Quantifying and revisiting canopy stomatal conductance above the maritime pine FR-Bil ICOS station, France

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Experimental design

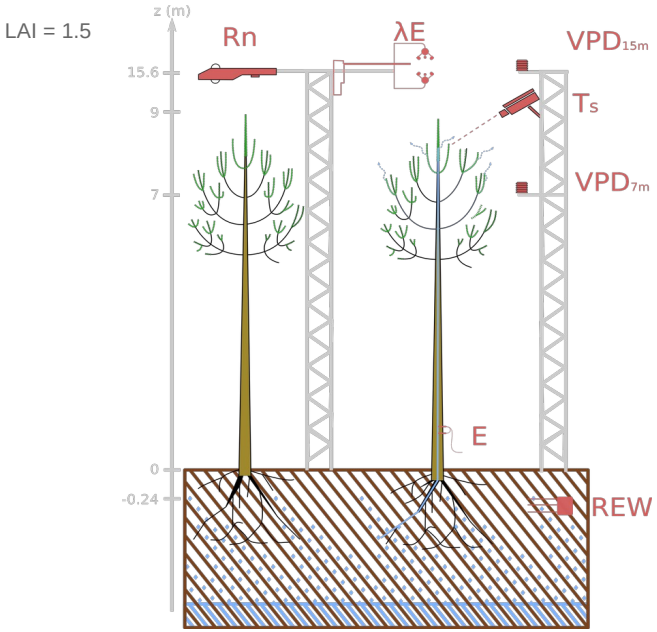
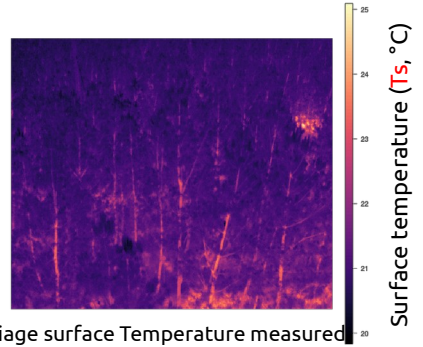


Figure 1: Description of the instrumentation used in the calculation of the different stomatal conductance (g_s):

- net radiometer (CNR4, KippZonen, Netherlands)
- Vapour pressuredeficit (VPD),Temperature and relative humidity profile (HMP155 probes, Vaisala, Finland)
- soil moisture content (hydraprobe, Stevens, USA)
- Half-hourly latent heat flux (HS50, Gill, UK and CO_2 /H_2O analyser LI-7200, Licor, USA).



Foliage surface Temperature measured from a high resolution infrared camera (sc 655, Flir camera). We calibrated the camera output with the use of a reference target equipped with 16 taped thermocouples.

Tree transpiration (E) was measured with Granier-type sap flow sensors (30mm sensors, Dynamax, USA) installed on six trees. Sap flow density was corrected to account for radial variability (Delzon, 2004). Stand water use was then calculated by scaling up using whole stand sapwood to ground area ratio.

Penman-Monteith inversion

(Granier and Loustau, 1994)

$$\frac{1}{g_s}=\frac{1}{g_a}\left(\frac{s}{\gamma}\frac{Rn_{15m}}{\lambda\cdot E}-1\right)+\frac{\rho_a\cdot c_p\cdot VPD_{15m}}{\gamma\cdot\lambda\cdot E}$$

Water transport equation

$$g_s=\frac{1}{0.662\cdot\rho_a}\frac{P\cdot E}{VPD_{leaf-air}}$$

$$with: VPD_{leaf-air}=e_s(T_s)-e(T_{7m})$$

Simplified water transport equation

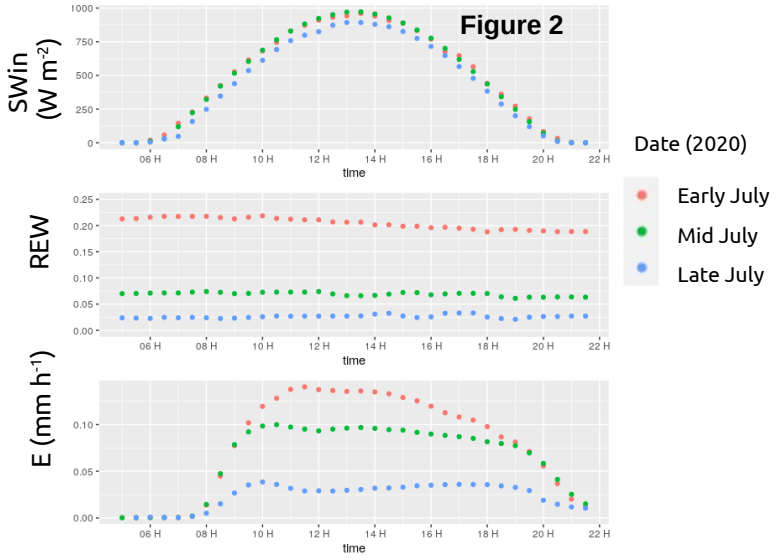
(Phillips and Oren, 1998)

$$g_s=\frac{K_G(T_{7m})\cdot E}{VPD_{7m}}$$

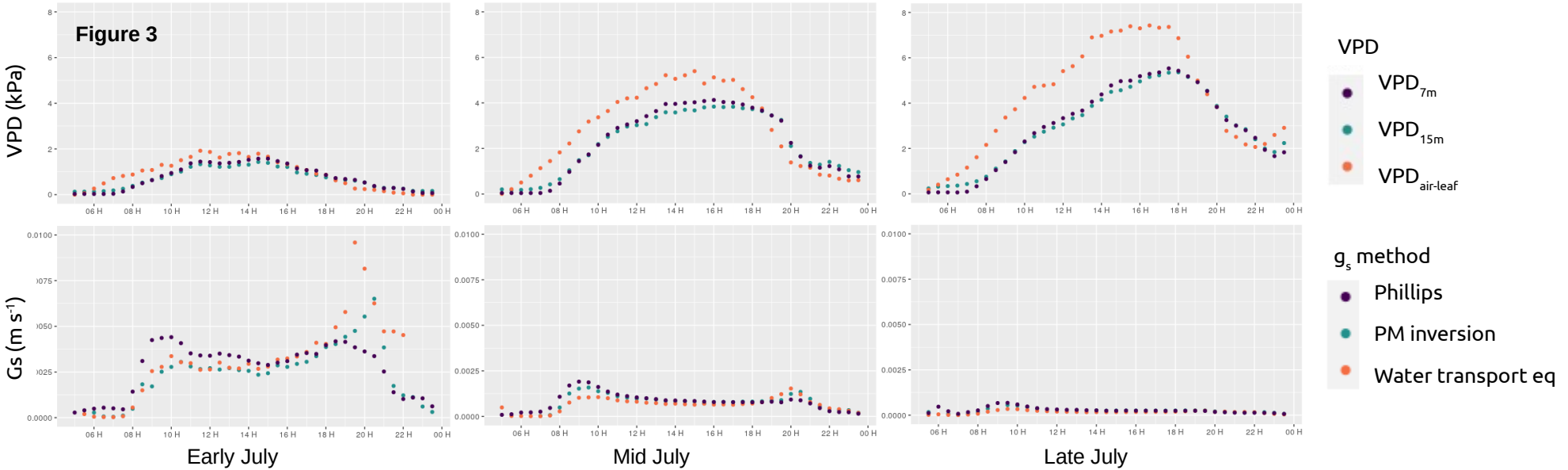
$$with: K_G(T)=115.8+0.4236T$$

P : atmospheric pressure (Pa)
ρ_a : air density (kg m^{-3})
γ : psychrometric constant (Pa $°C^{-1}$)
s : slope vapor pressure curve (Pa $°C^{-1}$)
λ : latent heat of vaporization (Pa $°C^{-1}$)

Results



- Large differences in flux where observed between the beginning and the end of July as relative extractable water (REW) decreased (figure 2).
- Stomatal conductances were correlated with incoming short-wave (SWin) radiation and REW.
- Most of the differences in the calculated g_s appeared just after dawn and just before sunset (figure 3). Using the air VPD instead of the air-to-leaf VPD overestimates g_s in the morning $VPD_{air\text{-}leaf}$, values in early and late July were 0.5 and 2 kPa higher than either VPD_{7m} or VPD_{15m}, respectively, and underestimates it in the evening.



Results

Table 1: $g_{s,max}$ and g_s sensitivity to VPD based on water transport equation and $VPD_{air\text{-}leaf}$

REW	$g_{s,max}$ ($m\ s^{-1}$) (g_s at VPD =1)	g_s sensitivity to VPD ($m\ s^{-1}\ ln(kPa)^{-1}$) (slope)	r^2
0.3 ≤ REW	1.6x10-2	-1.8x10-3	0.81
0.2 ≤ REW < 0.3	1.5x10-2	-1.6x10-3	0.63
0.1 ≤ REW < 0.2	1.2x10-2	-1.3x10-3	0.62
0.05 ≤ REW < 0.1	8.1x10-3	-9.1x10-4	0.74
0.01 ≤ REW < 0.05	4.0x10-3	-4.7x10-4	0.33

Table 2: $g_{s,max}$ and g_s sensitivity to VPD based on the Penman-Monteith inversion using VPD_{15m}

REW	$g_{s,max}$ ($m\ s^{-1}$) (g_s at VPD =1)	g_s sensitivity to VPD ($m\ s^{-1}\ ln(kPa)^{-1}$) (slope)	r^2
0.3 ≤ REW	$1.7x10^{-2}$	$-2.0x10^{-3}$	0.74
0.2 ≤ REW < 0.3	$1.3x10^{-2}$	$-1.4x10^{-3}$	0.82
0.1 ≤ REW < 0.2	$1.2x10^{-2}$	$-1.3x10^{-3}$	0.73
0.05 ≤ REW < 0.1	$8.1x10^{-3}$	$-9.4x10^{-4}$	0.56
0.01 ≤ REW < 0.05	$5.7x10^{-3}$	$-7.1x10^{-4}$	0.56

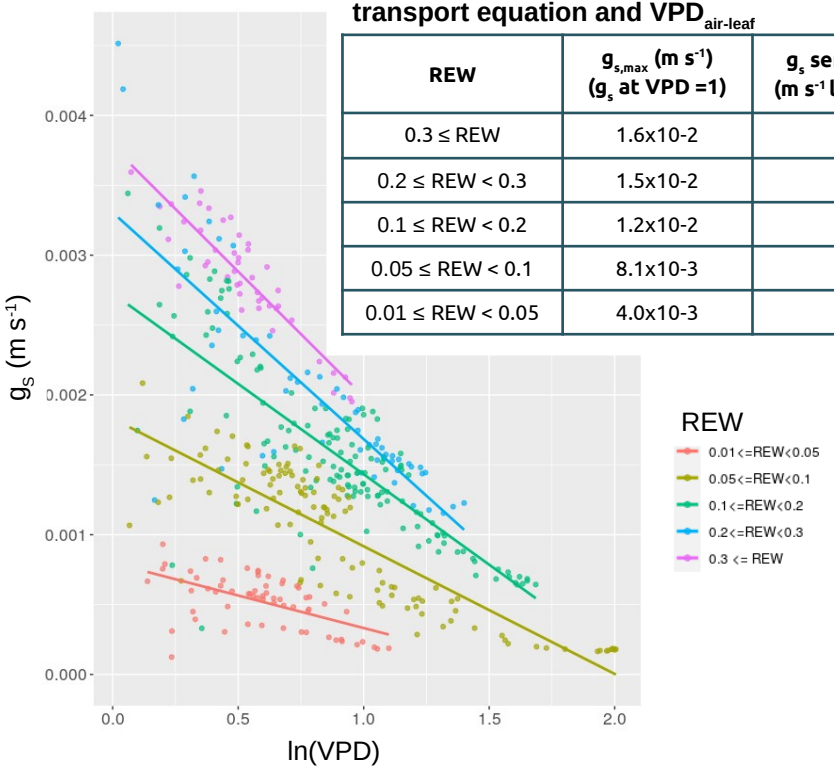


Figure 4: g_s as a function of ln(VPD) based on Oren et al. (1999)

Conclusions

- $g_{s,max}$ and g_s sensitivity to VPD decreased with decreasing REW (table 1, figure 4).
- Using the foliage surface temperature for calculating the canopy stomatal conductance leads to substantially different results than the classical inversion of the Penman-Monteith equation. Specifically absolute values of stomatal conductance differ during morning and evening.
- Those results emphasized the need to accurately determine leaf temperature and leaf-to-air VPD for ecophysiologicals surveys.

Refs

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