

VPDrought

A novel approach to disentangle atmospheric vs. soil drought

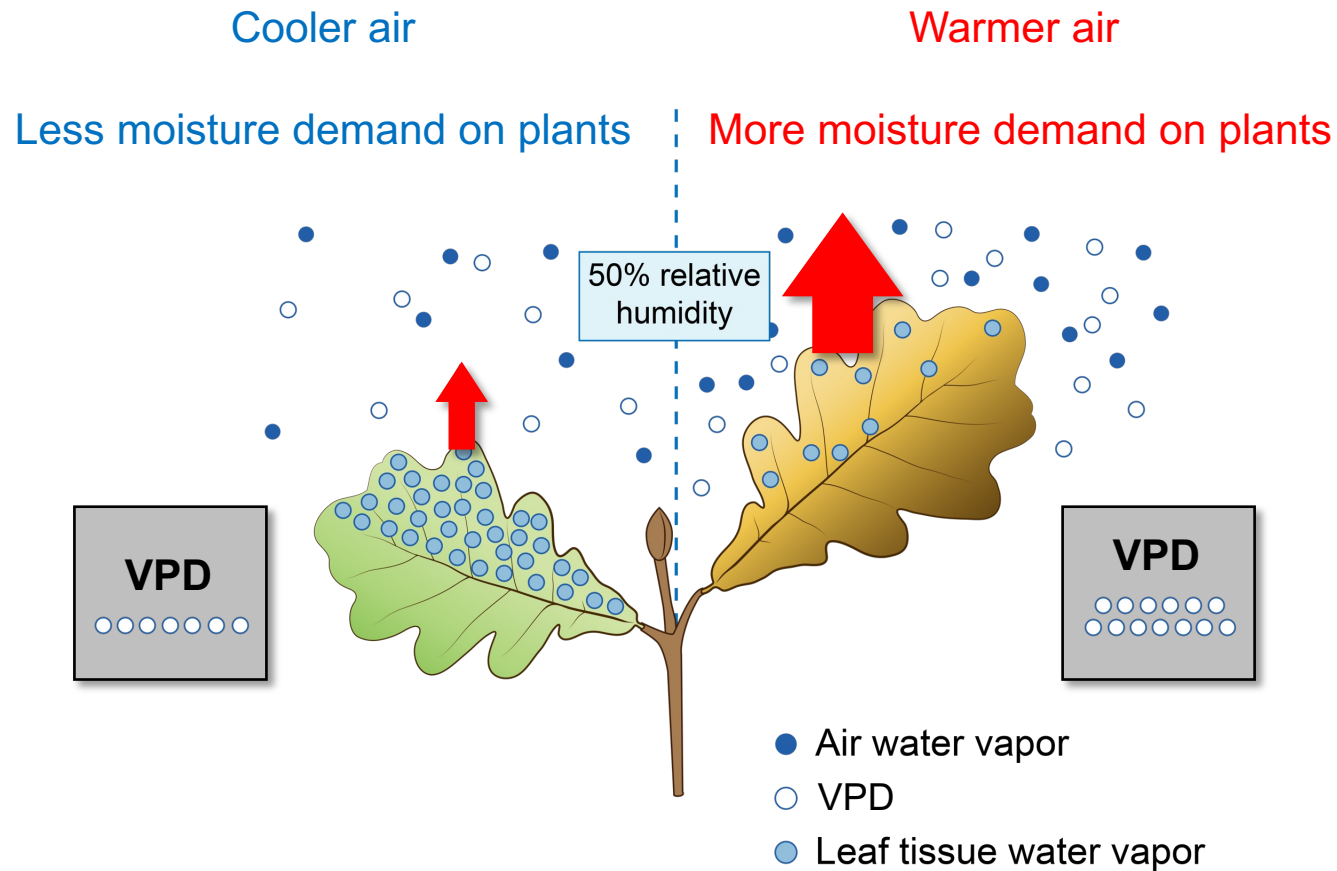
Marcus Schaub
Jonas Gisler
Stefan Hunziker
Volodymyr Trotsiuk
Charlotte Grossiord

EPFL

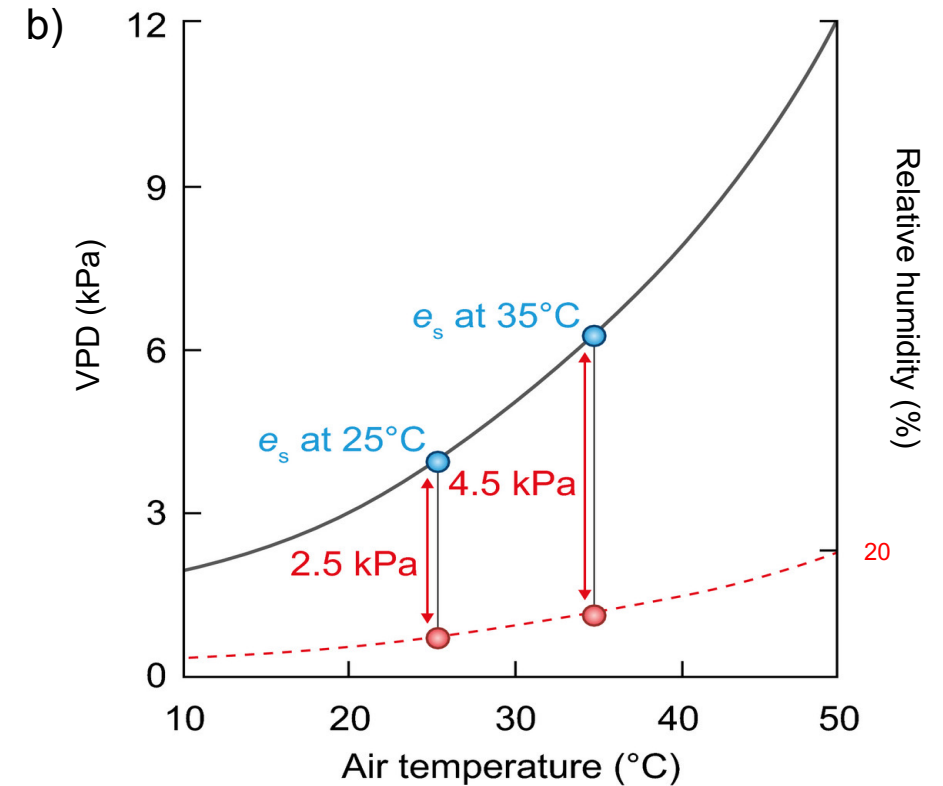


Vapor pressure deficit (VPD)

$$VPD = e_s - e_a = (611 \exp(17.27 \times T / 237.3 + T)) - (RH \times e_s / 100)$$



USGCRP, 2018



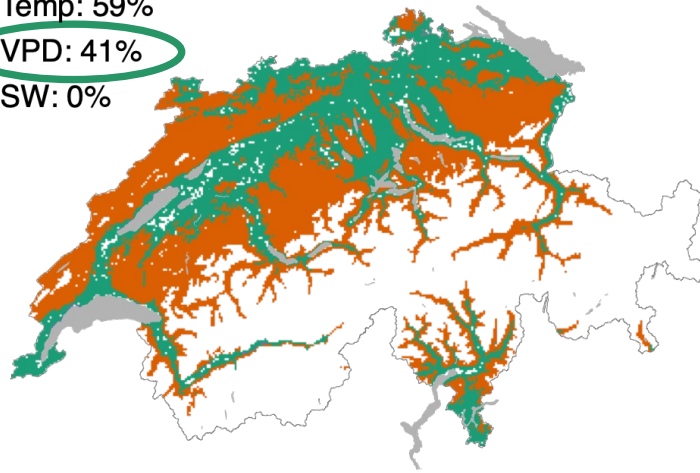
Grossiord *et al.* (2020) *New Phytologist*

Tree growth constraints by T, VPD and SWC in 1991-2018



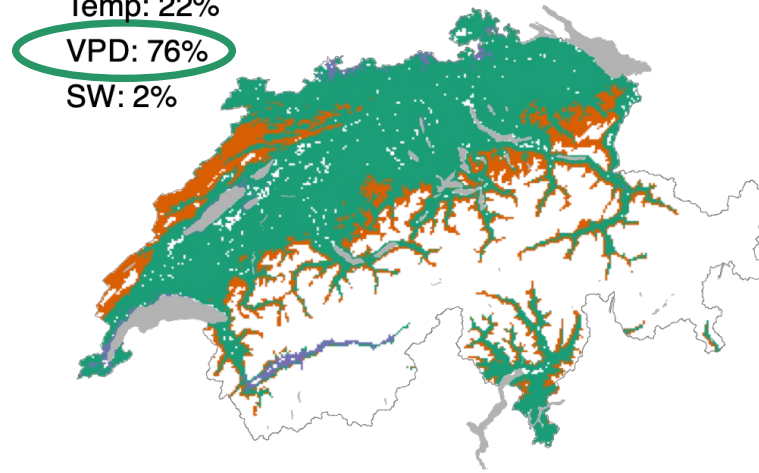
Jun

Temp: 59%
VPD: 41%
SW: 0%



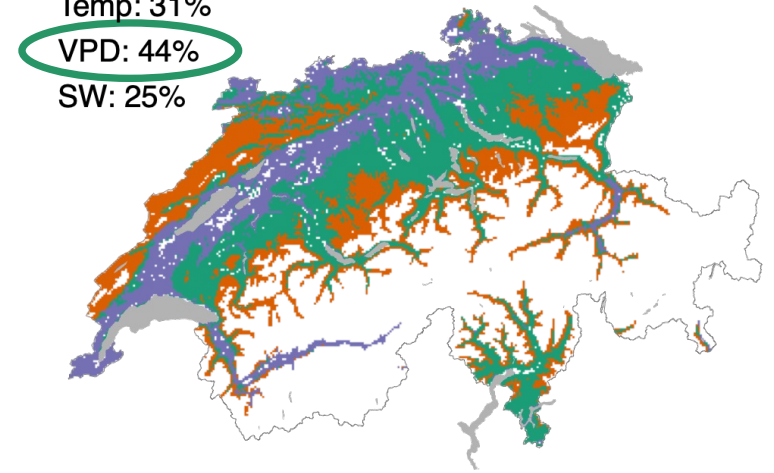
Jul

Temp: 22%
VPD: 76%
SW: 2%



Aug

Temp: 31%
VPD: 44%
SW: 25%



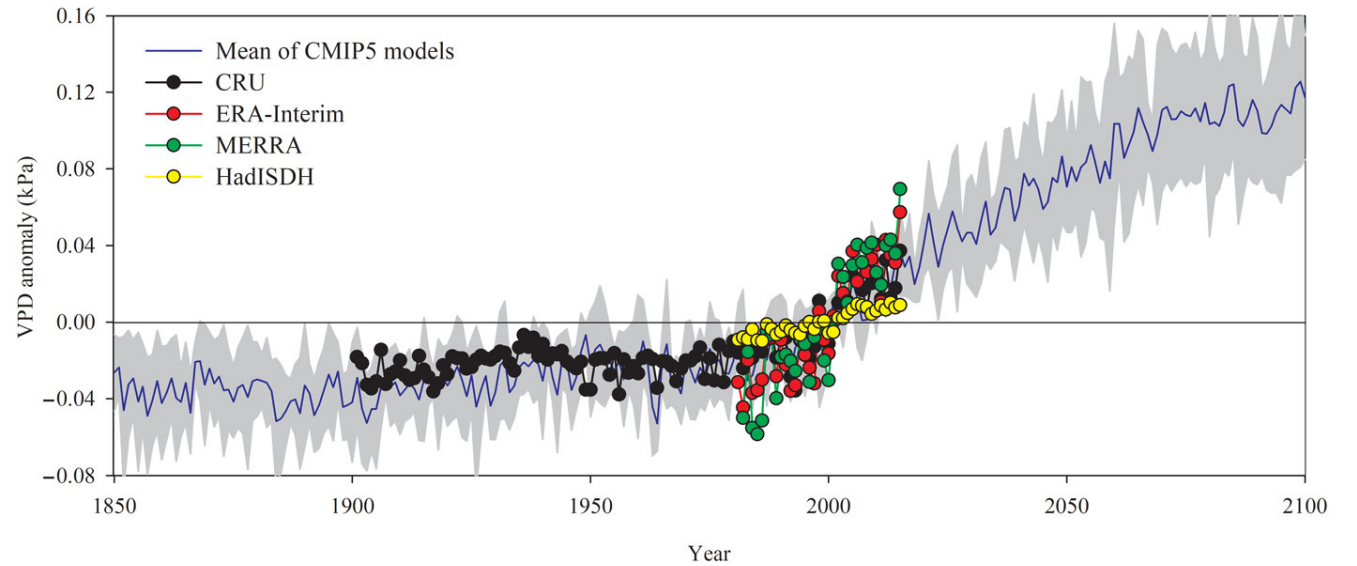
Temperature VPD Soil water

F. sylvatica

Future VPD ...

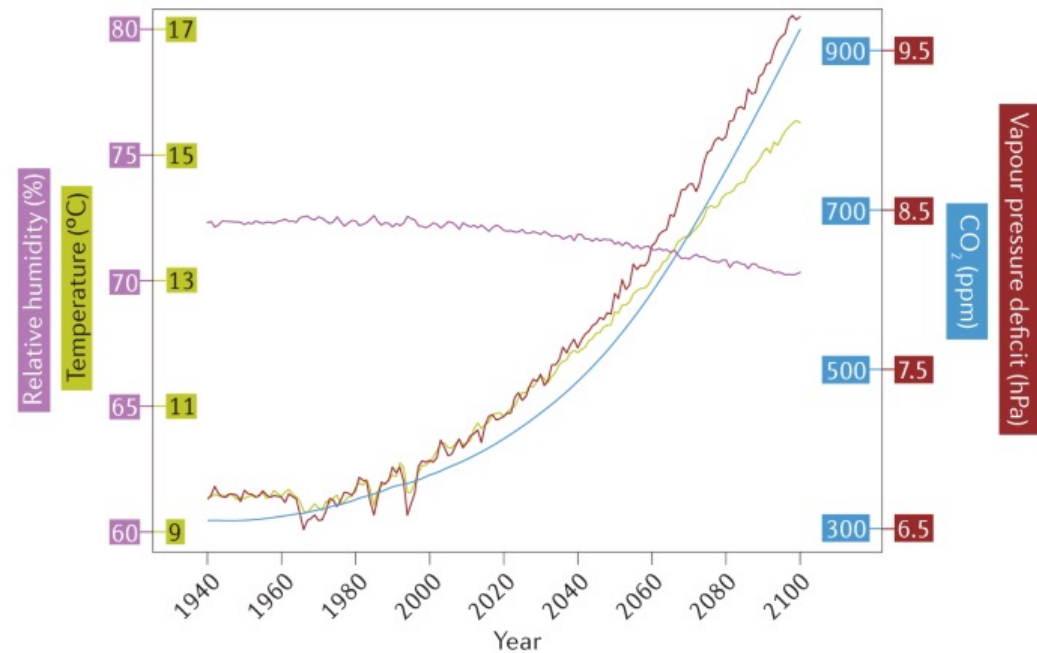
Yuan *et al.* (2019) *Science*

Global mean VPD anomalies – relative to 1982-2015 – of vegetated area over the growing season.



McDowell *et al.* (2022) *Nature*

Average simulated CO₂, T, RH and VPD from 1940 – 2100.



*“How do changes in atmospheric vs. soil drought affect *Pinus sylvestris* from molecular to ecosystem level?”*

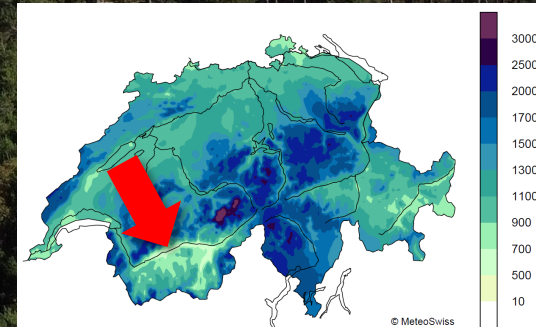
Marcus Schaub & Charlotte Grossiord

VPDrought

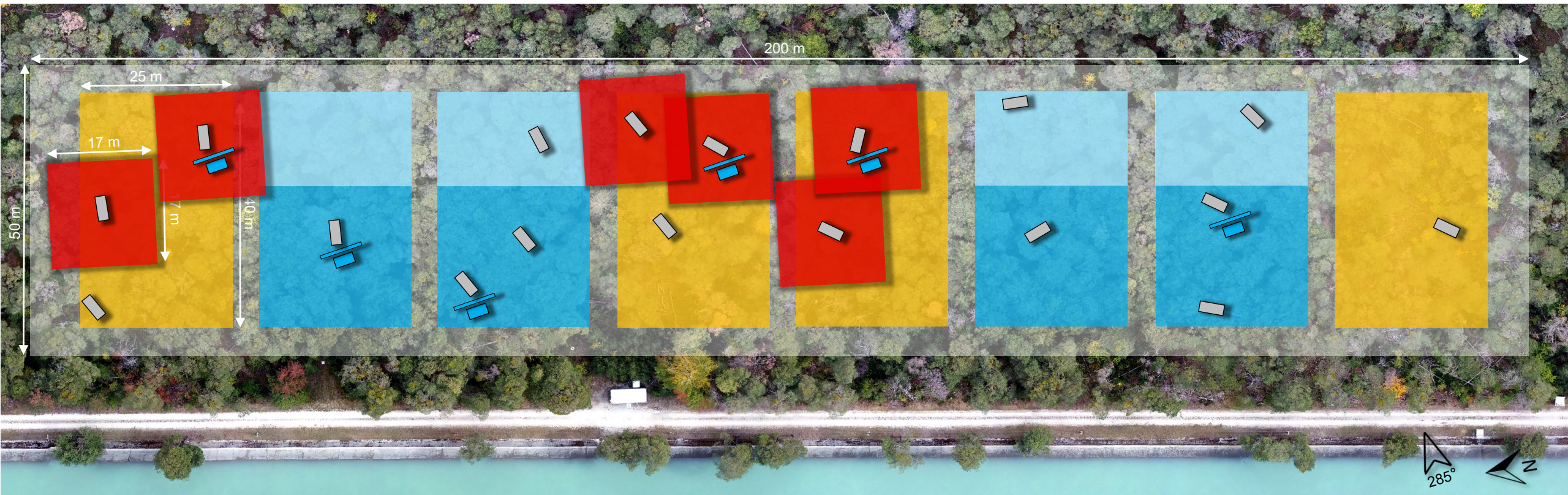
- 2022 Funding
- 2023 Permissions & test system
- 2024-2029
 - Multiple stresses (VPD x SWC)
 - 20-30% VPD reduction
- Processes and ecosystem understanding
- Long-term experimental research platform Pfywald

The Long-term Irrigation Experiment Pfynwald

- Natural, even aged, xeric Scots pine forest in the Rhone Valley
- 876 *Pinus sylvestris* trees / ha
- Natural precipitation < 600 mm/year (driest region in CH)
- Since 2003 irrigation (+ 600 mm/year)
- Since 2014 irrigation-stop on 1/3 of each irrigated plot
- 30 individual tree- & ecosystem-level traits (Bose *et al.* 2021)



Plot design



Soil Treatments

- Control
- Irrigation
- Drought

Irrigation-Stop

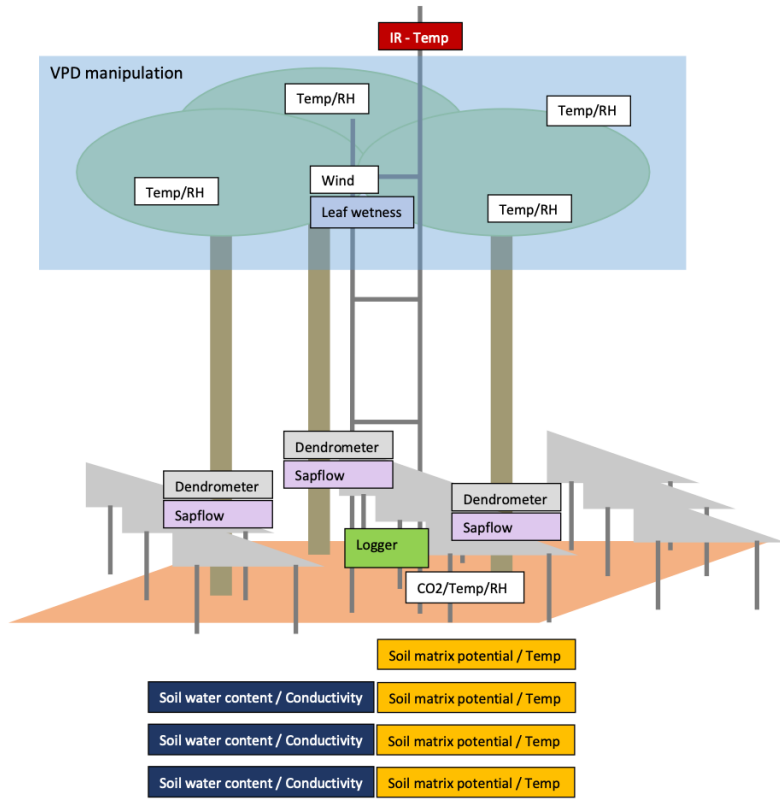
Atmospheric Treatments







- Control
- Reduced VPD

Infrastructure

- 18 Measurement scaffolds
- 6 VPD manipulation scaffolds
- 6 Rainout shelters

Treatment combinations



Atmosphere Soil	Control 	Reduced VPD 
Drought 		
Control 		
Irrigation-Stop 		
Irrigation 		

Example: Drought & Reduced VPD

Replicates: 3 scaffolds x 3 trees

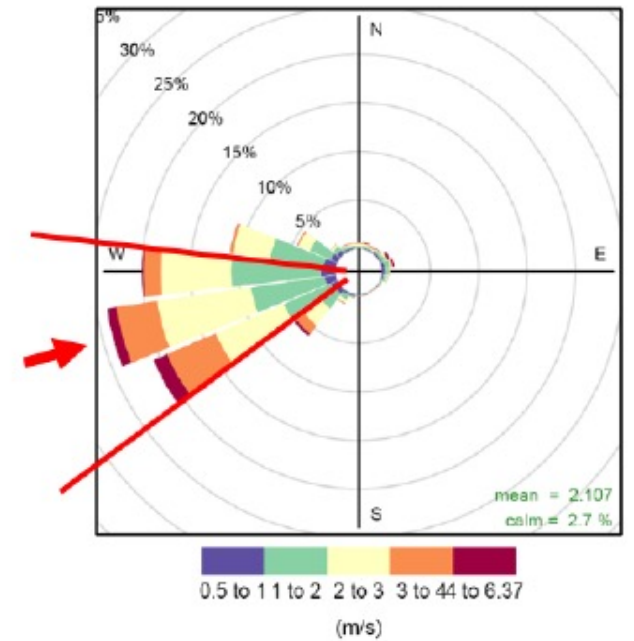
System control

- **VPD = f(T, RH)**
- **Stable wind conditions**
Wind direction: $285^\circ \pm 50^\circ$
Wind speed: $< 0.1 \text{ m/s}$

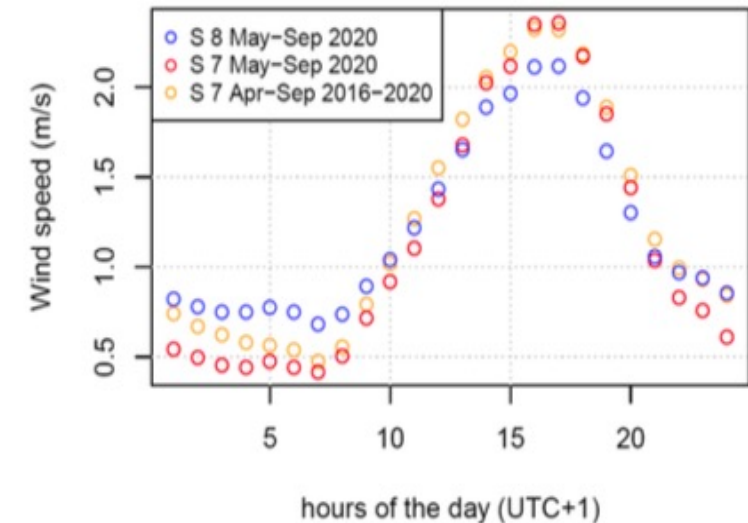
➤ **Continuous adjustment of system**

- **Capacity:** $1.5 - 10 \text{ L/m}^2/\text{h}$
- **Dimension:** $5 \times 10 \text{ m}$ nozzle field

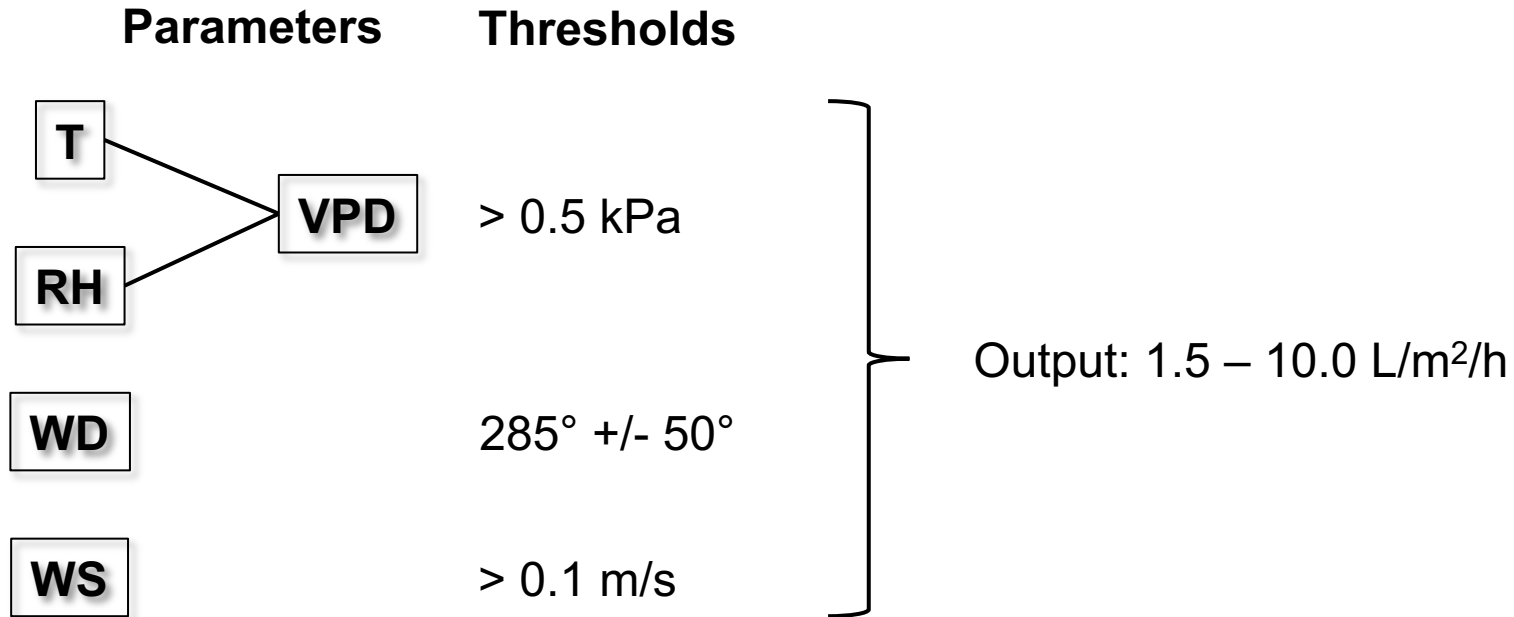
Wind direction at 15-16 UTC+1



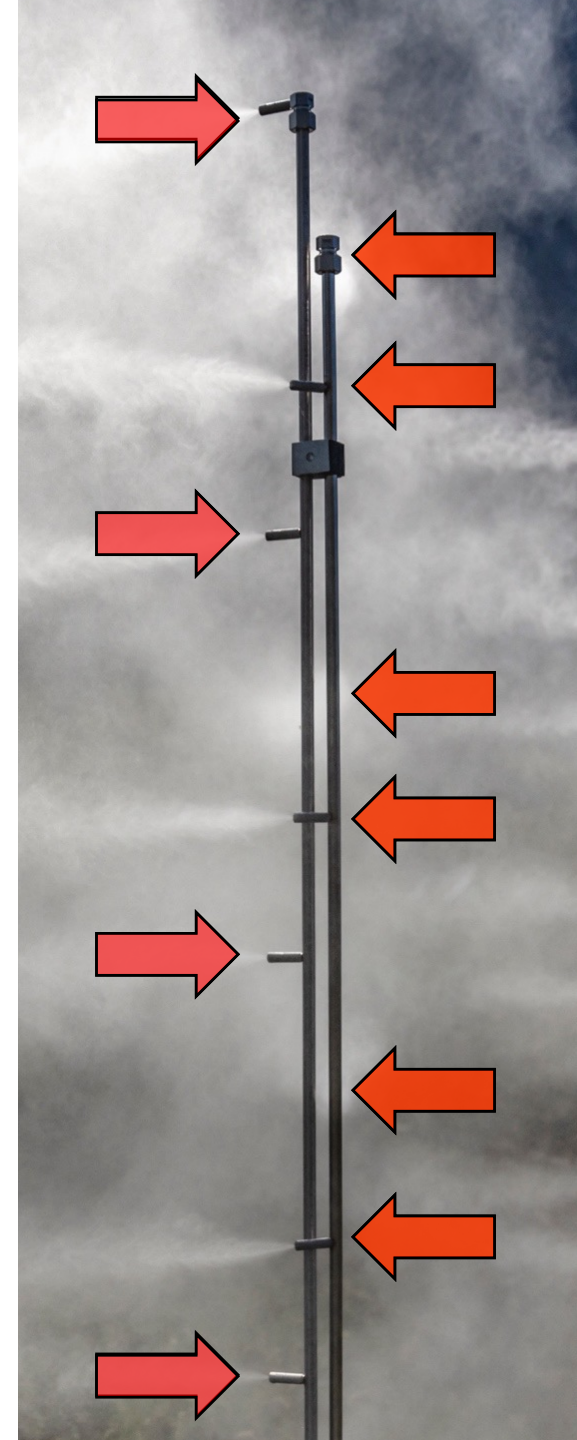
Diurnal wind speed



System control parameters



Level	Circle	Pressure (bar)	Output (l/m ²)
1	1	70 – 150	1.5 – 3.5
2	2	70 – 150	3.6 – 6.5
3	2 & 1	70 – 150	6.6 – 10.0











VPDrought - Anlagensteuerung

Disabled [-152x0] Überstromschutzklemme 5 Reserve

07.09.2023 13:10:14

Web-Cam 1 5 A WSL ksa

Umkehrosiose Hochdruck Bewässerung SC-Felddaten Logger-Status I/O-Signale Meldungen Allgemein

VPD

Sens Min	Sens Max	TA SC16	RH SC16	TA SC17	RH SC17	TA SC1	RH SC1
14.7 °C	25.17 °C	26.52 °C	26.74 %	27.19 °C	27.66 %	26.52 °C	26.49 %
Sens Min	Sens Max	TA avg	RH avg				
11.7 °C	16.03 °C	26.75 °C	26.62 %				
VPD AVG							
21.4 hPa							
Length	Weight						
10	1.00						
TH_OFF	TH_ON	VPD Trend					
0.30	0.34	1.00					

WD

Sens Min	Sens Max	WD SC16	WD SC15	WD SC14	WD SC12	WD SC6	WD SC10
0 °	360 °	232 °	190 °	209 °	253 °	222 °	188 °
Limit Min	Limit Min	Limit Min	Limit Min	Limit Min	Limit Min	Limit Min	Limit Min
0 °	0 °	230 °	0 °	0 °	0 °	0 °	0 °
Limit Max	Limit Max	Limit Max	Limit Max	Limit Max	Limit Max	Limit Max	Limit Max
360 °	360 °	330 °	360 °	360 °	360 °	360 °	360 °
Length	Weight						
10	1.00						
TH_OFF	TH_ON	Trend 1	Trend 2	Trend 3	Trend 4	Trend 5	Trend 6
0.30	0.34	1.00	1.00	0.42	1.00	1.00	1.00

WS

Sens Min	Sens Max	WS SC16	WS SC15	WS SC14	WS SC12	WS SC6	WS SC10
0.0 m/s	30.0 m/s	0.5 m/s	0.3 m/s	1.0 m/s	0.3 m/s	0.2 m/s	0.3 m/s
Limit							
0.10 m/s							
Length	Weight						
10	1.00						
TH_OFF	TH_ON	Trend 1	Trend 2	Trend 3	Trend 4	Trend 5	Trend 6
0.20	0.34	1.00	1.00	1.00	1.00	1.00	0.85

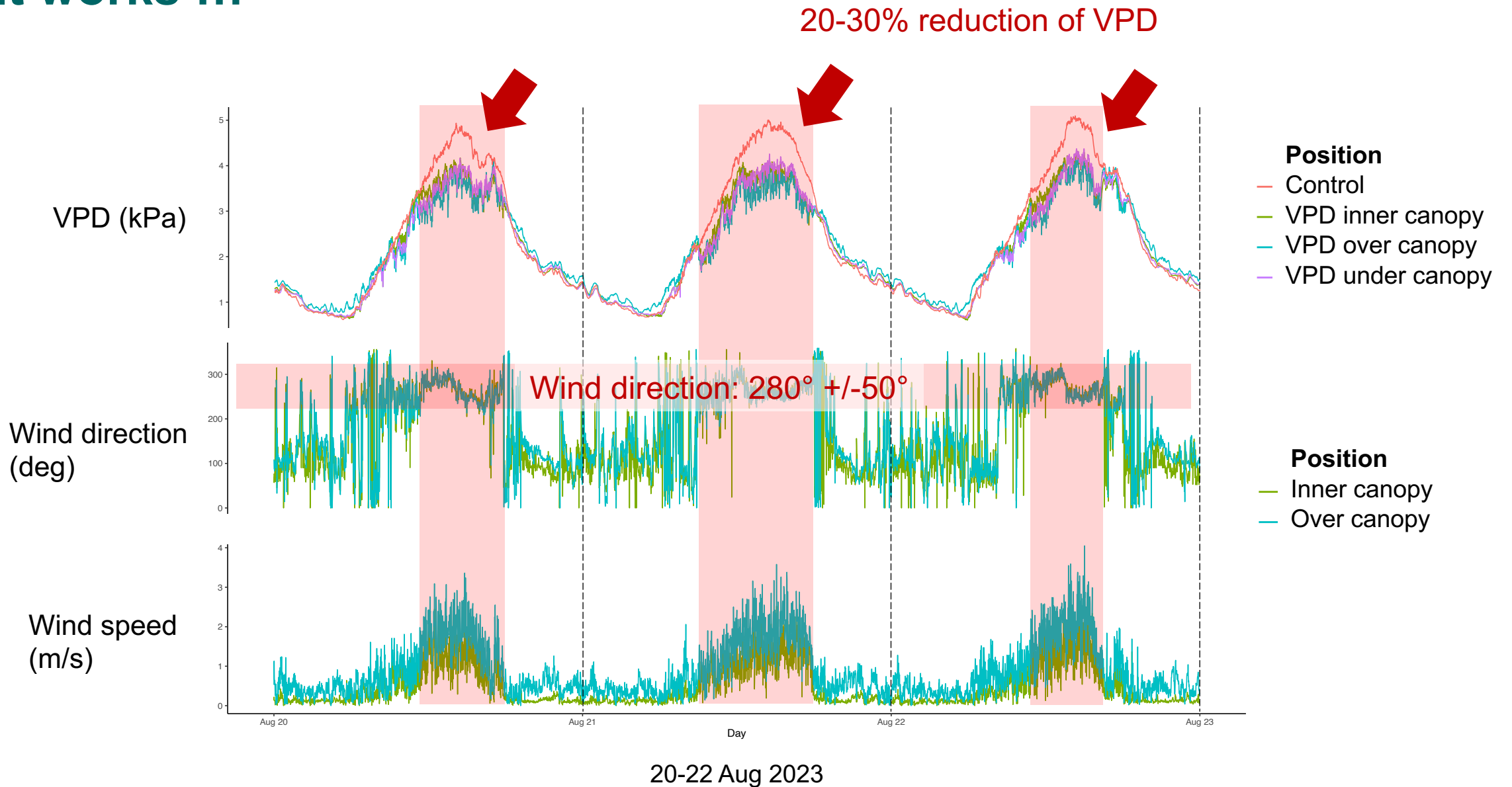
Water Calc

Duesencalc Parameter			Input					
NozzleDist	NozzleDist S1	NozzleDist S2	VPD RED	TA	RH	VPD	WS	
1.400 m	0.700 m	0.300 m	95.0 %	26.75 °C	38.63 %	21.55 hPa	0.39 m/s	
NozzleCount	NozzleCount S1	NozzleCount S2	VPDred					
8	10	16	TA	RH	VPD	Water add		
Pressure Min	Pressure Max	L/hm2 Min	17.30 °C	94.55 %	1.08 hPa	5.93 L/hm2		
70.0 Bar	130.0 Bar	1.48 L/hm2	V1	V2	V3	Pump Pressure	Water add Total	Water add
V1 Enable	NozzleCount V3	L/hm2 Max	1	1	1	124.2 Bar	595.7 L/h	5.93 L/hm2
1	52	6.51 L/hm2	Backtrack					
			VPD RED	TA	RH	VPD		
			95.01 %	17.30 °C	94.55 %	1.08 hPa		

BECKHOFF



It works ...



... the soil-plant-atmosphere-continuum

