



TreeNet – The biological drought and growth indicator network

Micah Wilhelm & Roman Zweifel

TreeNet Annual Meeting 2024
WSL, 12 November 2024

Networking the forest infrastructure

Forest observation infrastructure levels

Knowledge gain increase

Field methods

Sites and remote sensing

Networks

Targets

Ecosystem

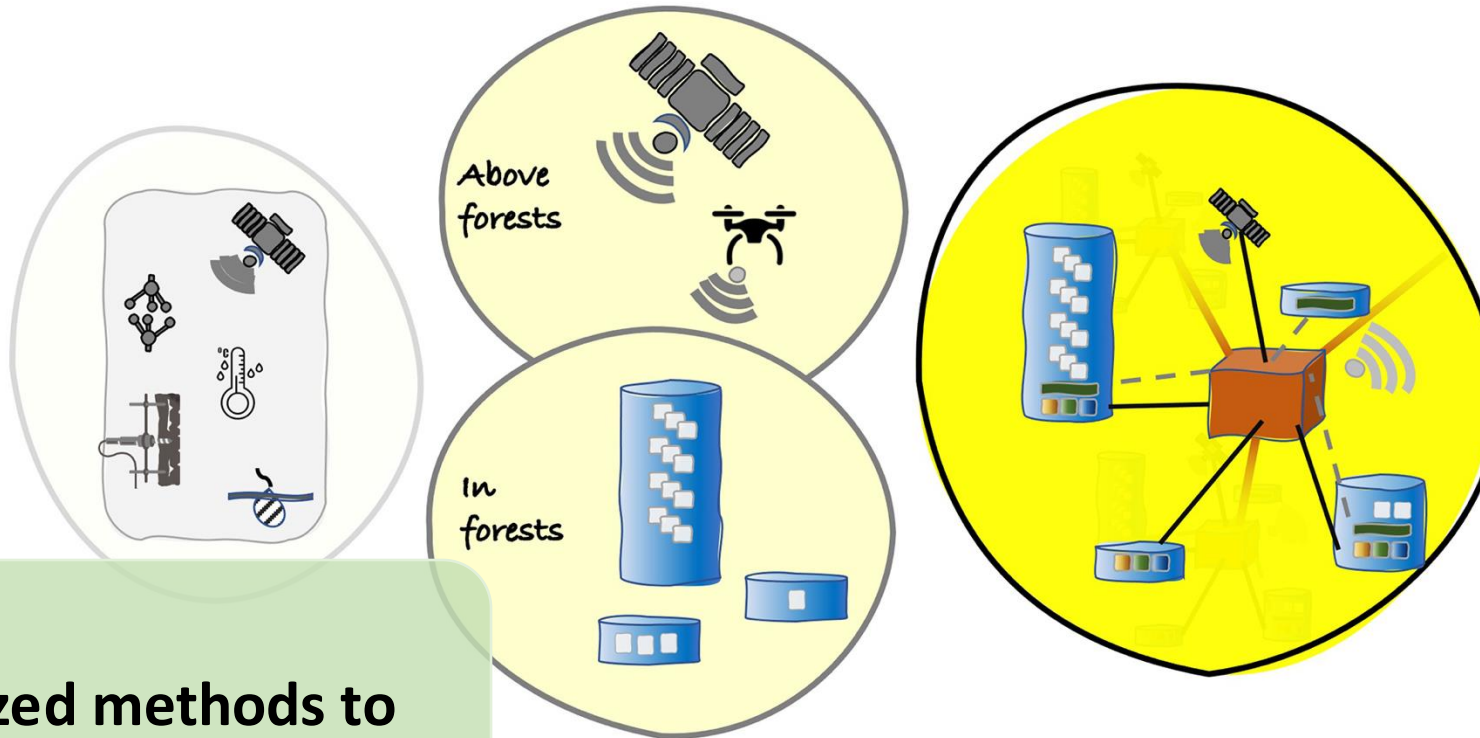
Forest stand

Tree Plant

Cell to organ

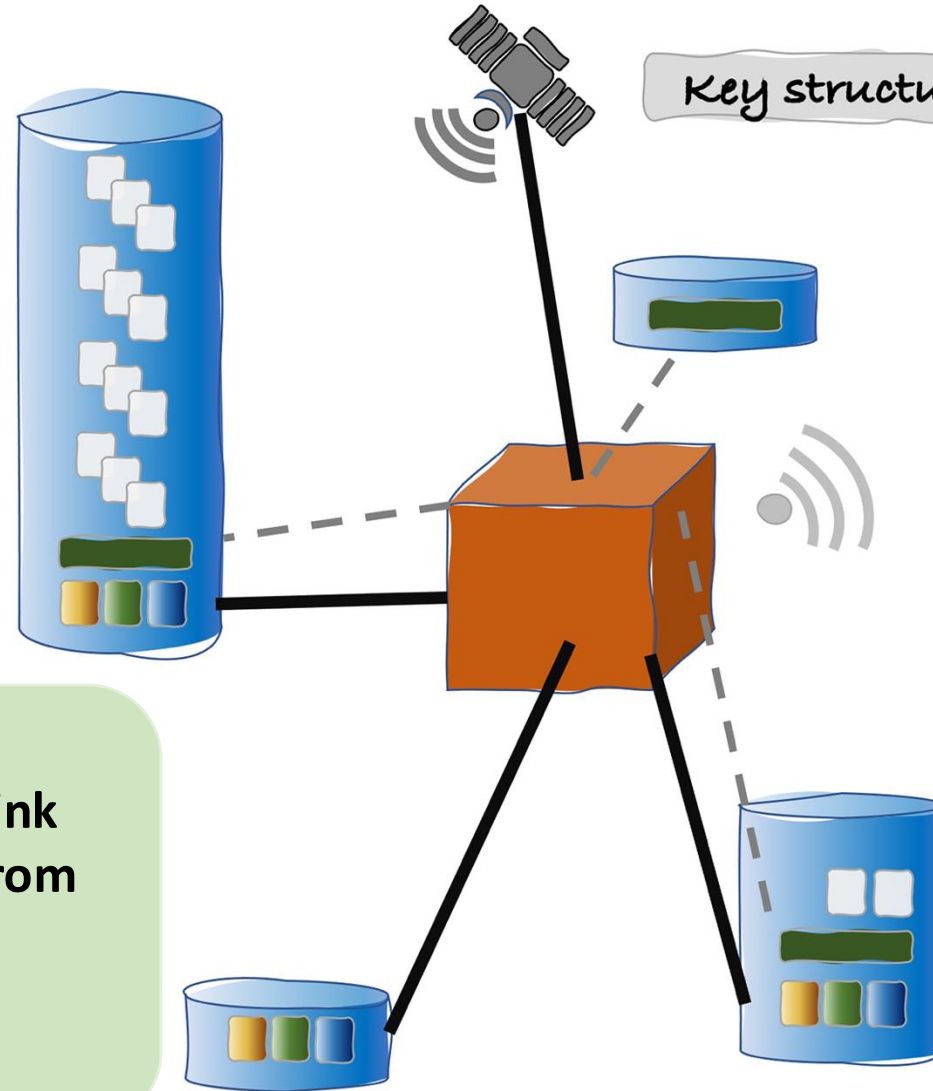
Spatio-temporal uncertainty

We need
standardized methods to
link existing infrastructure



Zweifel et al 2021, Frontiers
Zweifel et al 2023, STOTEN

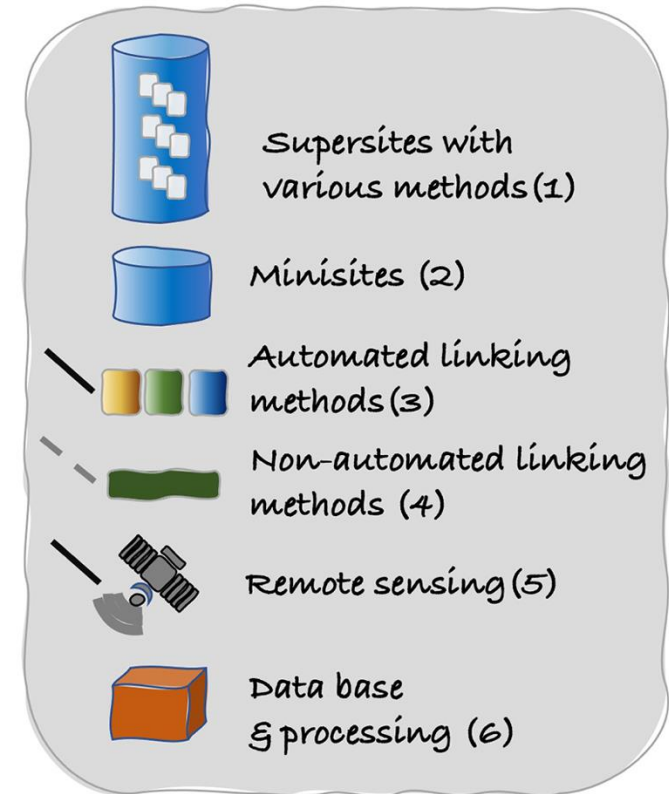
Networking forests with TreeNet



Key structural elements of an optimized network

We established

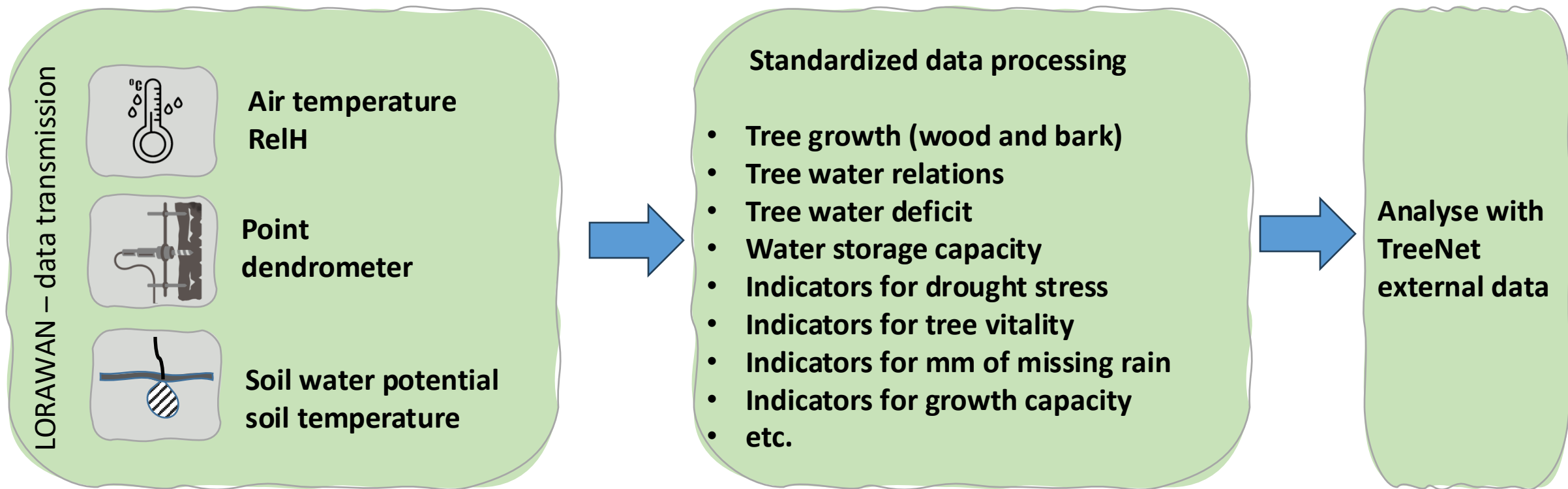
- > **standardized methods to link point dendrometer data from various sites**
- > **a central database**
- > **Processing methods**



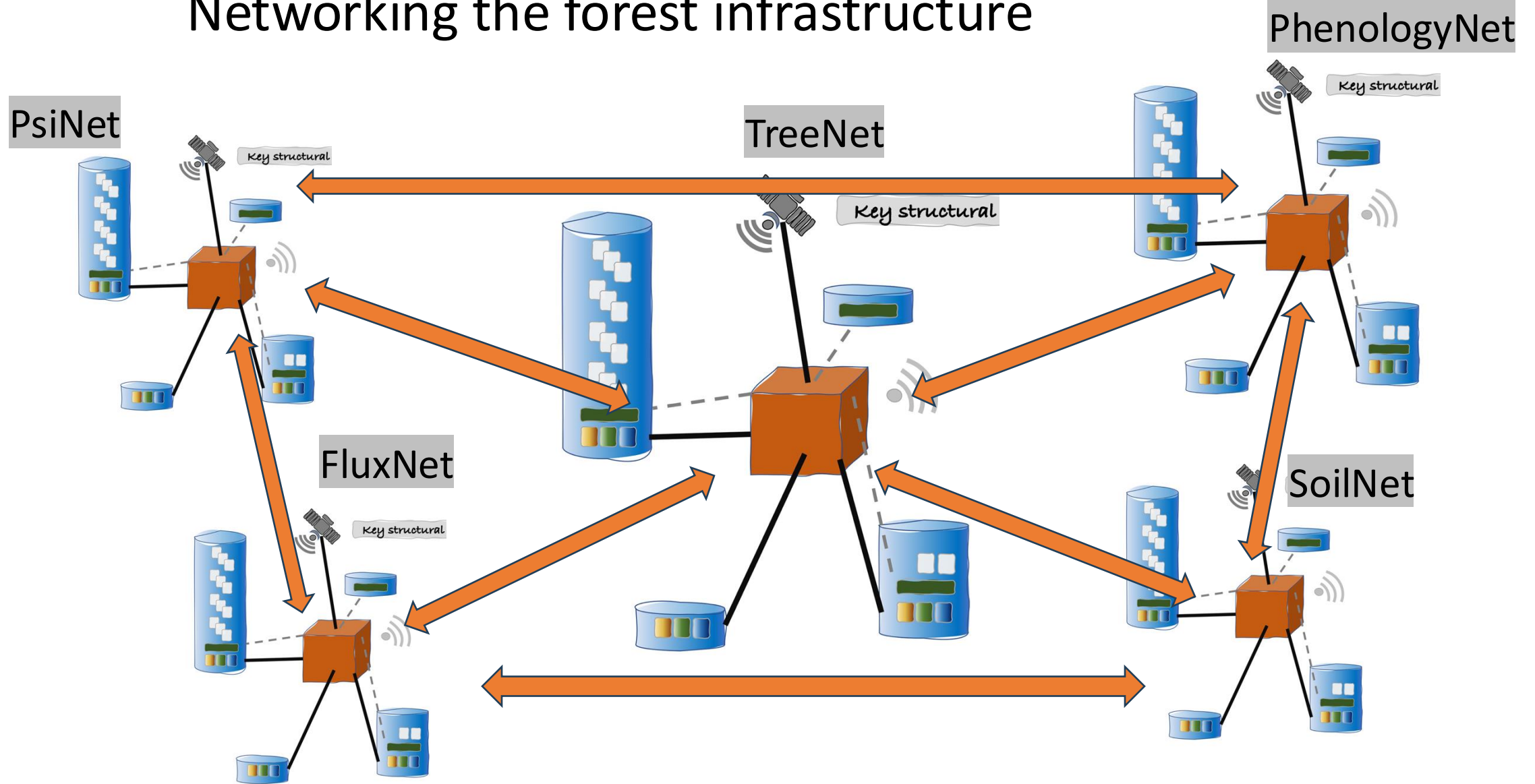
Zweifel et al 2021, Frontiers
Zweifel et al 2023, STOTEN

TreeNet developed:

Automated, standardized LINKING METHODS for dendrometer measurements incl. air temp, RelH, water potentials in air and soil and the related data treatment



Networking the forest infrastructure



Zweifel et al 2023, STOTEN

Point dendrometers (Natkon, Oetwil am See)



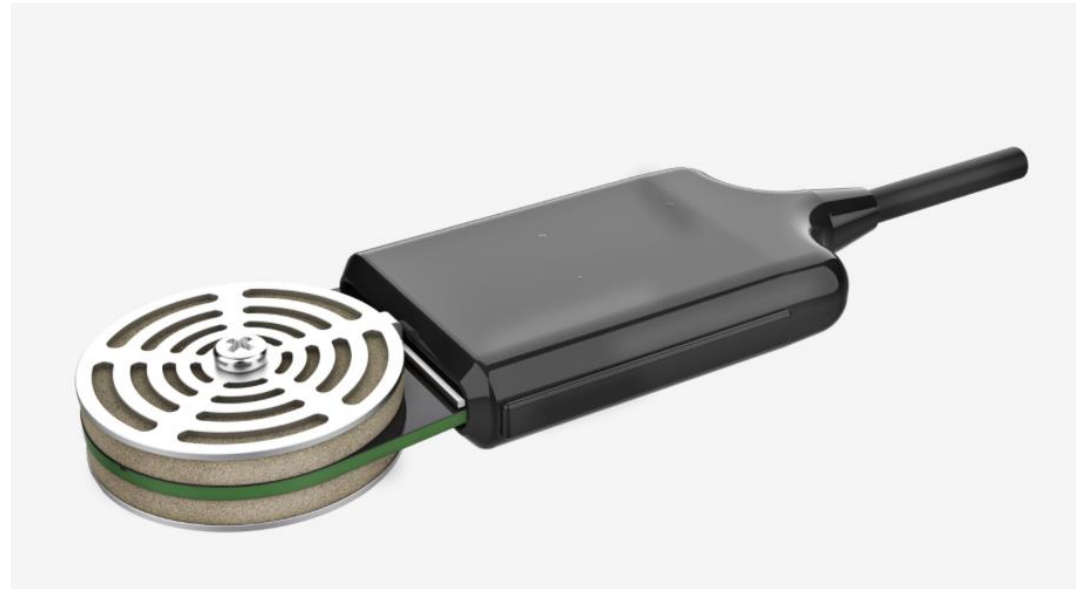
LORA WAN Nodes (Decentlab GmbH, Dübendorf)



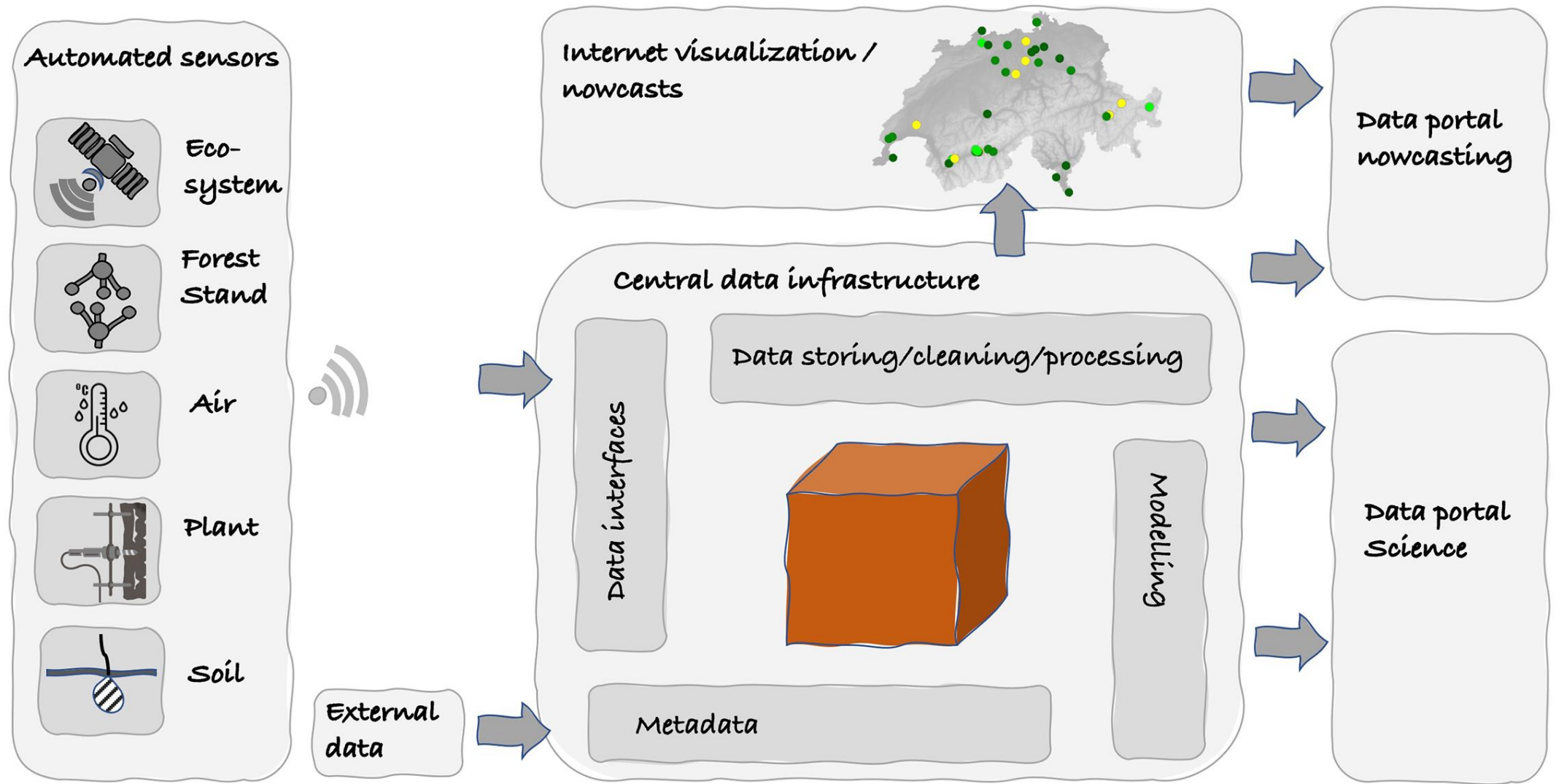


Air Temp/RelH (Sensirion/Decentlab)

Soil sensor (TEROS-21, Meter Group)



Data flow from sensors in the field to users

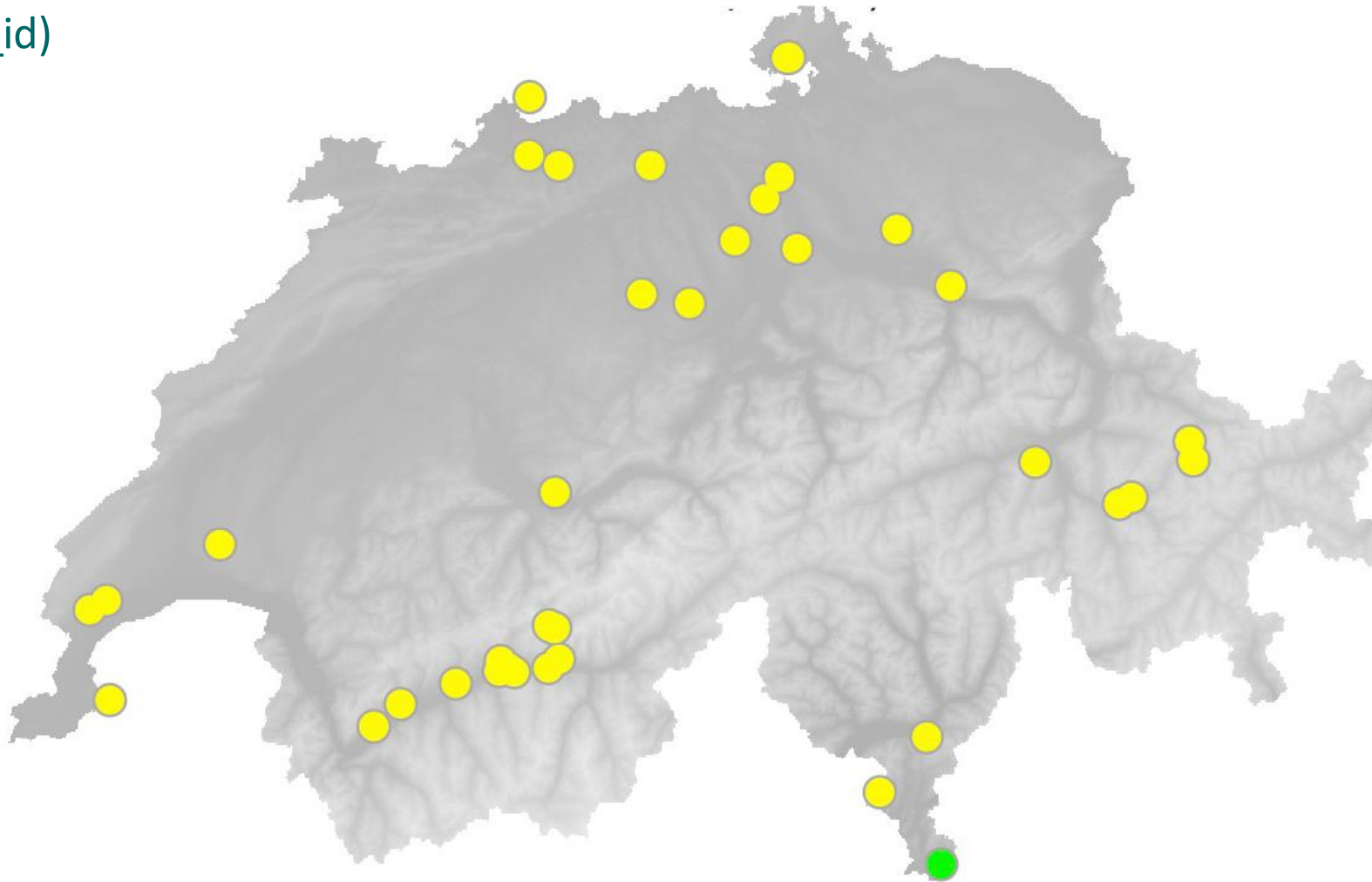


TreeNet Partners 2024

Contact	Site_affiliation	Site_all
Roman Zweifel/ Andreas Rigling	BLS	7
Charlotte Grossiord	EPFL	2
Nina Buchmann	ETHZ_Grass	2
Marius Floriancic	ETHZ_IEE	1
Andrea Carminati	ETHZ_Soil	8
Sabine Braun	IAP	11
Ansgar Kahmen	UniBasel	2
Roman Zweifel	WSL_TN	1
Eric Gehring	WSL_Come	1
Patrick Fonti	WSL_Dendro	16
Nina Buchmann	WSL_ETHZ_Grass	1
Arthur Gessler	WSL_LWF	18
Martina Peter	WSL_Myko	3
Alessandro Bottero/Esther Frei	WSL_SLF	2
Lorenz Walthert	WSL_Soil	4
Marcus Maeder	ZHdK	3
Total (per year)		82

TreeNet Sites 2024 Switzerland

(site_id)



94 sites in total
82 are active

Sites are measurement
plots with specific
conditions in air and soil

e.g. different expositions
e.g. treatments

TreeNet Sensors Switzerland 2024



Dendrometers: 734 (active 588)

Temp/RelH: 90 (63)

Soil Temp/WP: 200 (181)

Others: ca. 300 (100)

Projects with TreeNet involvement

LWF (WSL, BAFU)

Interkantonale Walddauerbeobachtung (IAP, BAFU)

ICOS (SNSF, EU RI project)

SwissCanopyCrane II (SNFS, BAFU)

VPDrought – Pfynwald (SNFS, WSL)

UPSCALE (SNSF-Sinergia)

FORWARDS (EU-project)

BLS - Klimaangepasste Baumarten im Schutzwald der BLS Südrampe (BLS)

SwissPhenocam - country-scale automated phenology tracking from imagery (GCOS)

Fore(st)cast (WSL, SDSC)

NCCS – FORTE APP (WSL, BAFU)

Stillberg (SLF)

Silva/Acla Soundscape (Science-Art project, ZHdK, Kt GR)

Waldlabor (ETH)

FOREMA GIS WSL/DRAINS (WSL)

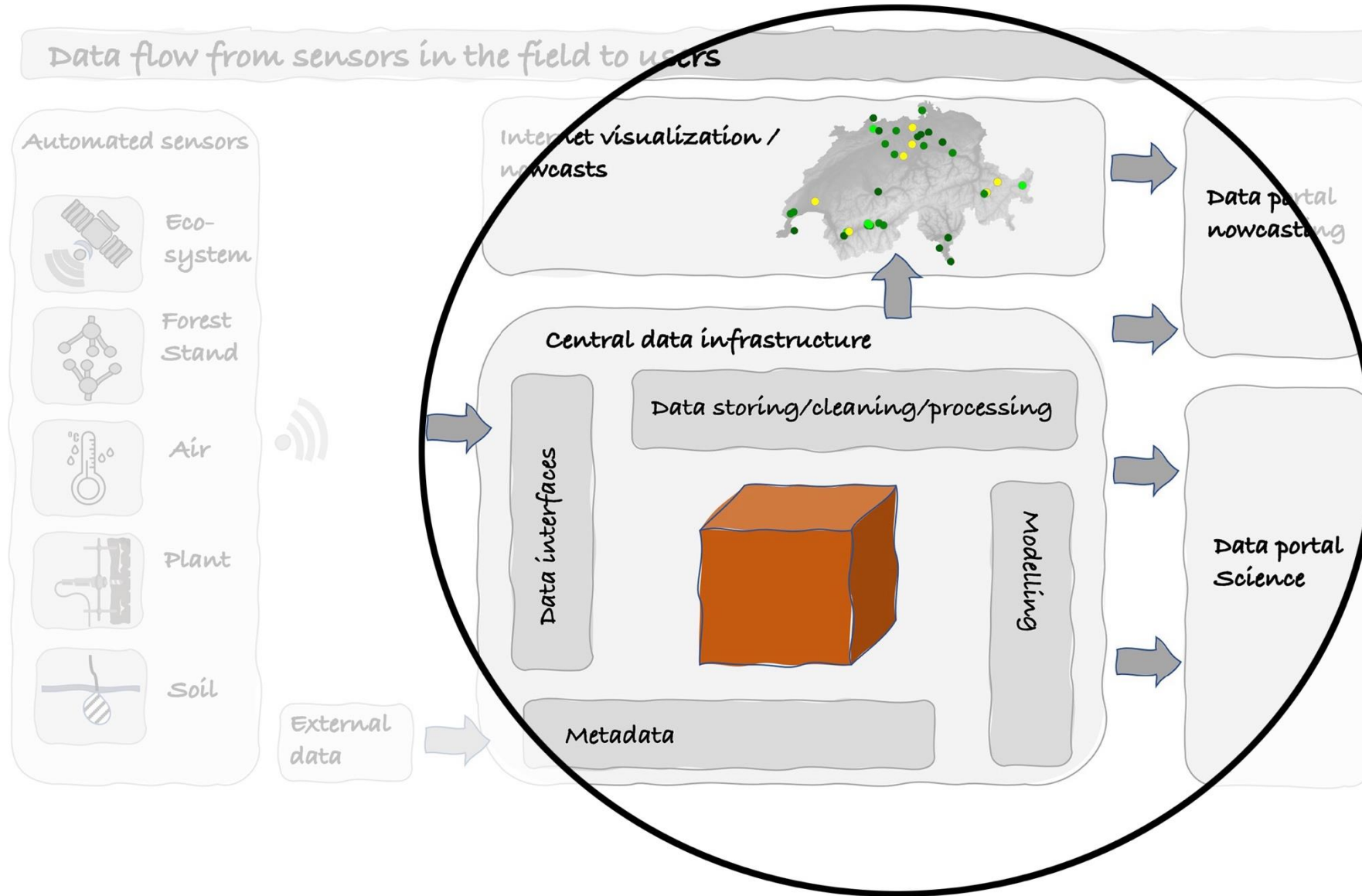
FLAME - Future resILient forest in a chAnging climate (Uni ZH)

TreeNetGaps – Gap filling dendrometer data with ML (WSL/ETH)

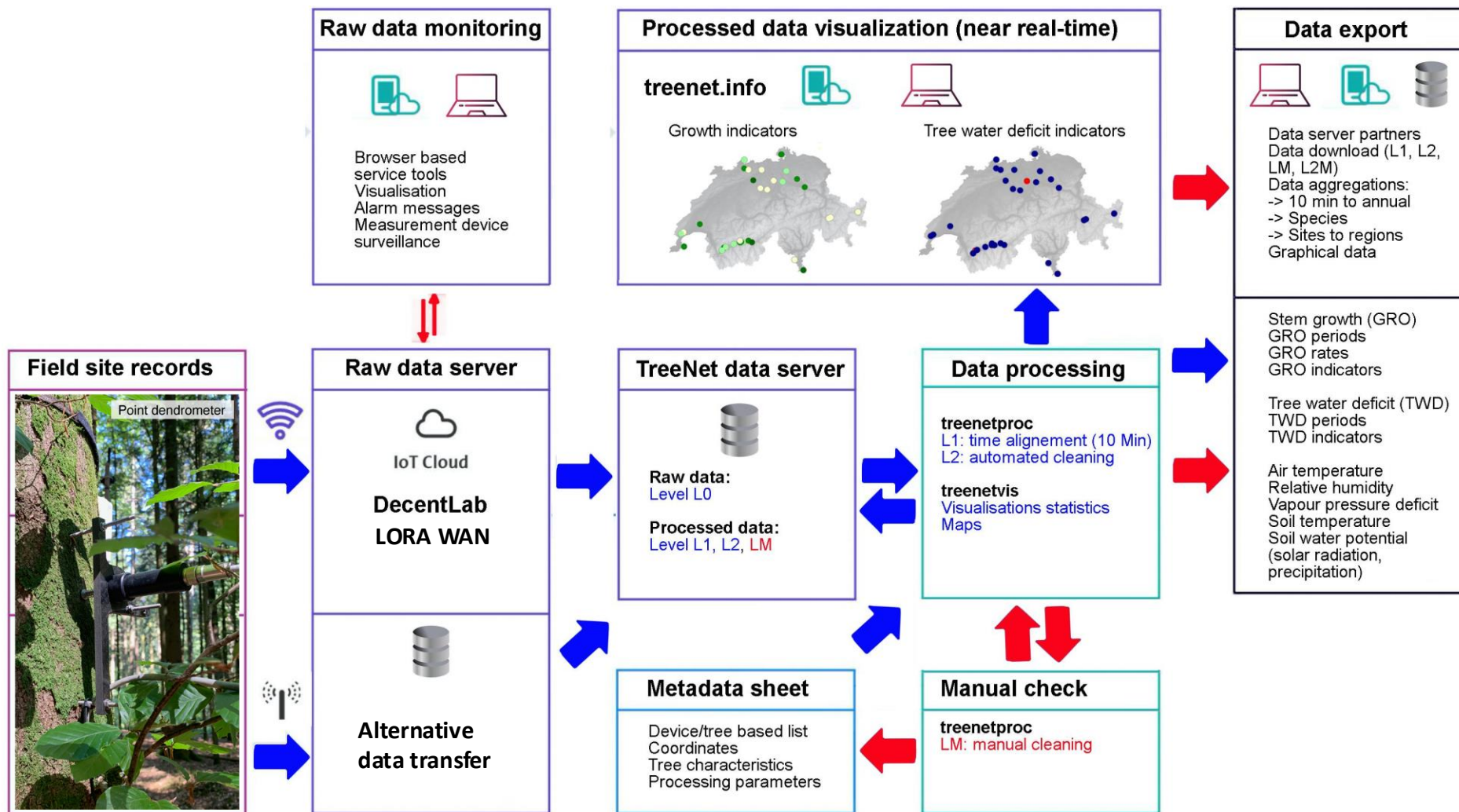
pino di roma/Giardino di Acclimatazione (Art projects, studio hemauer and keller)

...

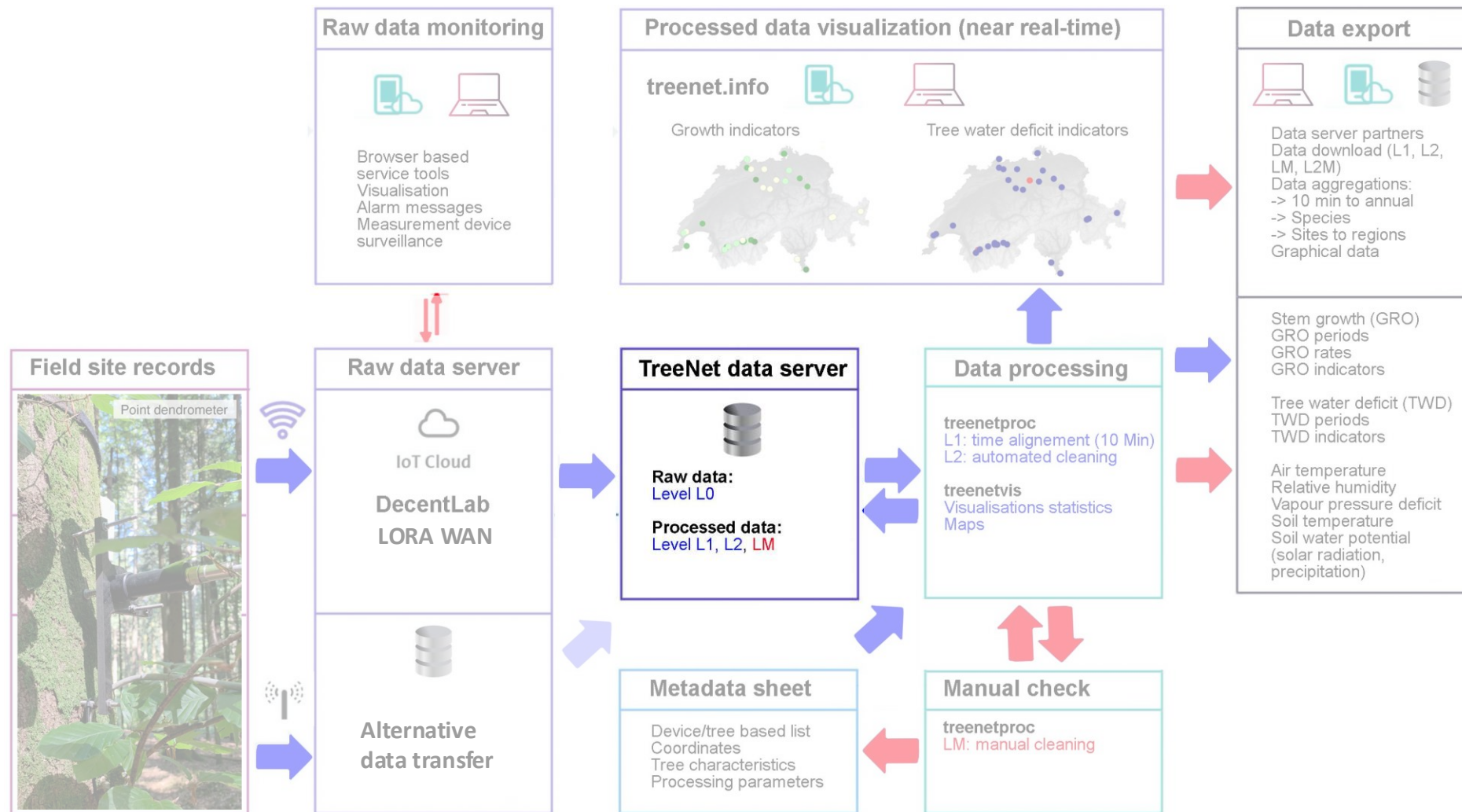
PhD and Msc projects with **ETH**, EAWAG, EPFL, Uni Basel, Uni Zürich



TreeNet Data flow



TreeNet Data flow



Database

PostgreSQL

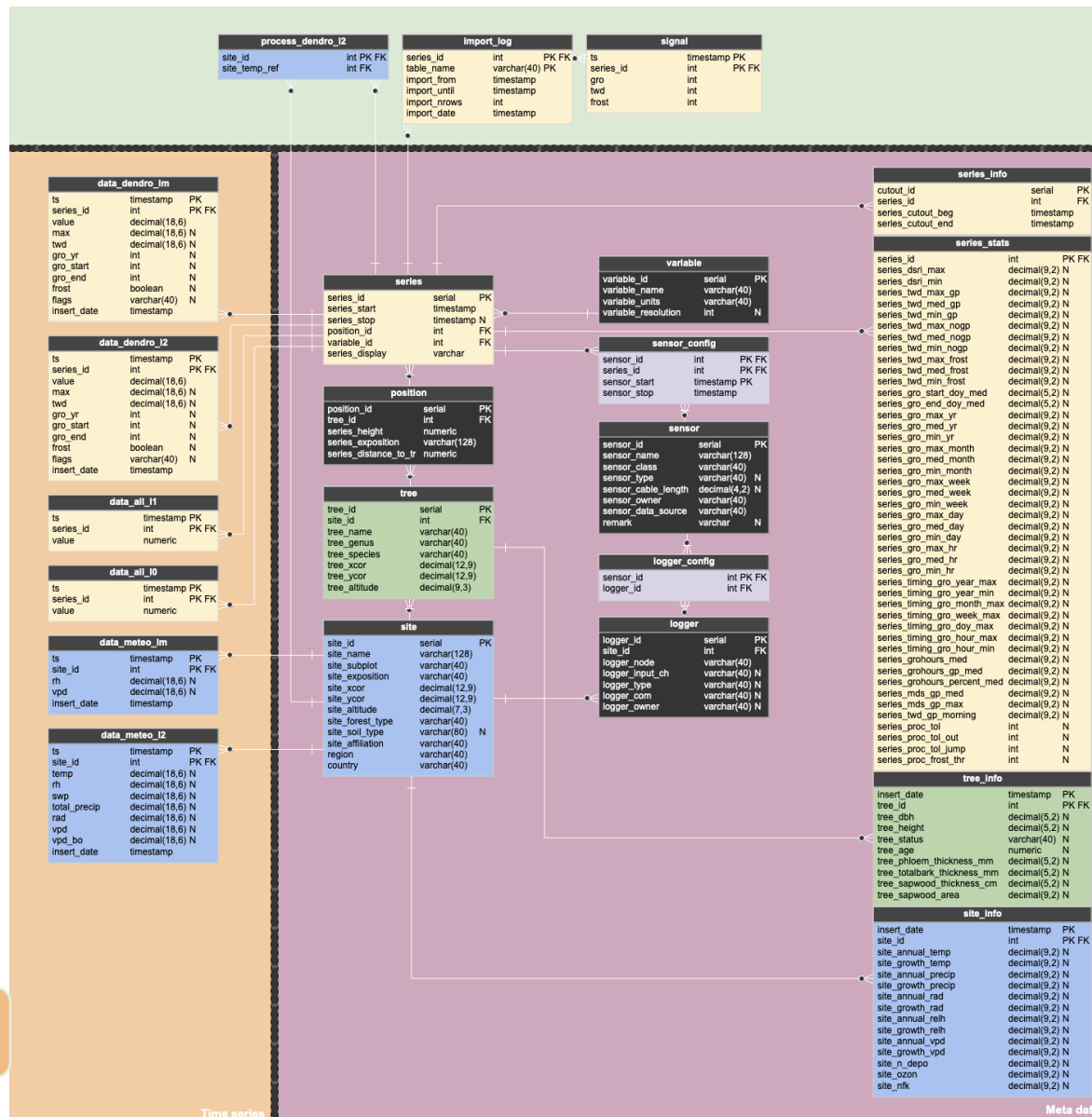
Table structure

- 5 site-level
- 2 tree-level
- 9 series-level
- 2 configuration
- 4 miscellaneous

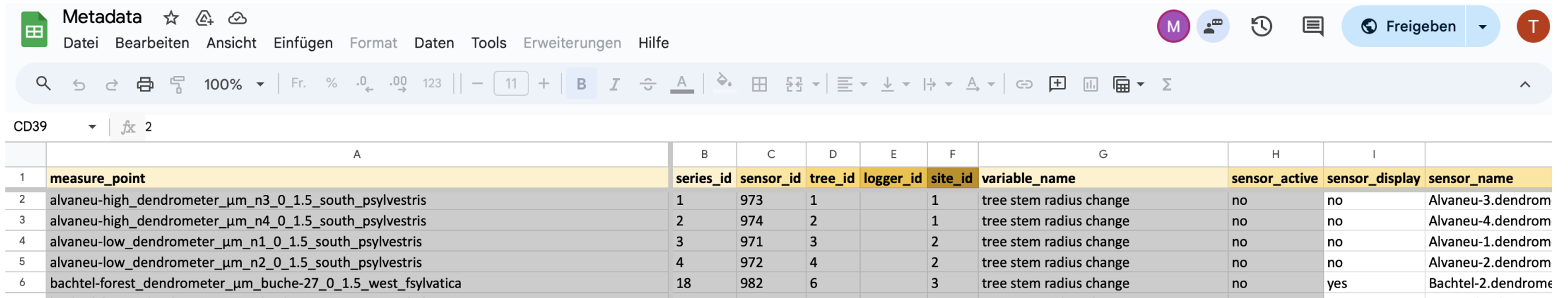
Time series

Processing

Metadata



Metadata – key to organise and connect data



The screenshot shows a Google Sheets interface with a spreadsheet titled 'Metadata'. The spreadsheet contains a table with 11 columns: 'measure_point', 'series_id', 'sensor_id', 'tree_id', 'logger_id', 'site_id', 'variable_name', 'sensor_active', 'sensor_display', and 'sensor_name'. The first row is a header row. The following rows contain data for different dendrometer measurements at various sites.

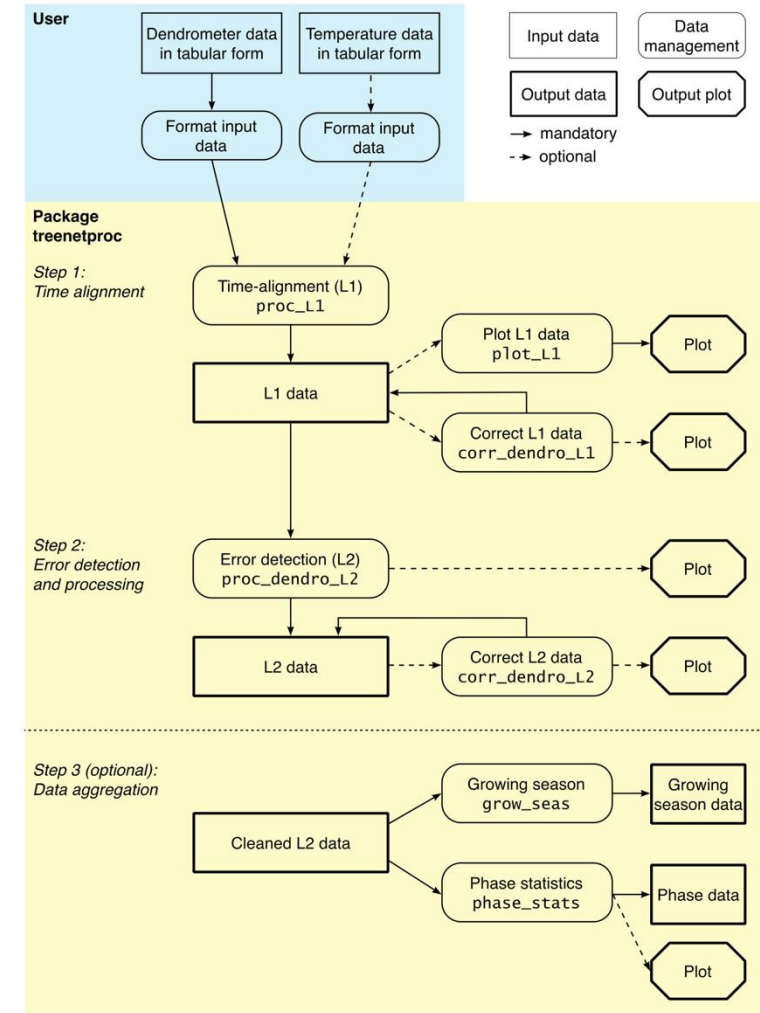
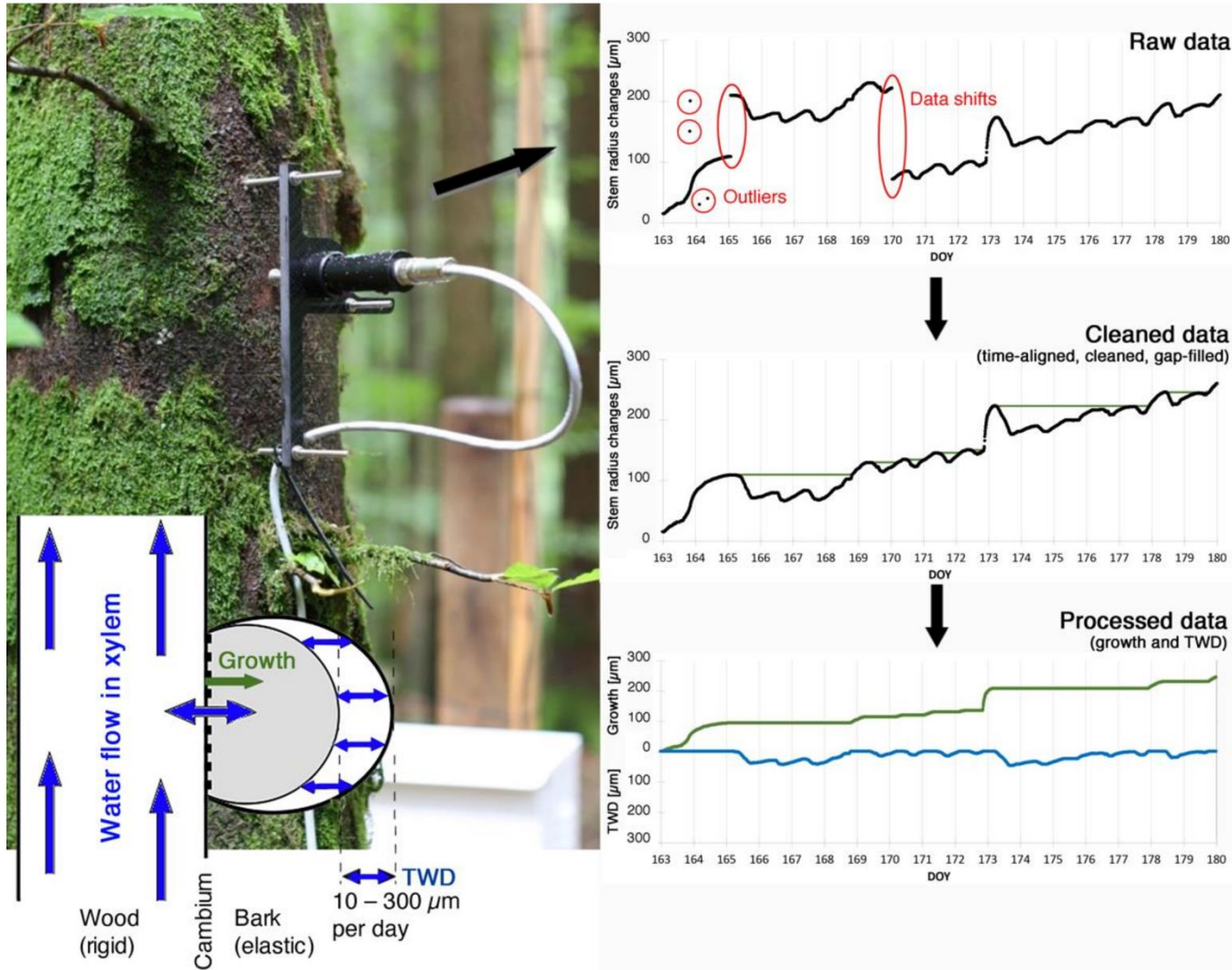
measure_point	series_id	sensor_id	tree_id	logger_id	site_id	variable_name	sensor_active	sensor_display	sensor_name
alvaneu-high_dendrometer_μm_n3_0_1.5_south_psyvestris	1	973	1		1	tree stem radius change	no	no	Alvaneu-3.dendrom
alvaneu-high_dendrometer_μm_n4_0_1.5_south_psyvestris	2	974	2		1	tree stem radius change	no	no	Alvaneu-4.dendrom
alvaneu-low_dendrometer_μm_n1_0_1.5_south_psyvestris	3	971	3		2	tree stem radius change	no	no	Alvaneu-1.dendrom
alvaneu-low_dendrometer_μm_n2_0_1.5_south_psyvestris	4	972	4		2	tree stem radius change	no	no	Alvaneu-2.dendrom
bachtel-forest_dendrometer_μm_buche-27_0_1.5_west_fsylvatica	18	982	6		3	tree stem radius change	no	yes	Bachtel-2.dendrom

TreeNet metadata - Each timeseries has 108 metadata entries!

- Sensor type, mounting location, IDs, units
- Owner ships, affiliation
- Coordinates
- Species, forest type, soil type
- Site, climate, and tree characteristics
- Physiological characteristics (GRO, TWD, GRO period, ...)
- Processing variables

-> heart of processing platform

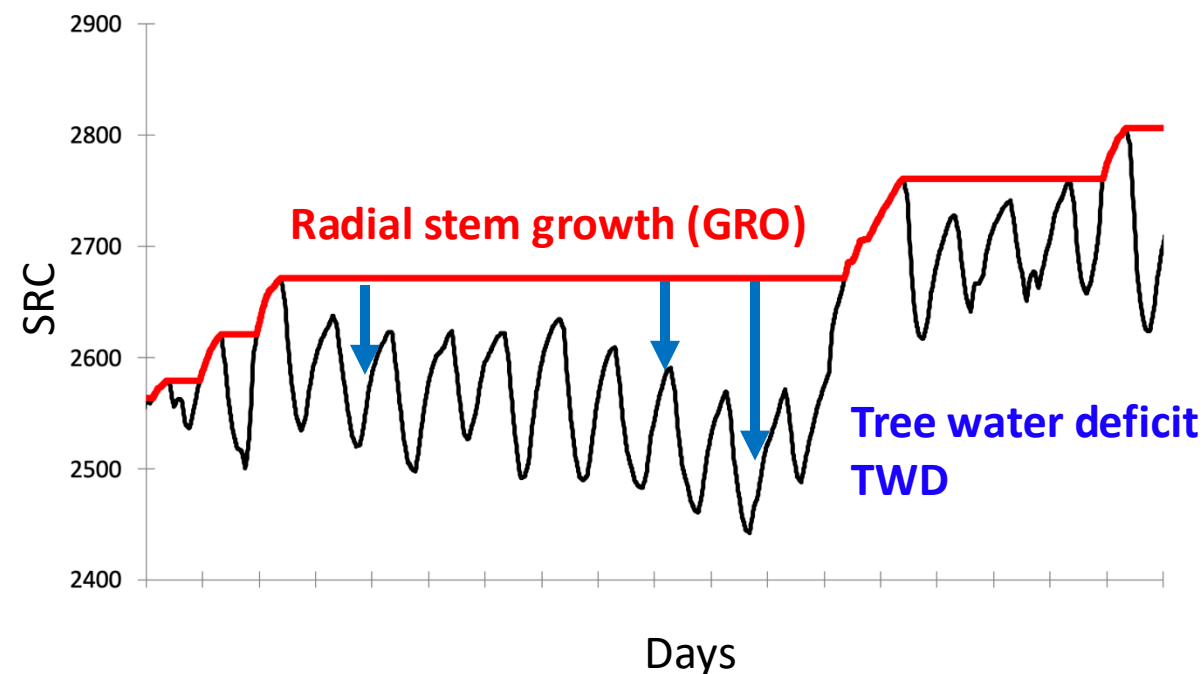
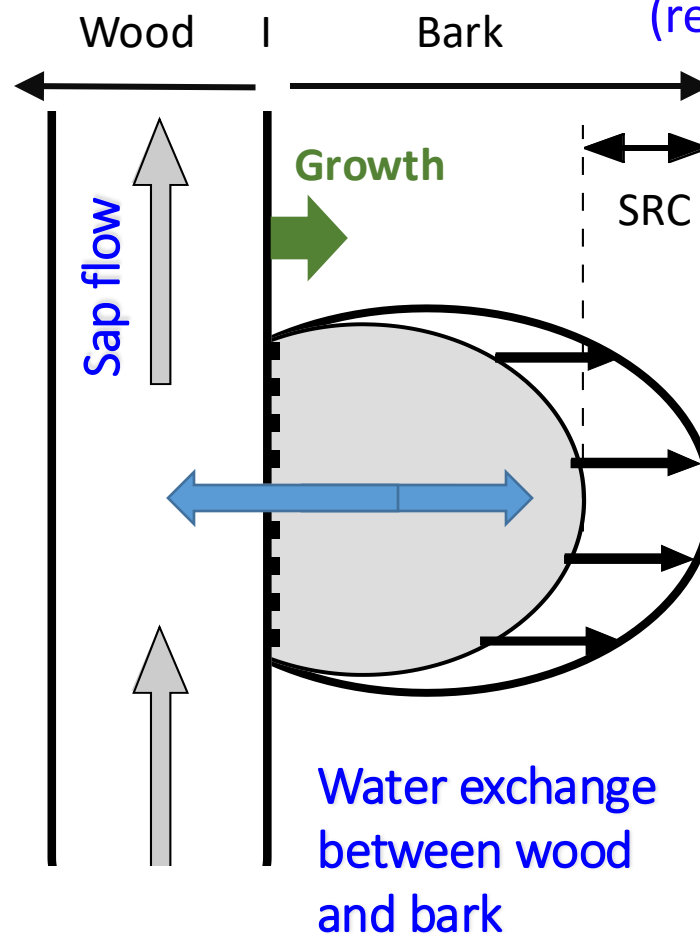
treenetproc – an R package to clean and process dendrometer data





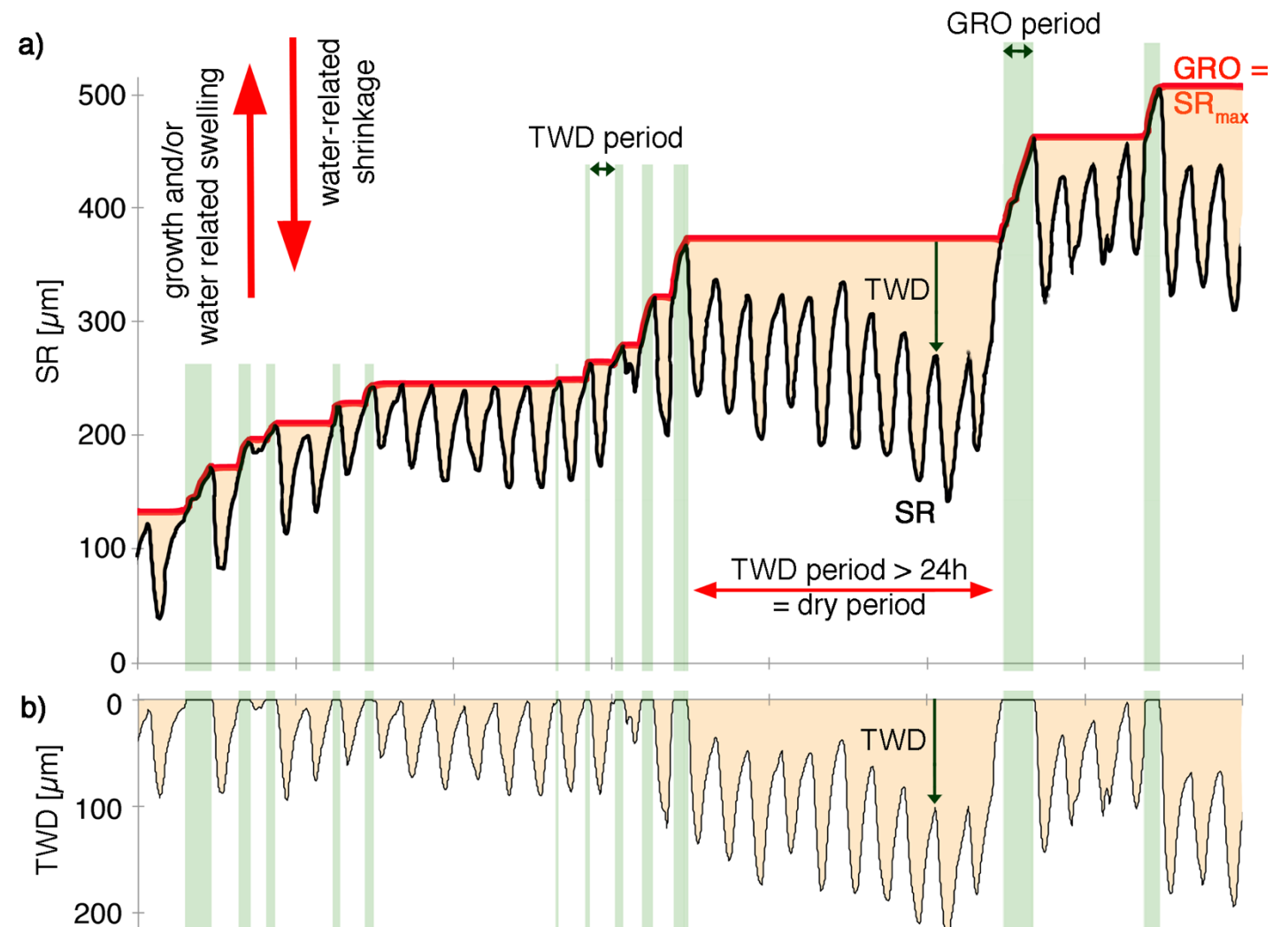
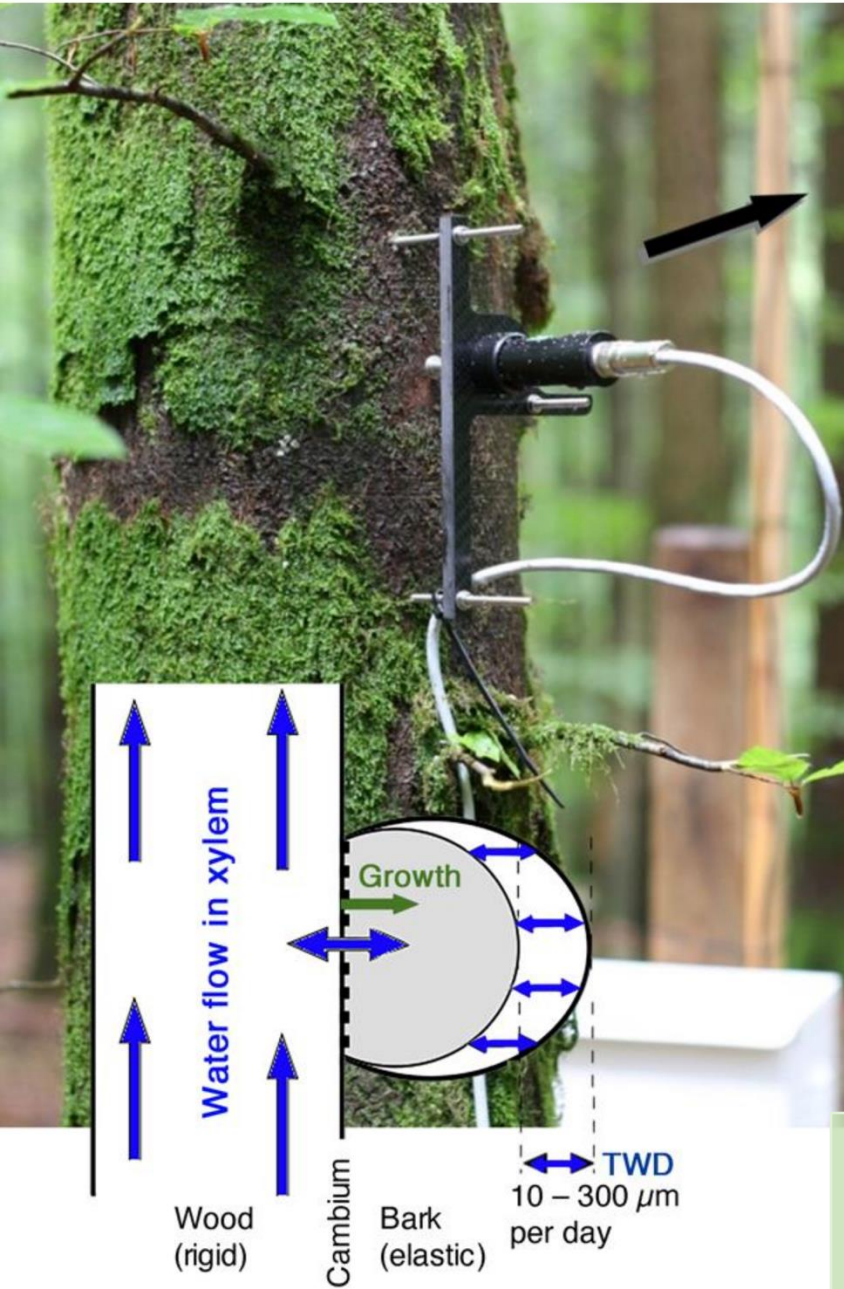
What do the measurements mean?

- new cells (growth, irreversible, GRO)
- water related swelling and shrinkage of bark and wood (reversible, TWD)



GRO: radius increase

TWD: radius increase and decrease according to the water potential gradients in a hydraulic system



**NOVEL chance to relate environmental conditions to growth and TWD
at an hourly resolution**

... and display that in near real-time!

Zweifel et al 2016

TreeNet data levels

L0: raw data

L1: aligned data (10-minute resolution)

L2: auto cleaned time series (GRO, TWD, growth start/end) -> nowcasting data (daily processed)

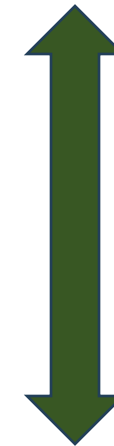
L2_nowcasts: Indices for growth and drought stress

L2M: manually checked and corrected -> scientific data (annually processed)

L3: gap-filled data (ML products under construction)

L4: gridded data (ML products under construction)

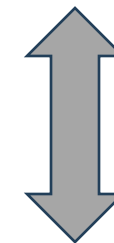
...



Near real-time



Post-processed



?

Access to TreeNet data

-> **Data repositories (Pangea, EnviDat, others)**

-> **TreeNet data portal (ShinyApp)** with login
-> all levels of data

-> **R-package: *treenetproc* access to DB**
-> all levels of data
-> restricted to WSL resp. VPN users

-> **API data exchange** (near real-time)
-> all levels of data

Accessible for ...

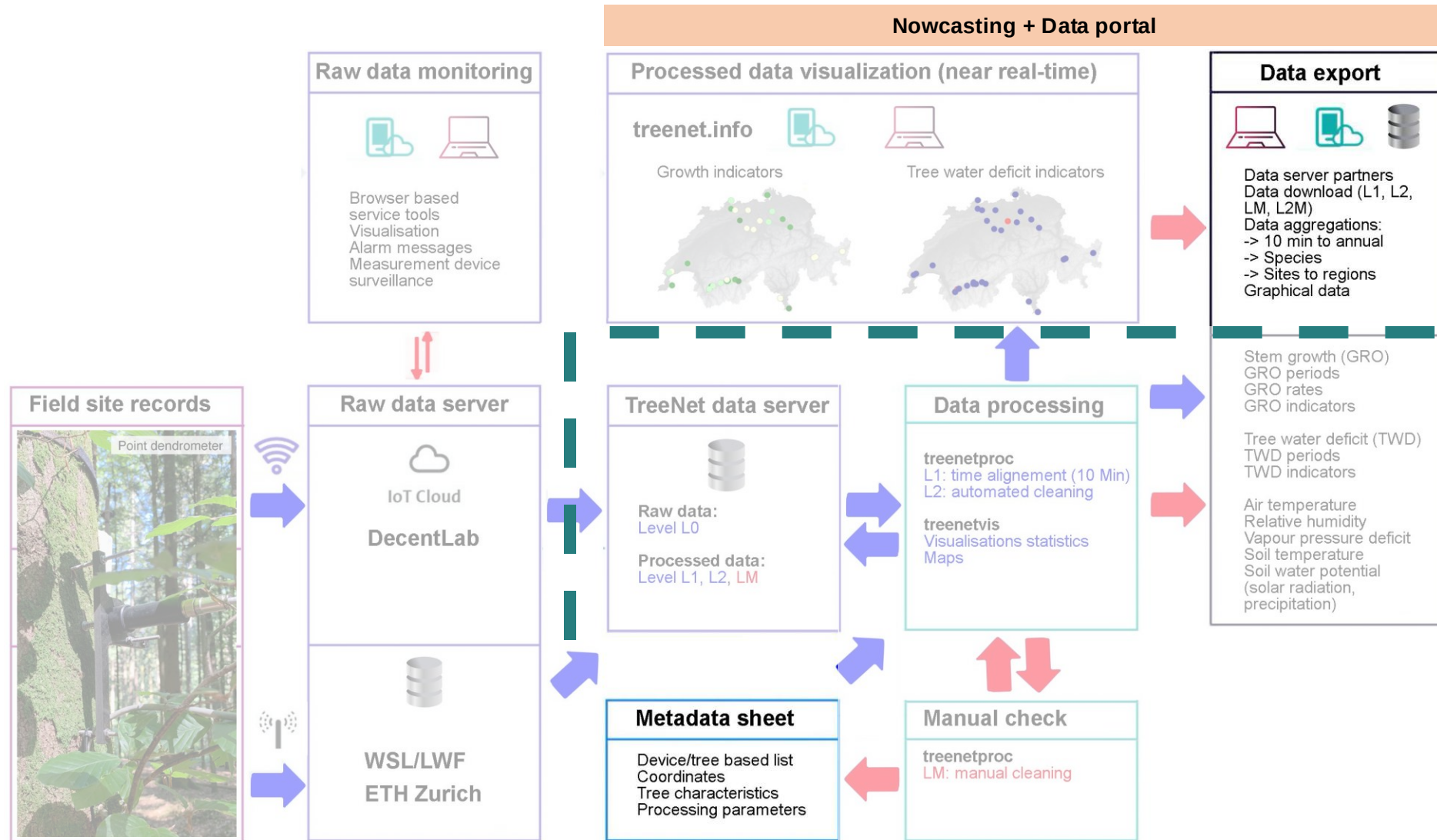
Everybody

Everybody with credentials

With WSL credentials

Customized solution

Externally accessible visualisation and download services



WSL firewall

TreeNet Data flow

Key points

- standardized field methods are the first tiny but important step
- near real-time data transfer
- central server infrastructure incl. metadata table
- standardized cleaning, gap-filling data
- standardized processing from raw data to physiological meaningful variables
- calculate nowcasts (and predictions)
- visualize output (for technicians and public)
- data transfer/export

Whole cascade of steps processed within hours

Fully automated

Standardized processes in near real-time

treenetweb – an R package to calculate nowcasts and visualisations

Tree growth performance (all species)

2022-01-01

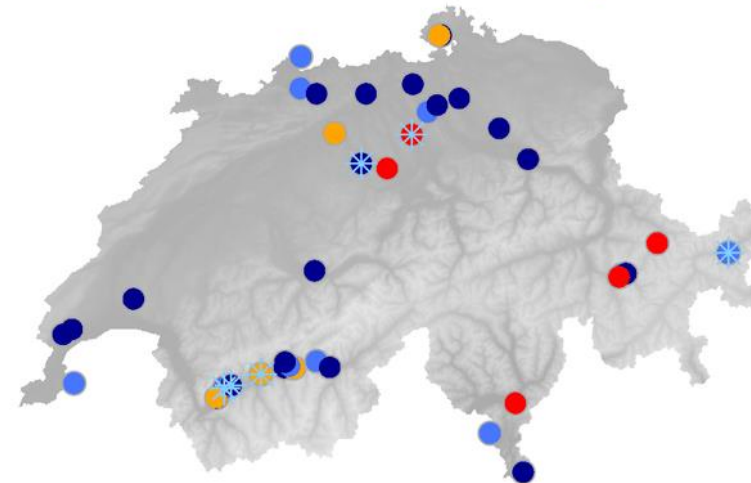
- high GRO
- above avg. GRO
- below avg. GRO
- poor GRO
- dormant



Tree water deficit (all species)

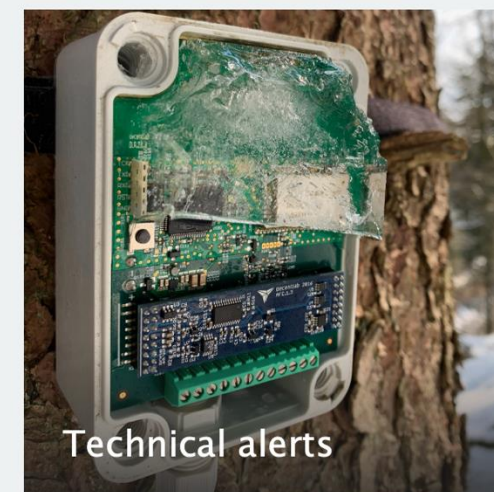
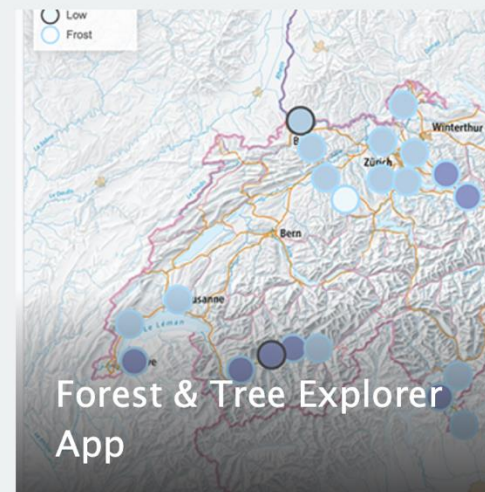
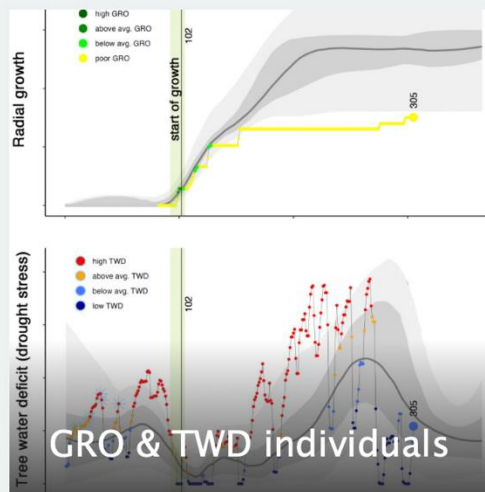
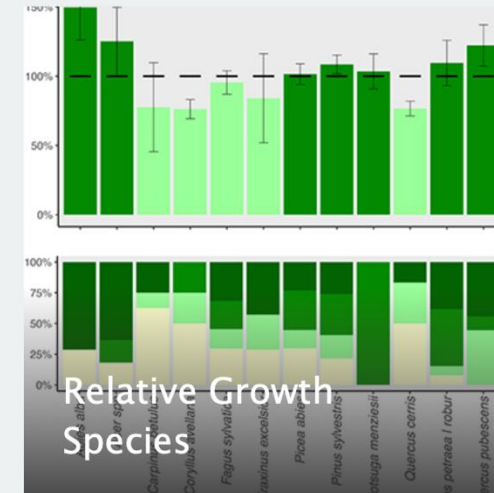
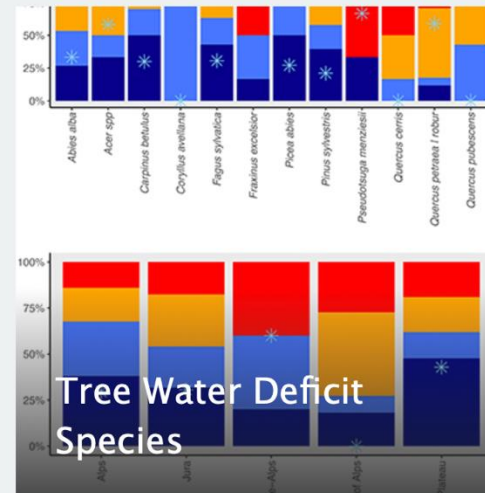
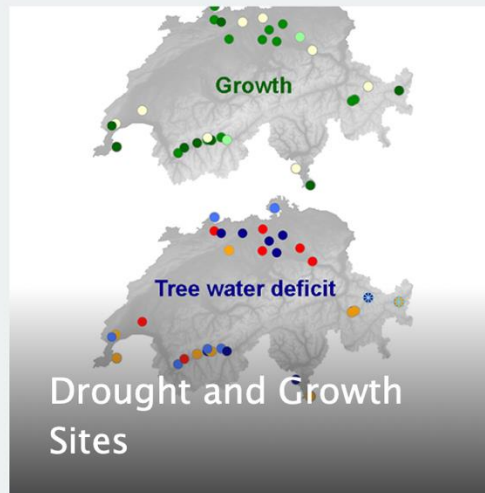
2022-01-01

- high TWD
- above avg. TWD
- below avg. TWD
- low TWD



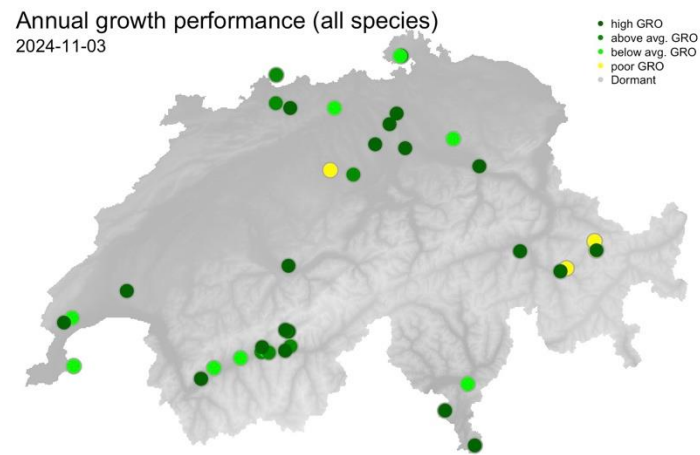
➤ <https://treenet.info/chronicles>

Nowcasts

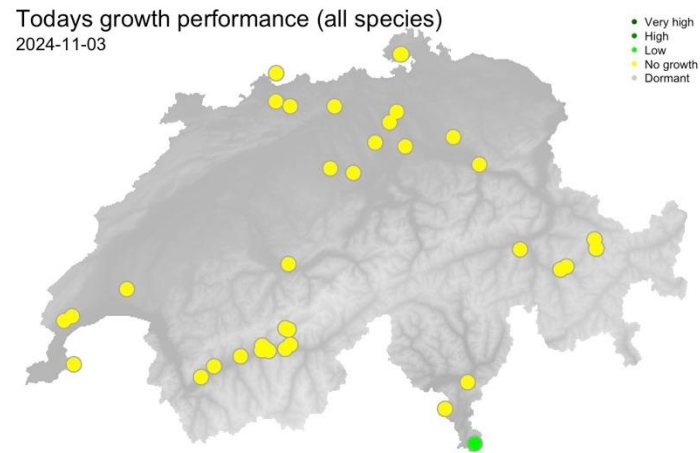


<https://treenet.info/nowcasts>

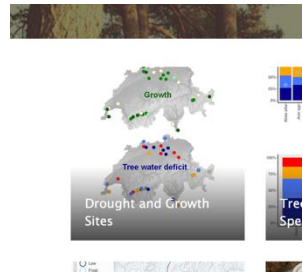
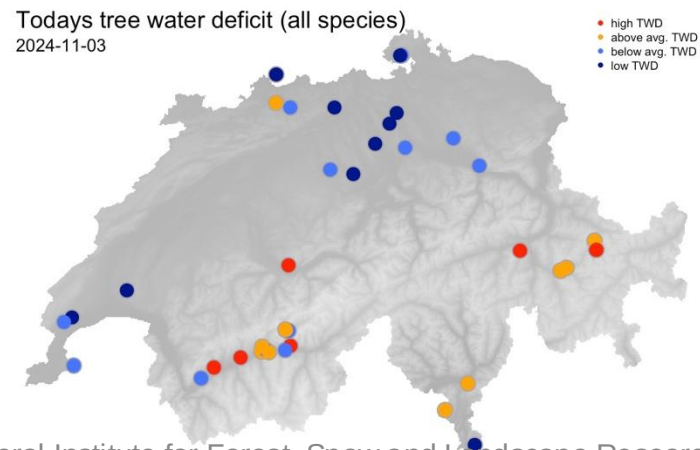
Annual growth



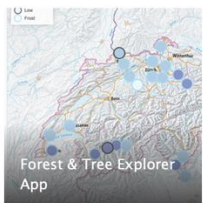
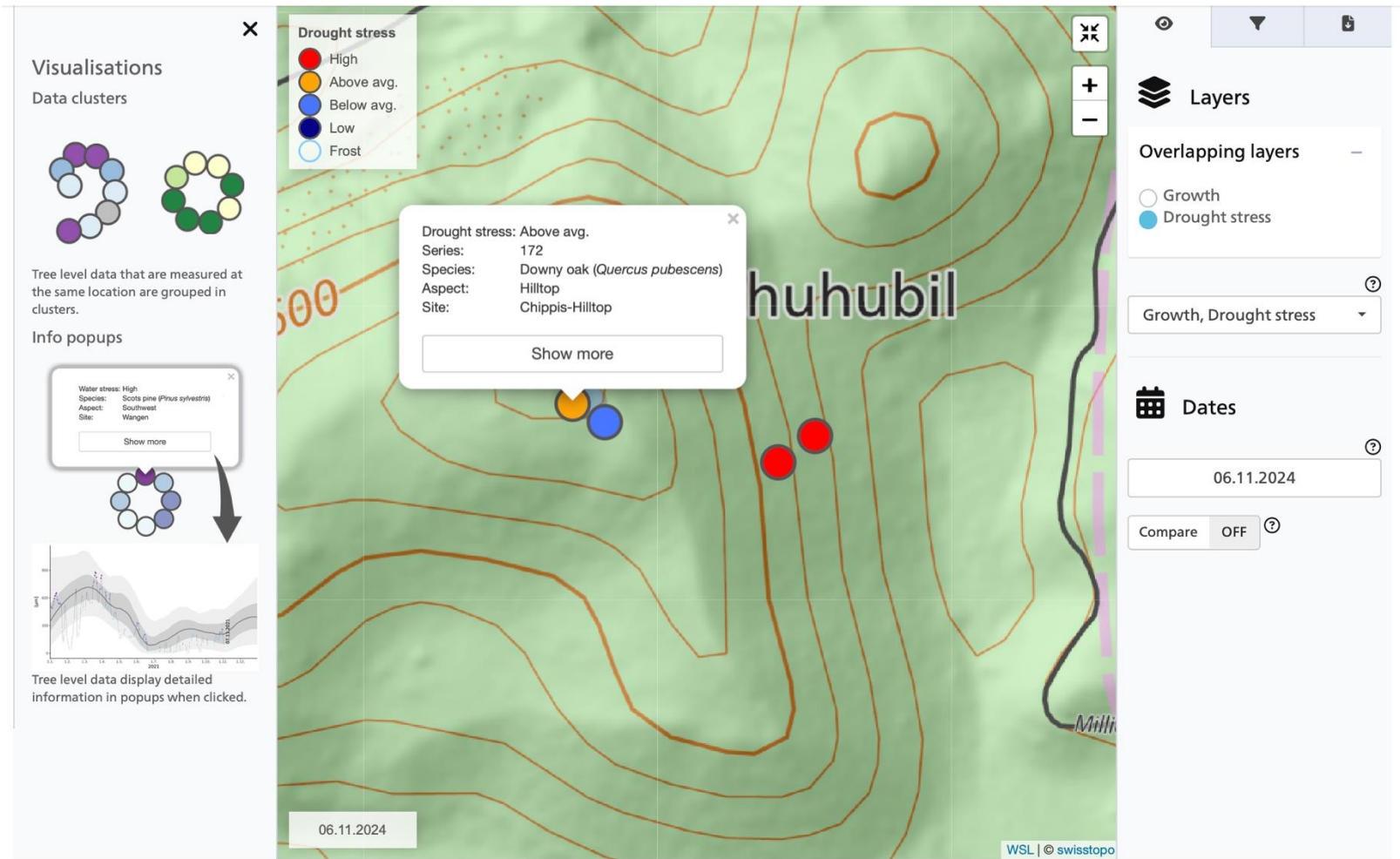
Today's growth



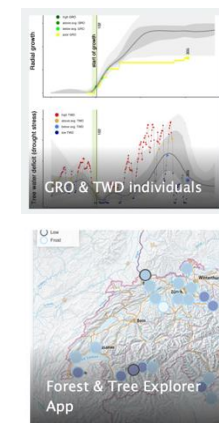
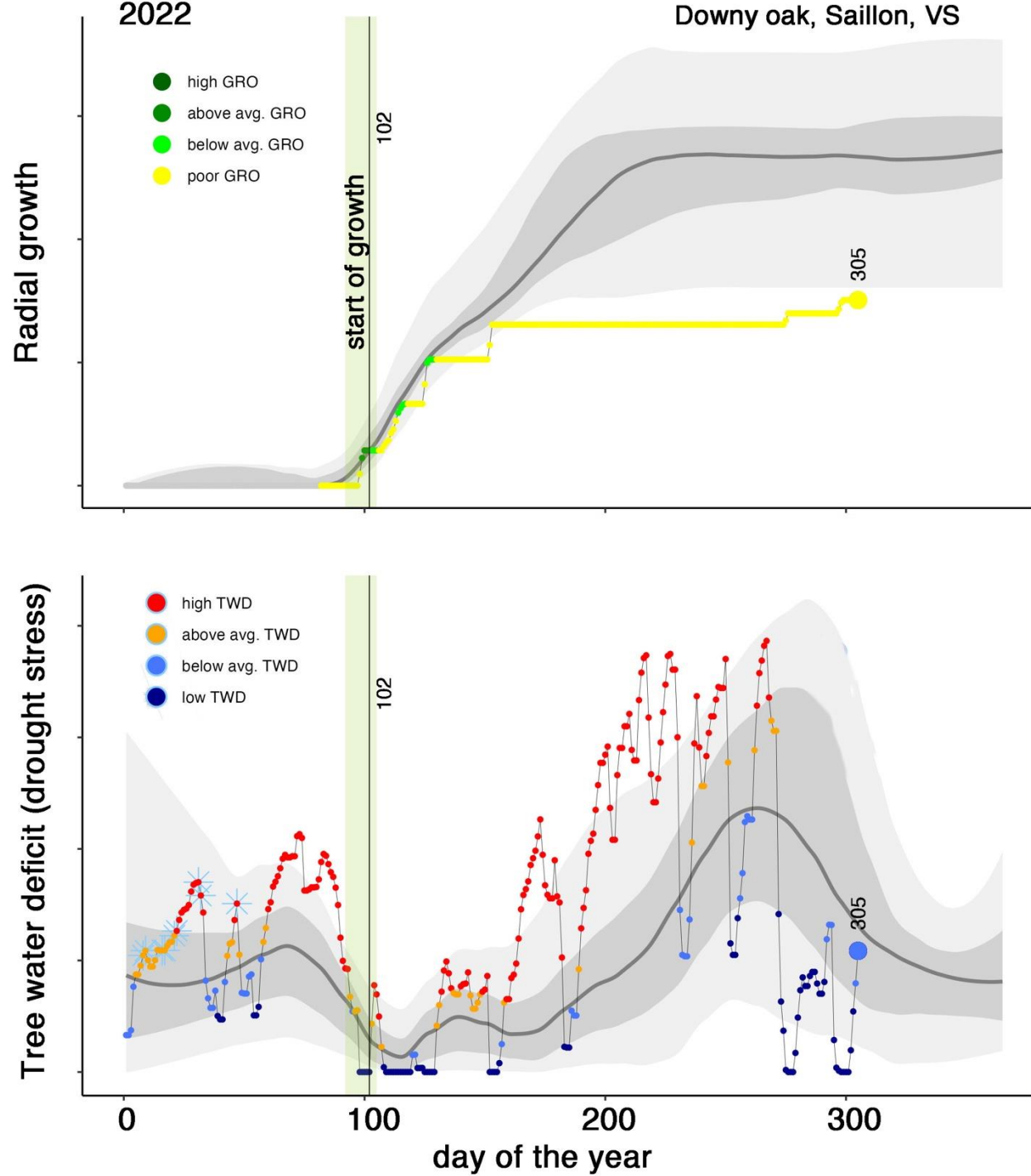
Today's drought stress



<https://treenet.info/nowcasts>

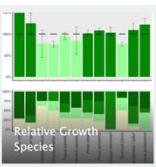
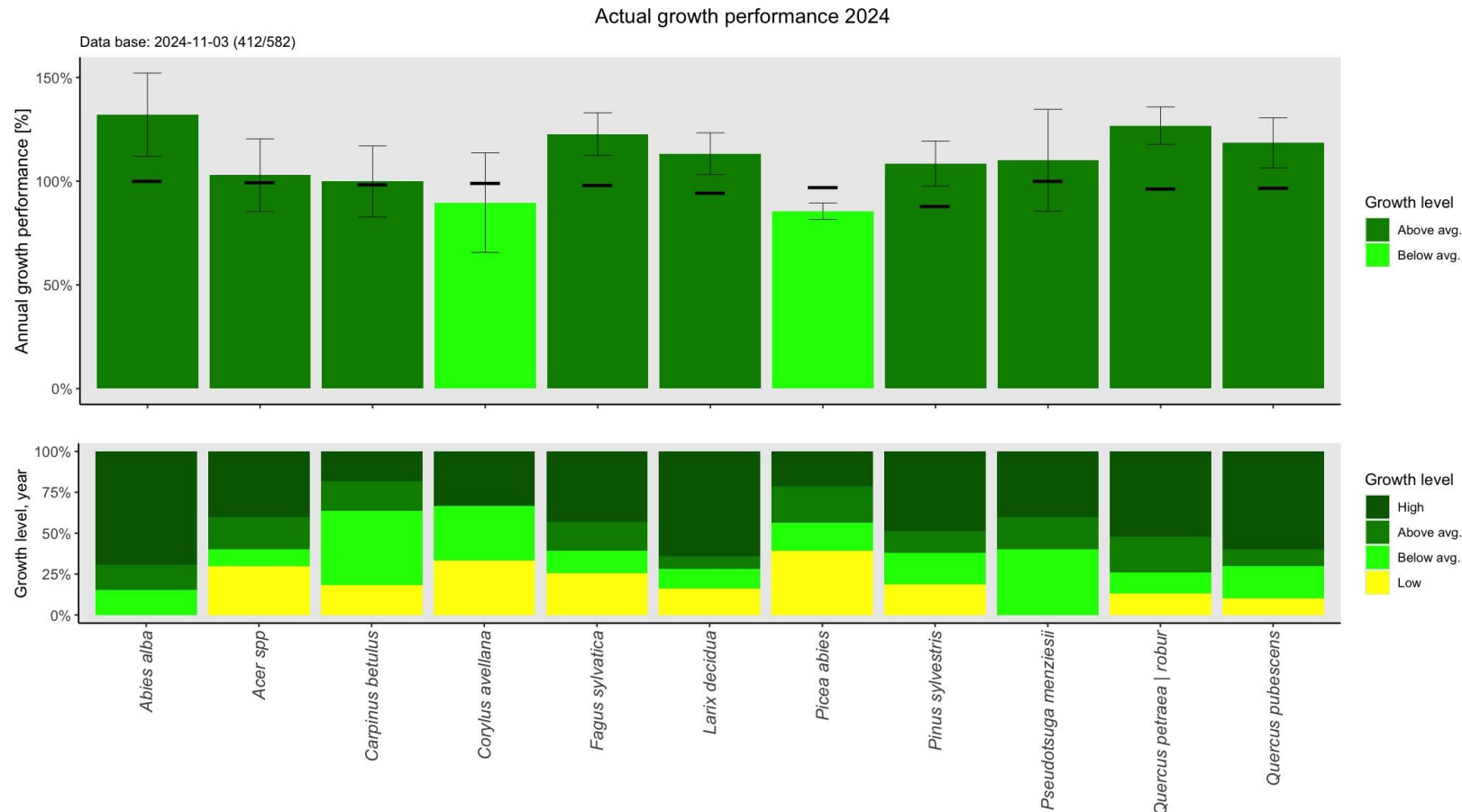


➤ <https://treenet.info/nowcasts>



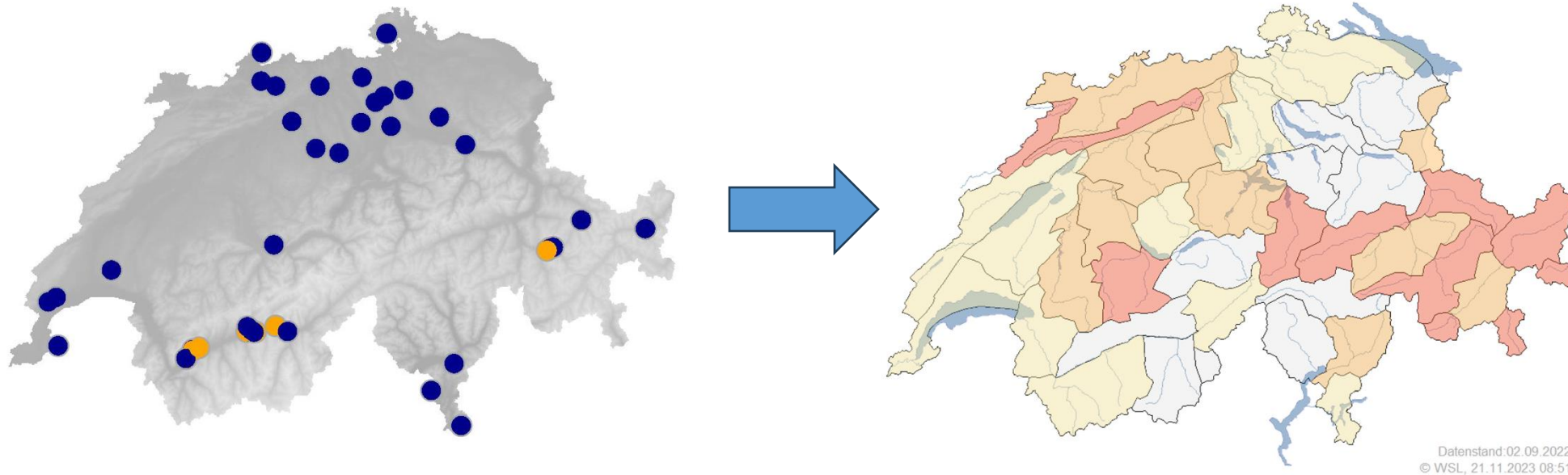
<https://treenet.info/nowcasts>

Exceptionally good growth year 2024!



➤ <https://treenet.info/nowcasts>

TreeNet to provide drought information to the government's new drought warning platform



TreeNet Annual Meeting 2024

WSL, 12 November 2024

09:15 Welcome coffee		
09:40 Introduction & Overview	Who and What is TreeNet today?	
Roman Zweifel	Sites and Partner	
& Micah Wilhelm (WSL)	The TreeNet standard	
	TreeNet data processing platform	
	Recent Output	
	Nowcasting Products	
10:30 National drought warning		
Yannick Barton, BAFU	The new national drought warning and information platform	
11:00 Science with TreeNet (I)	Recent scientific results (Chair: Sophia Etzold)	
Arthur Gessler, WSL	Linking ground based analysis of forest functioning with models and remote sensing products	
Nina Buchmann, ETHZ	Ecosystem greenhouse gas fluxes in a changing climate	
Marius Floriancic, ETHZ	Water dynamics across the soil-plant-atmosphere continuum	
Lorenz Walther, WSL	Coordination between degree of isohydricity and root water uptake in trees	
Andreas Rigling, ETHZ	How to reshape an irrigated forest?	
12:15 Discussion/Questions		
12:30 LUNCH		
13:30 Nowcasting 2.0	TreeNet's machine learning approaches (Chair: Valentina Vitali)	
Mirko Lukovic, WSL	Virtual trees	
Jan Svoboda, WSL	How much rain fills a TWD?	
William Aeberhard, SDSC	From point data to smooth maps	
Frank Sterck, Wageningen Uni	Disentangling VPD and SWP effects on growth	
14:30 Science with TreeNet (II)	Recent scientific results (Chair: Petra D'Odorico)	
David Basler, Uni Basel	Phenological phases from dendrometer data	
Richard Peters, TUM	Relative tree water deficit: An automated dendrometer signal to quantify drought stress in trees	
Colin Bloom, WSL	Can we measure TWD from space?	
Julian Schoch, ETHZ	The night is not long enough: Nighttime root water uptake limits drought stress in oak	
15:30 Discussion/Wrap up		
15:45 Coffee break / End of scientific part		
16:00 TreeNet Partner Board Meeting		
Budget 25		
Data policy and code of conduct		
16:30 End of meeting		

TreeNet Annual Meeting 2024



Thank you!



Sophia Etzold, Dominik Hummel, Frank Sterck, Sabine Braun, Arthur Gessler, Lorenz Walthert, Nina Buchmann, Richard Peters, Ansgar Kahmen, Matthias Häni, Simon Knüsel, Micah Wilhelm, Käthi Liechti, Nicolas De Girardi, Christian Hug, Georg Von Arx, Katrin Meusburger, Marcus Schaub, Andreas Rigling, William Aeberhard, Volodymyr Trotsiuk, Jan Svoboda, Dominik Hummel, Mirko Lukovic and many more ...