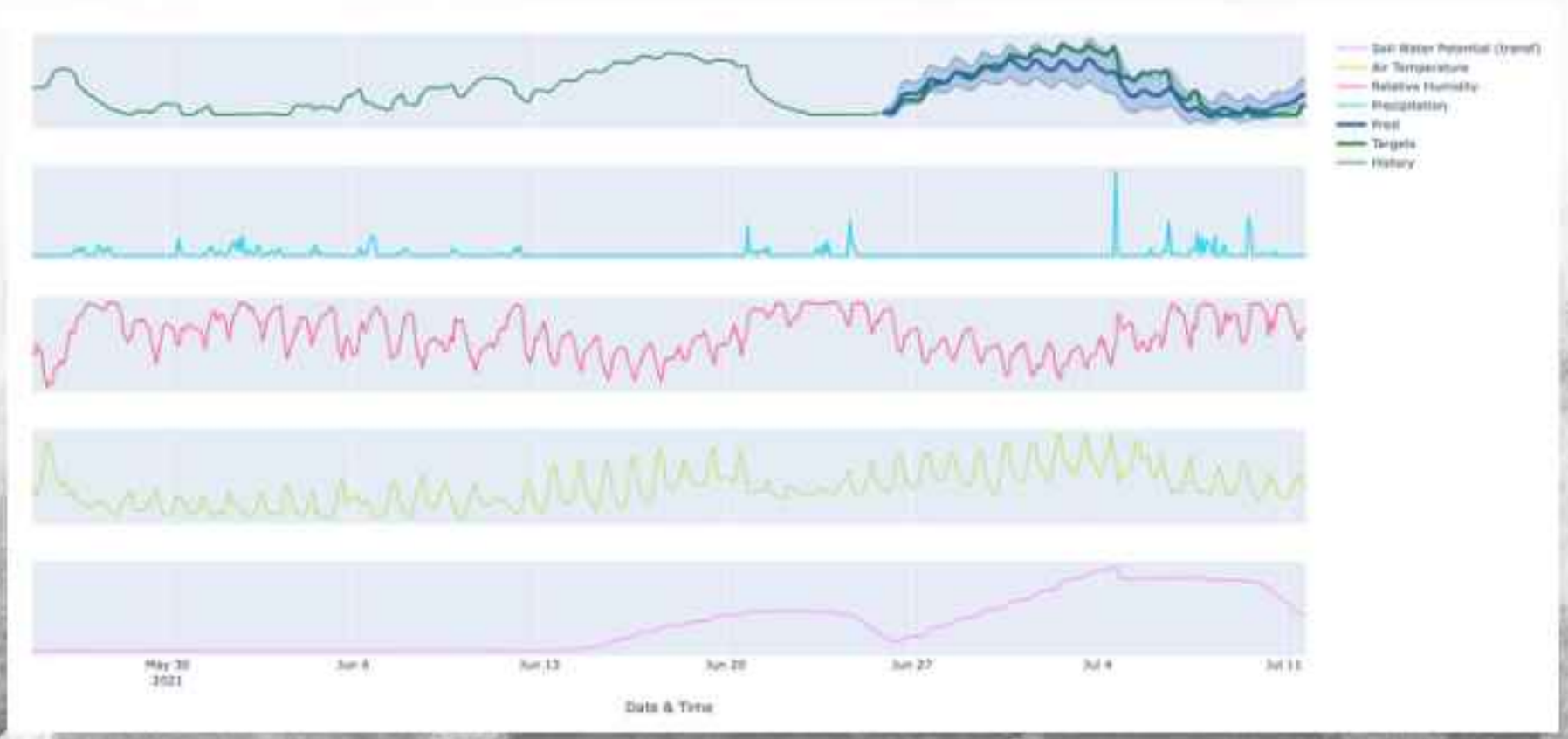


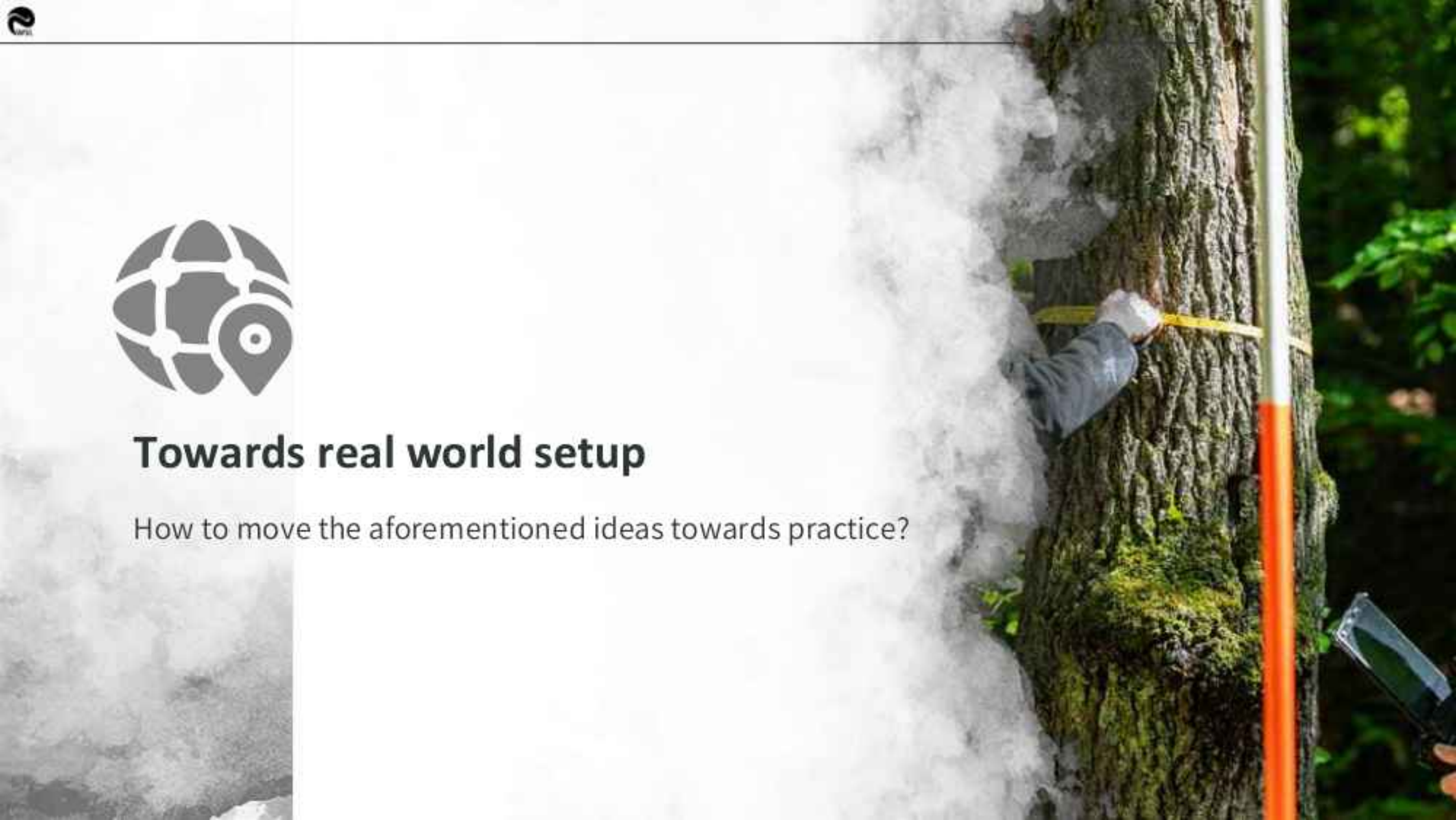
Assessing forecasting error

Proper data visualization helps to better understand the data one deals with.

Is observed forecasting error really something the model could avoid?

Tree 2





Towards real world setup

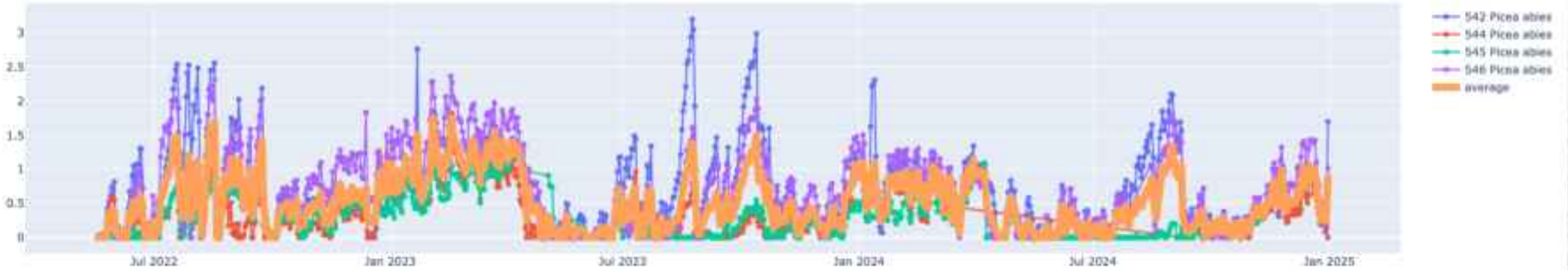
How to move the aforementioned ideas towards practice?

Getting rid of the variability within sites

Microclimate measurements are only available per-site.

Limit due to esolution of climate models - information only available per-site.

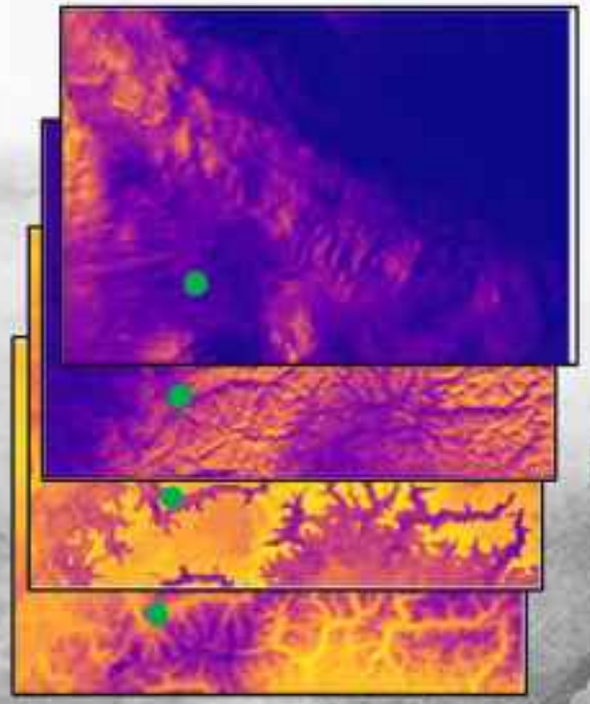
Aggregate TWD from all trees of the same species at each site (using mean/median/…).



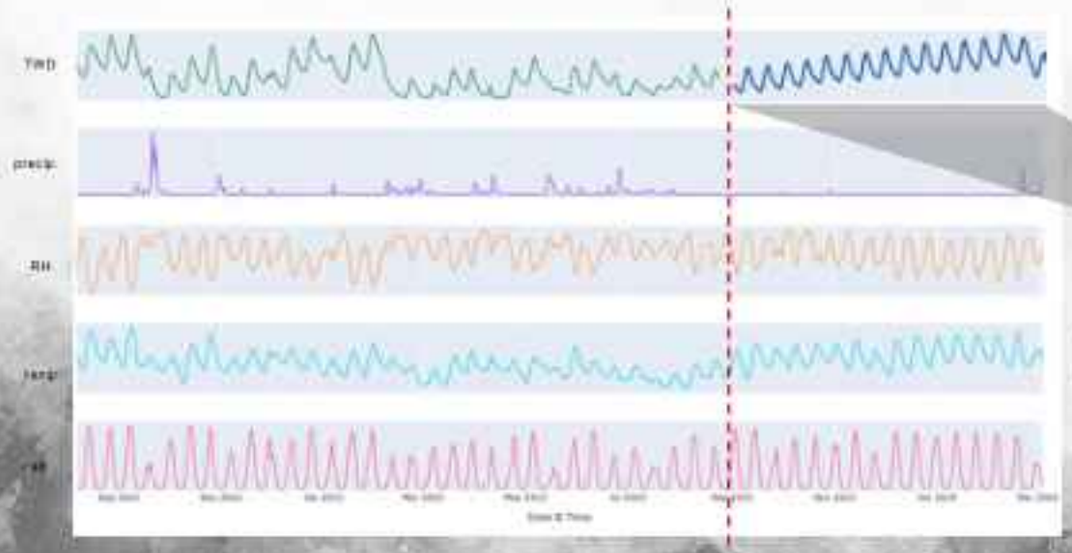
Using COSMO variables to forecast TWD

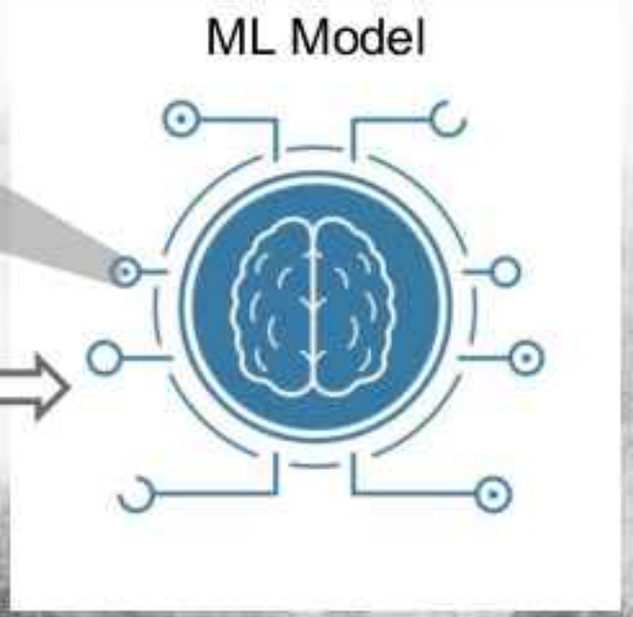
Assuming we have the COSMO gridded data for the past and COSMO forecast.

We take the TWD history and try to forecast its future development.



COSMO gridded data





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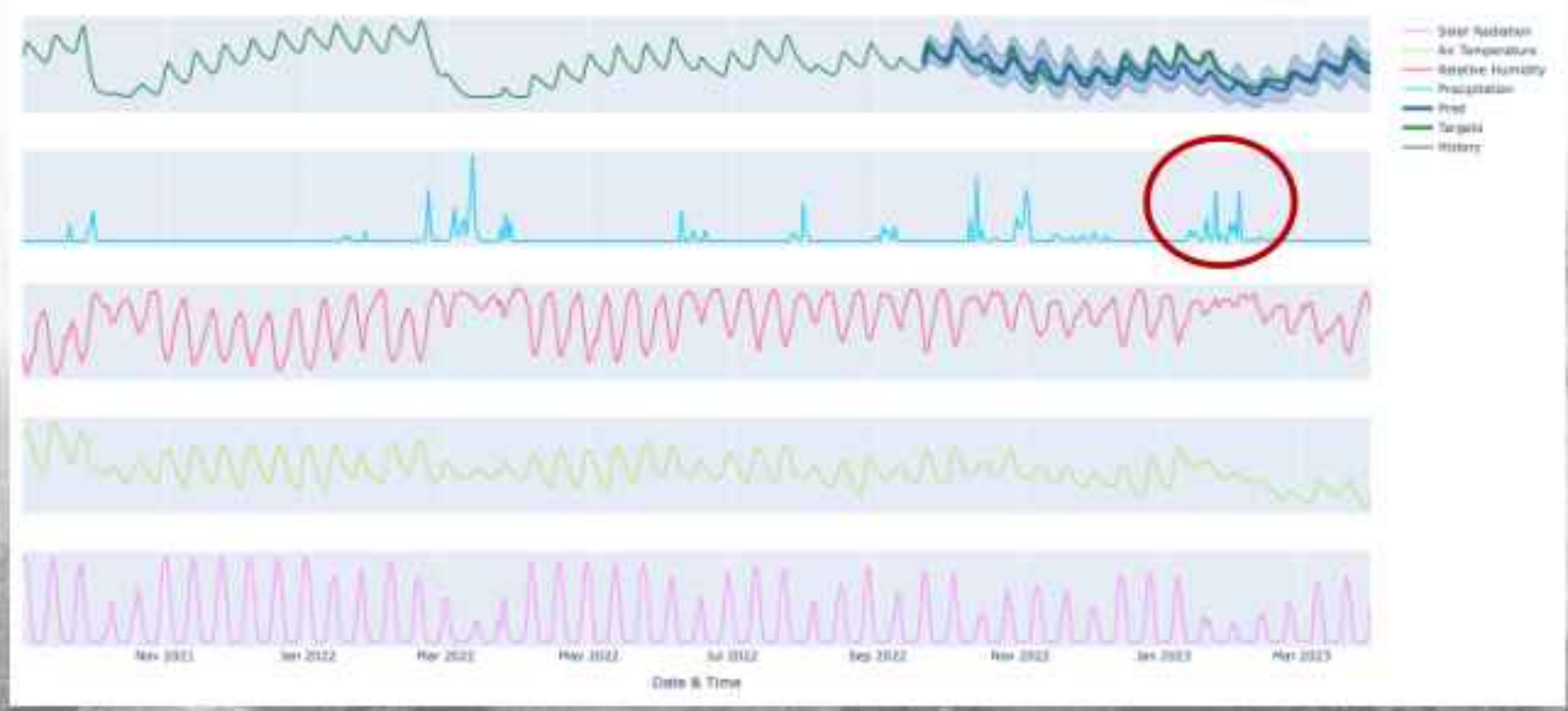

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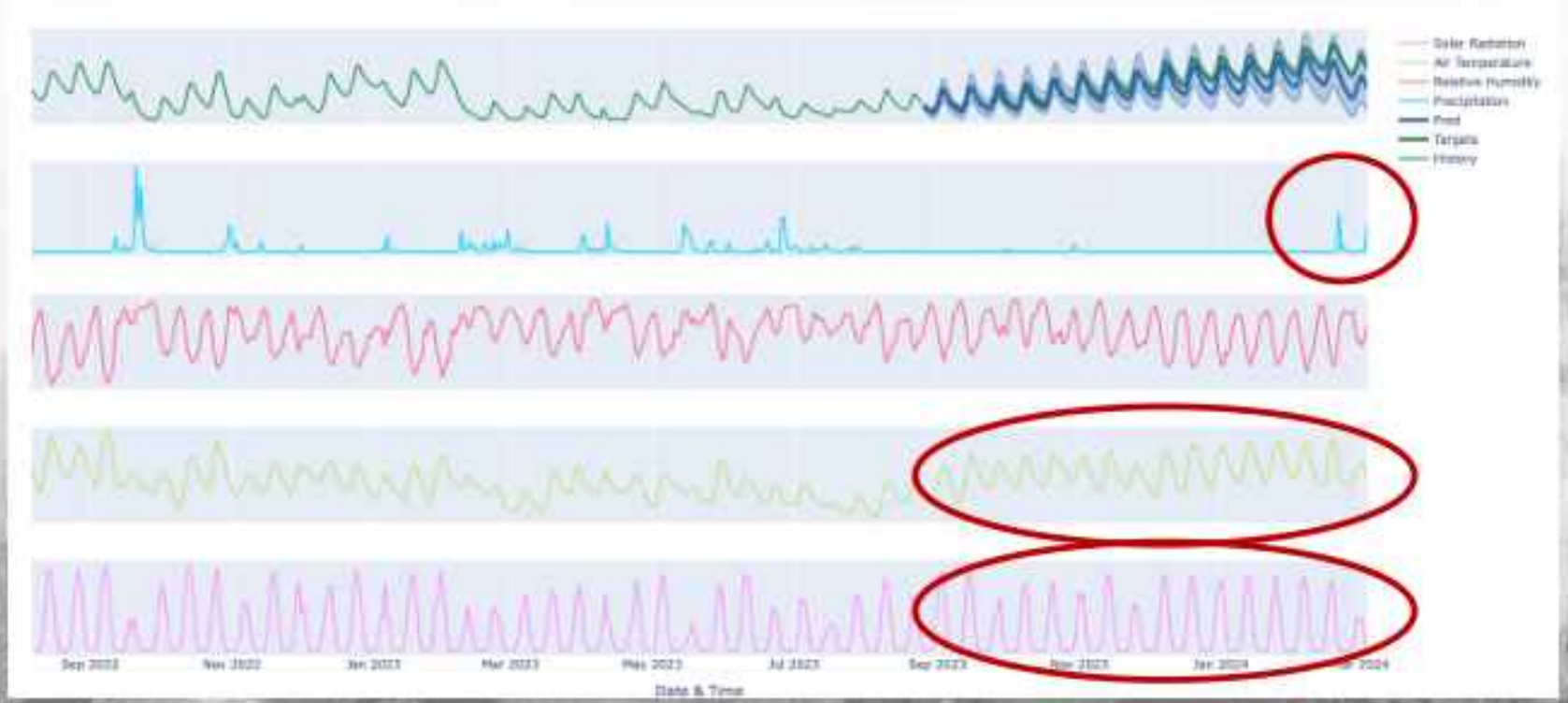
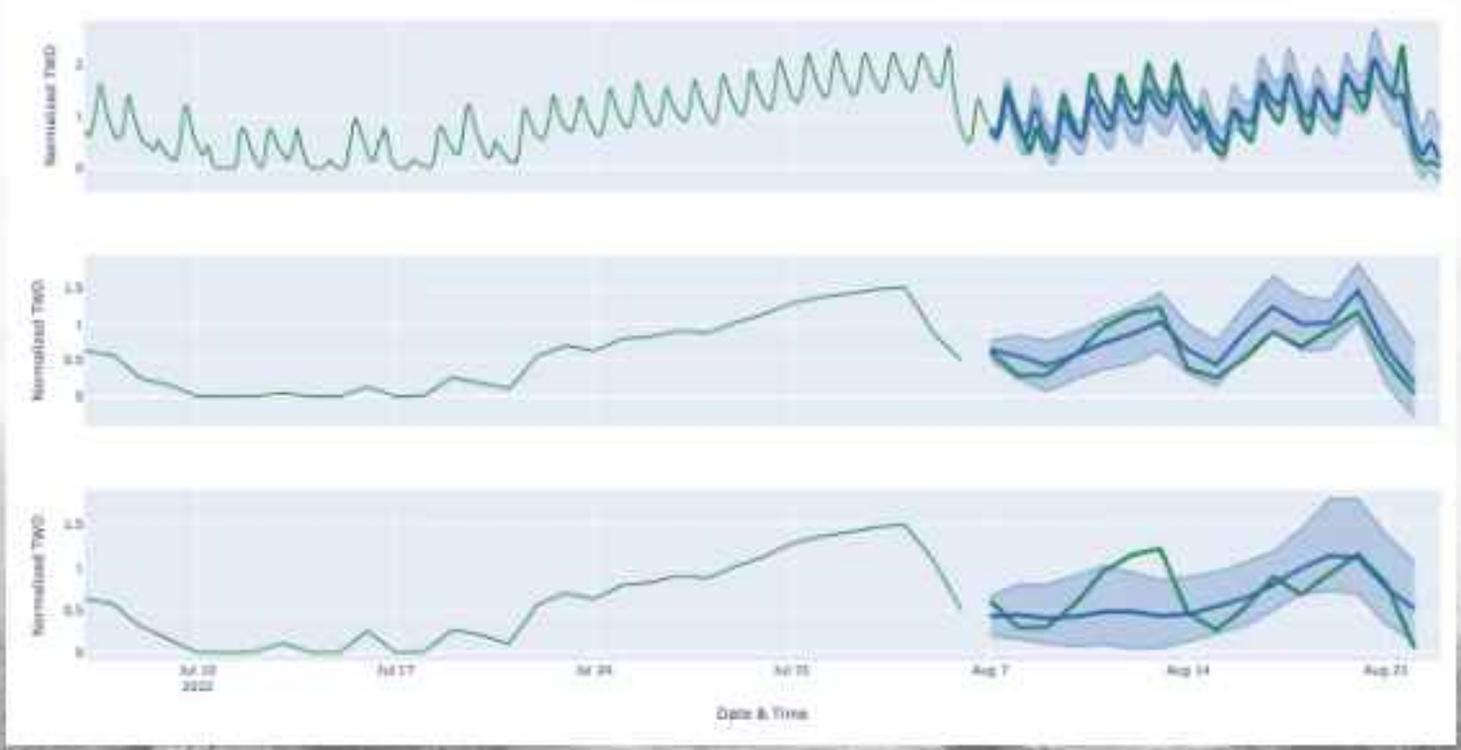


What about temporal resolution?

Comparing 2 hourly vs. daily measurements.

Using COSMO variables to forecast TWD

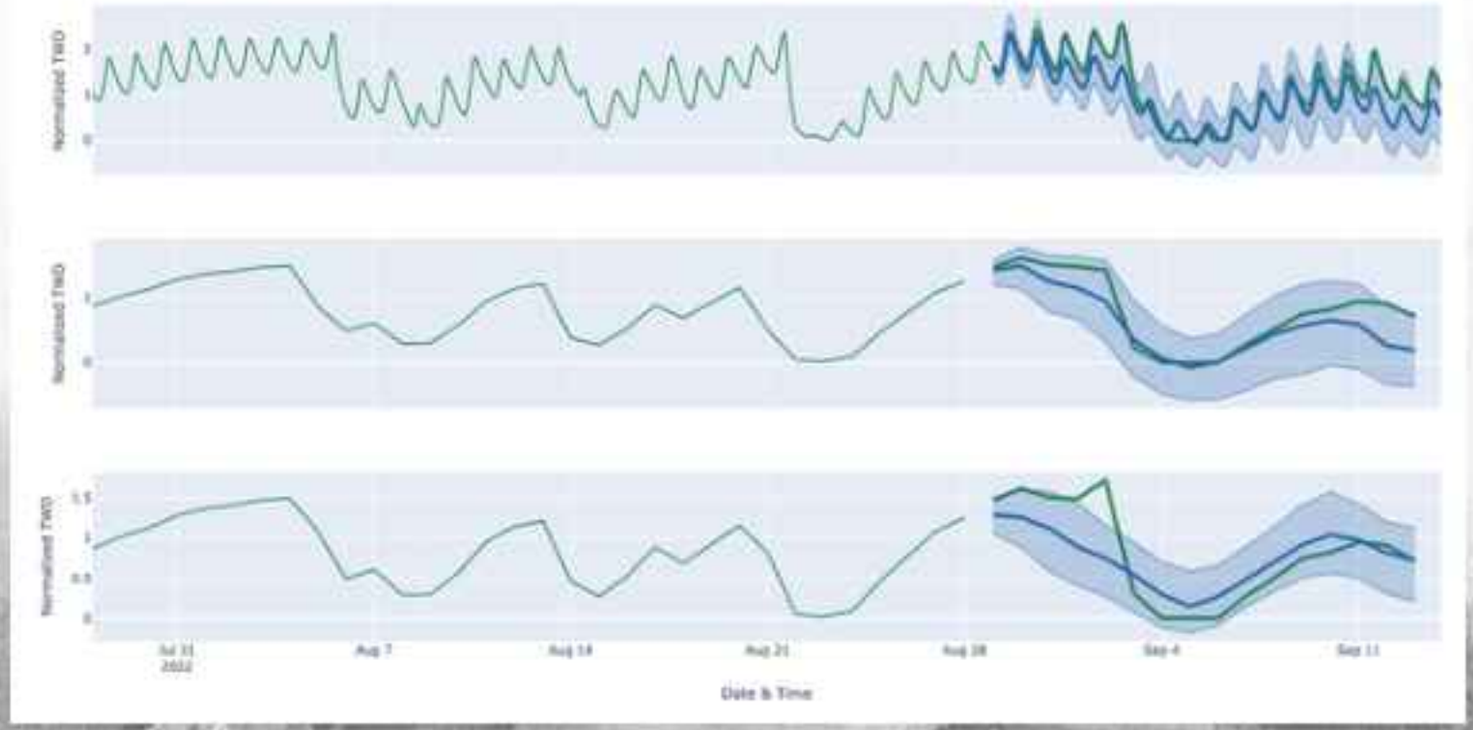
Forecasting in 2 hourly intervals and aggregating to daily seems more precise.



Using COSMO variables to forecast TWD

Forecasting in 2 hourly intervals and aggregating to daily seems more precise.

Need to gather more insights about what is the reason for that.

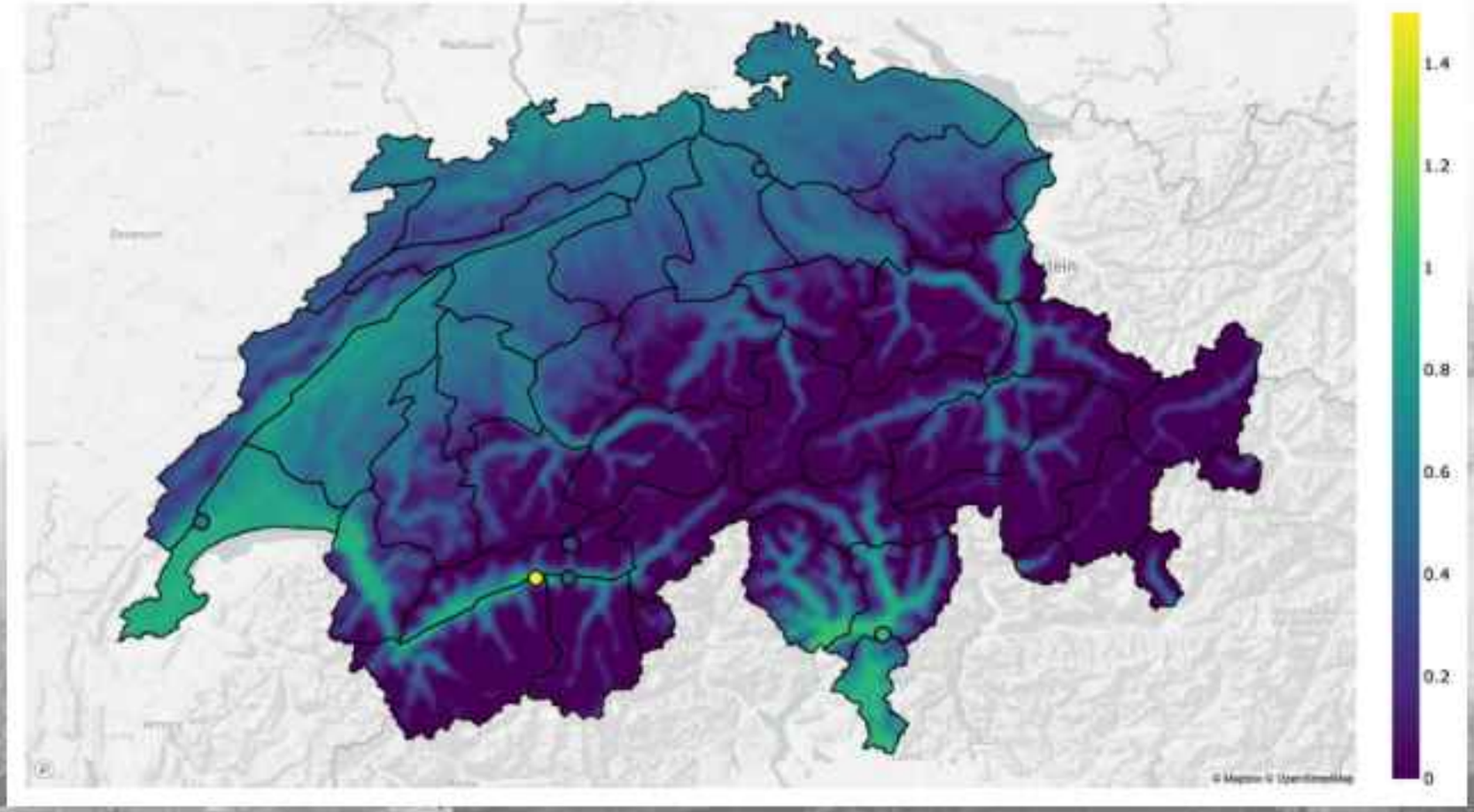


Can we map the forecast in space?

Time-then-space approach.

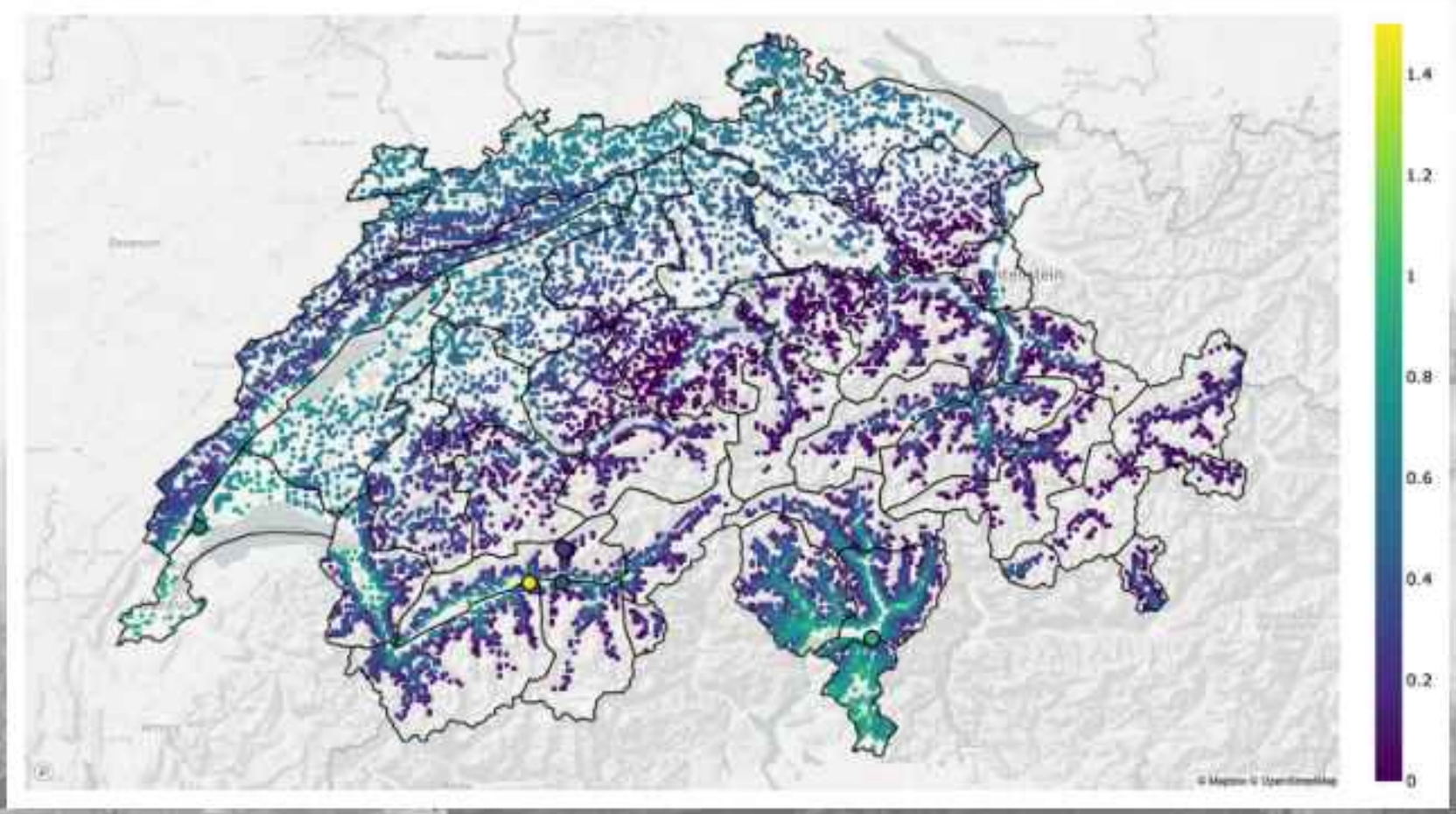
Gaussian process interpolation of TWD

Interpolation in space based on air temperature, relative humidity and solar radiation.



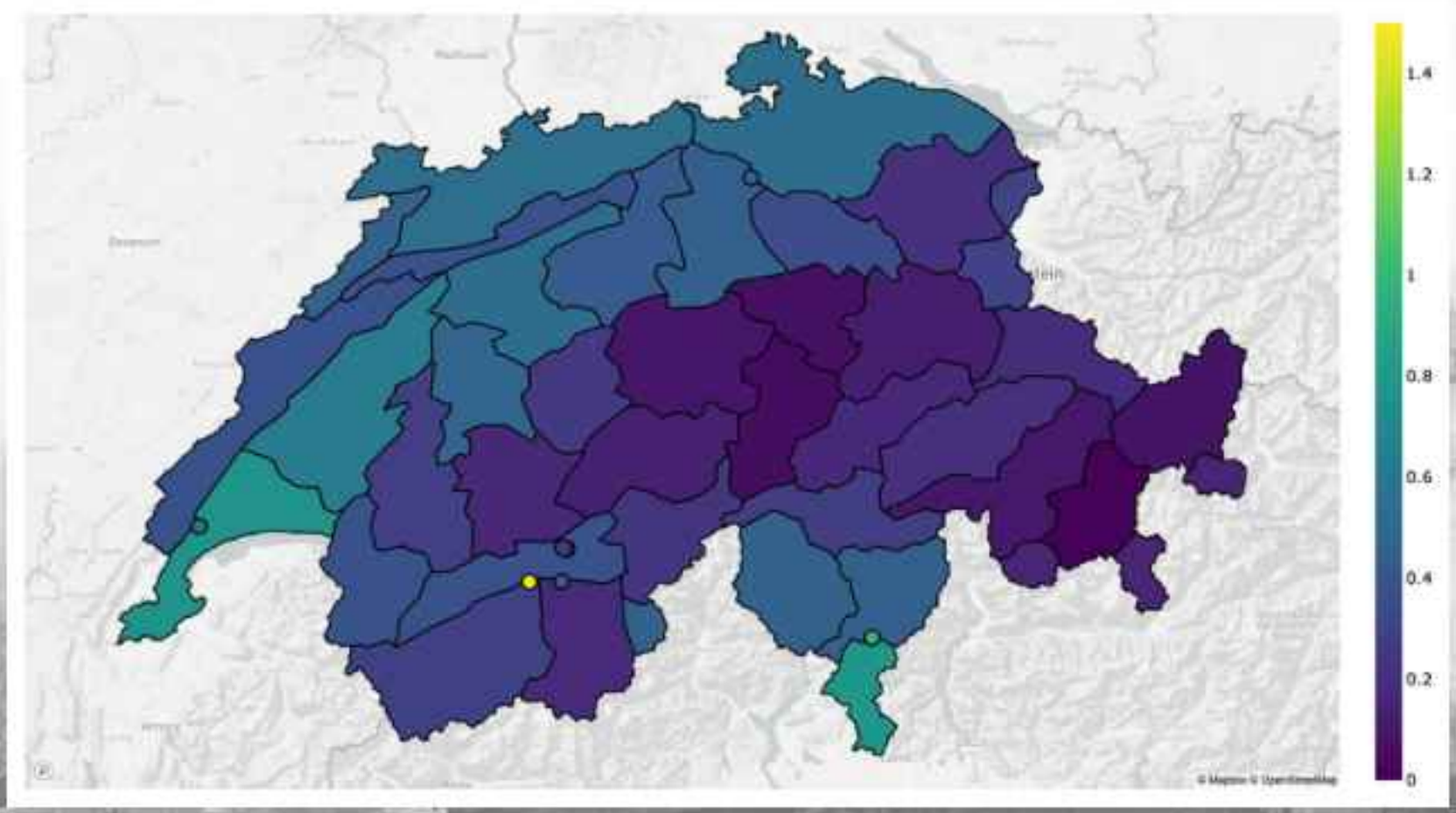
Gaussian process interpolation of TWD

Filtering of places with occurrence of species present in our data.



Gaussian process interpolation of TWD

Taking median for each region defined by FOEN.



Thank you!

Questions please!

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