Observed and modelled transpiration cooling from urban trees in Mainz, Germany

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WSL

Objective

- Examine transpiration-induced cooling effect of a few urban trees
  - Diurnal variation?
  - Influence of evaporative demand (VPD)?
  - Influence of drought stress?

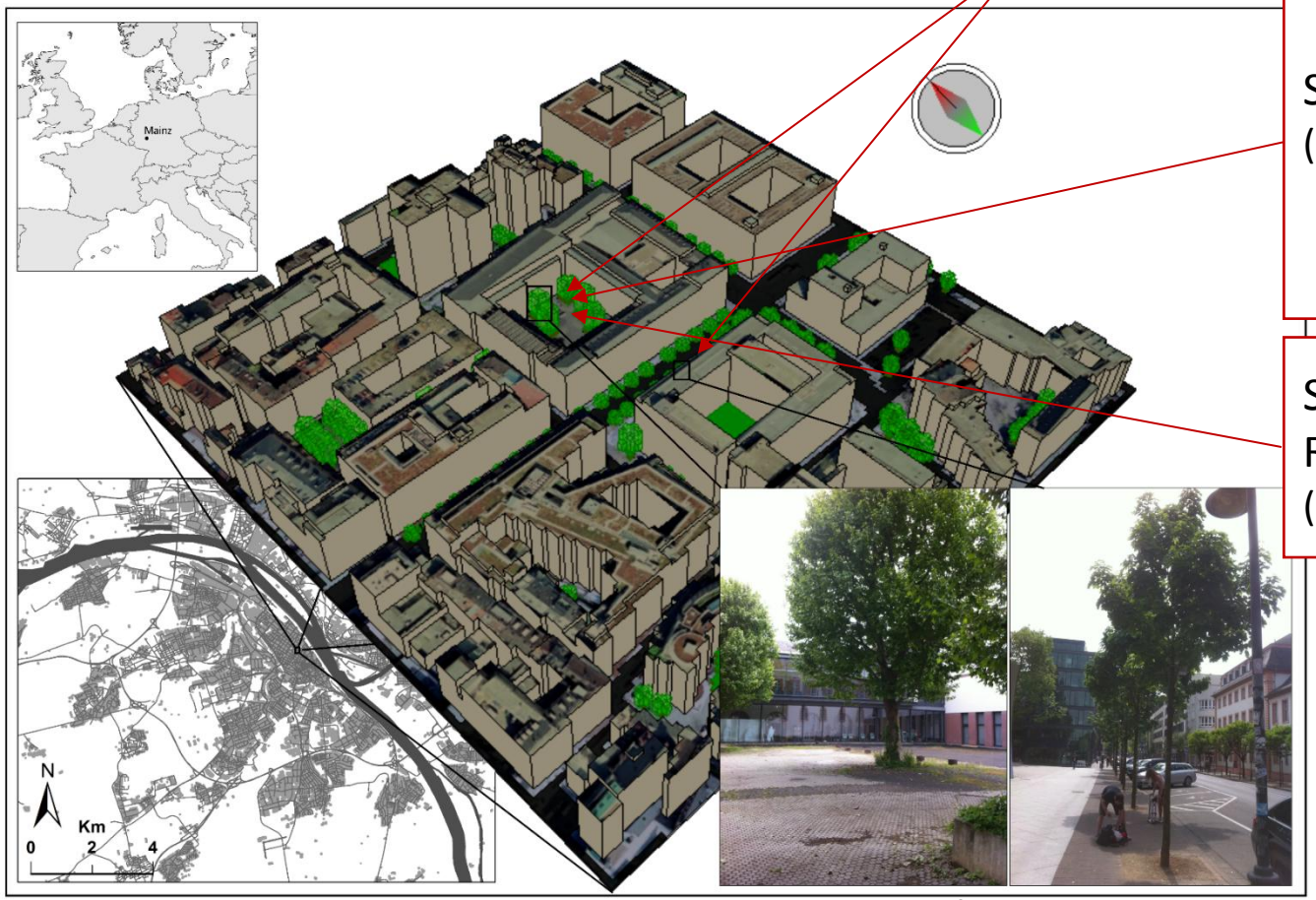
- Can the effect be replicated with the ENVI-met model?

Study area: Mainz, Germany

Air temperature and humidity (U23-001)

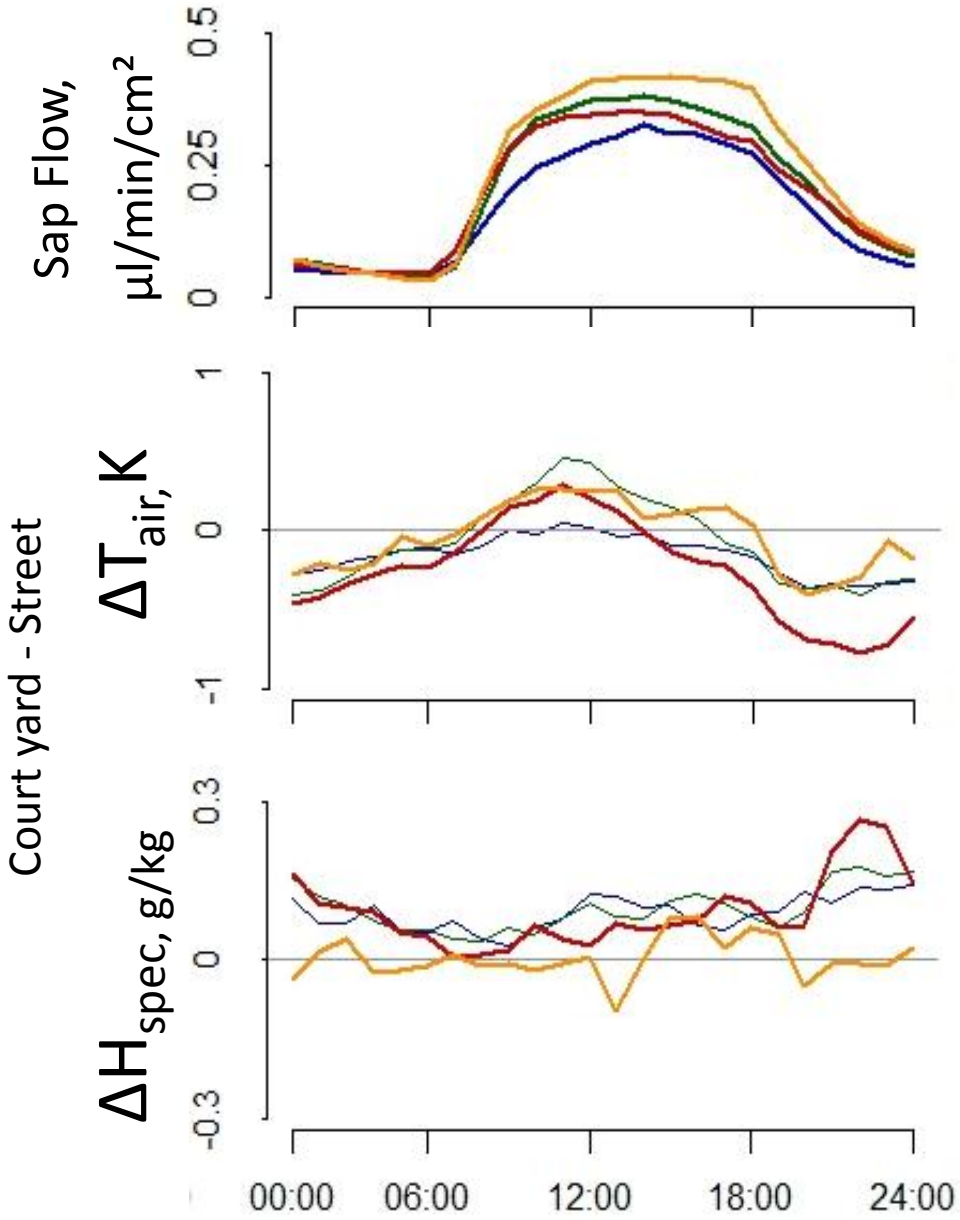
Sap Flow (SF-L)

Stem Radius (DR)



Court yard

Street



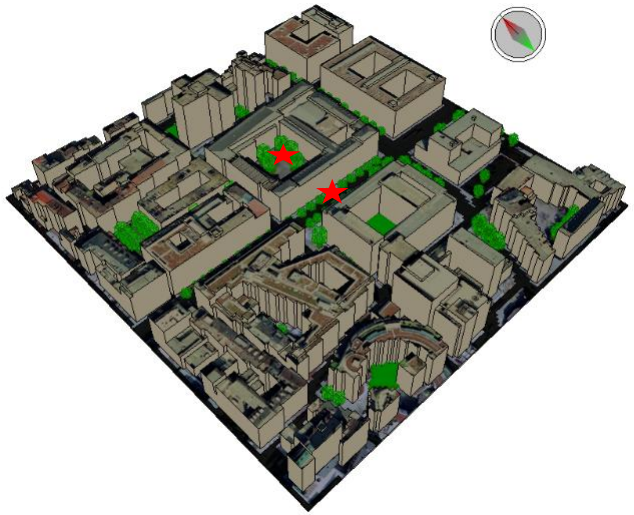
- Increase in transpiration with VPD
- Drought stress?

Night/Day Sap Flow:

$VPD_{low\ (n=20)}$	0.32
$VPD_{moderate\ (n=20)}$	0.33
$VPD_{high,\ <7\ days\ since\ precip\ (n=12)}$	0.34
$VPD_{high,\ >7\ days\ since\ precip\ (n=8)}$	0.26

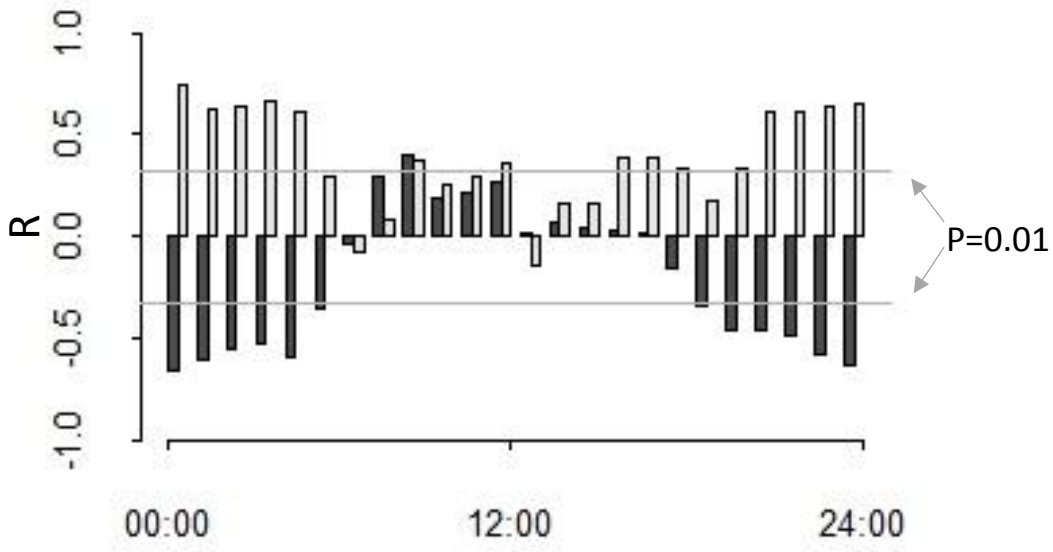
- Increased cooling and humidity at high VPD
- Nocturnal effect
- Cooling reduced due to drought stress?

Indications of transpiration-induced cooling?



Correlation between

Sap Flow and ΔT_{air}(▮) / $\Delta H_{(spec)air}$ (▯)

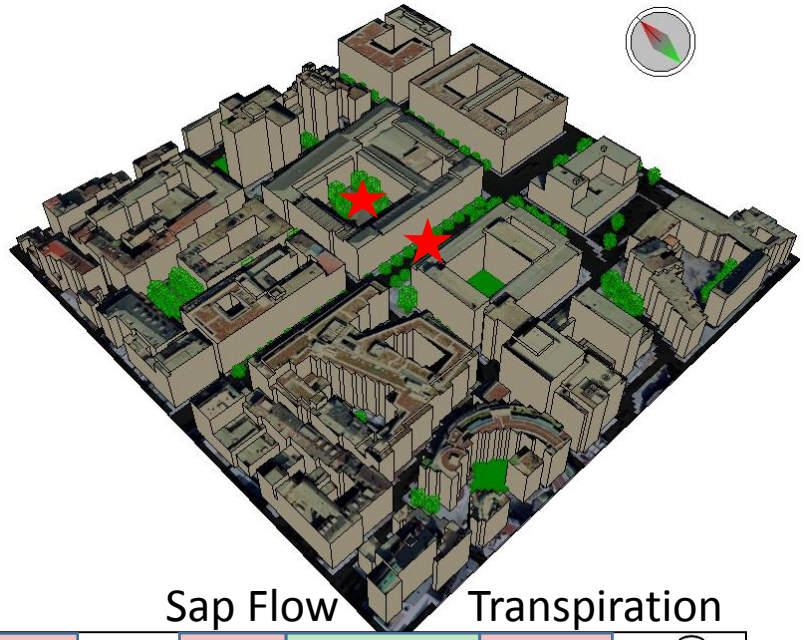


Stronger transpiration→ vegetated location cooler and more humid

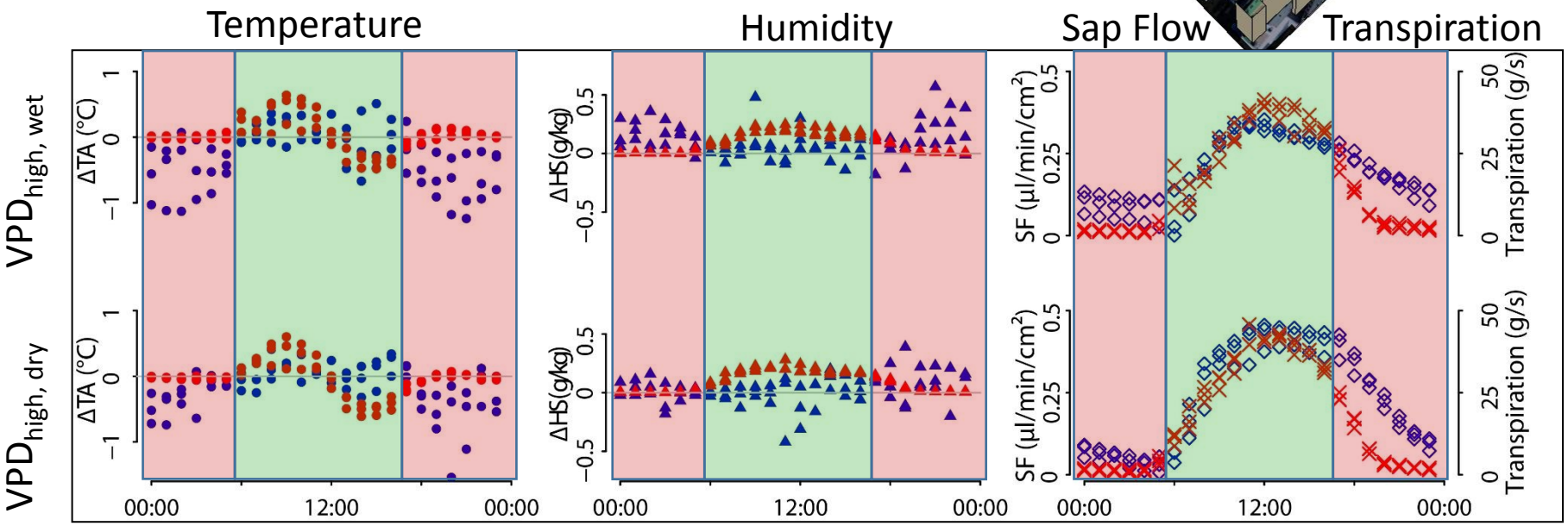
Nocturnal transpiration cooling

Agreement between measured and modelled results

Vegetation transpiration is modelled in ENVI-met using the Jacobs' A - gs model (Jacobs 1994)



Measured vs. modeled data
(n=3 in each category)

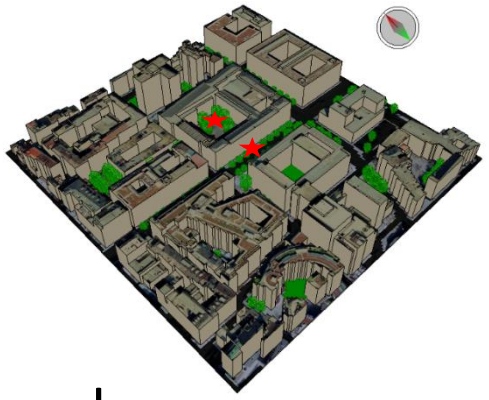


Summary:

- Nocturnal transpiration cooling
  - Increasing with VPD
  - Cooling reduced when dry?
- Model underestimates nocturnal cooling – assuming ceased nocturnal transpiration

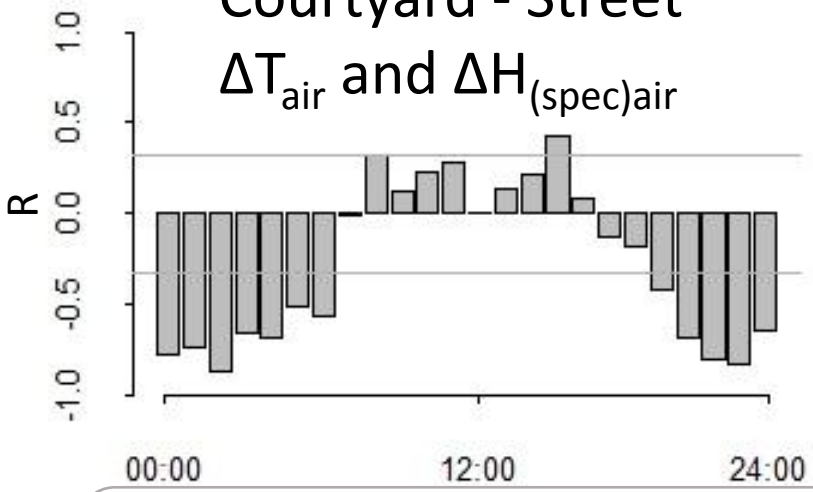
Thanks for your attention!

Indications of transpiration-induced cooling?

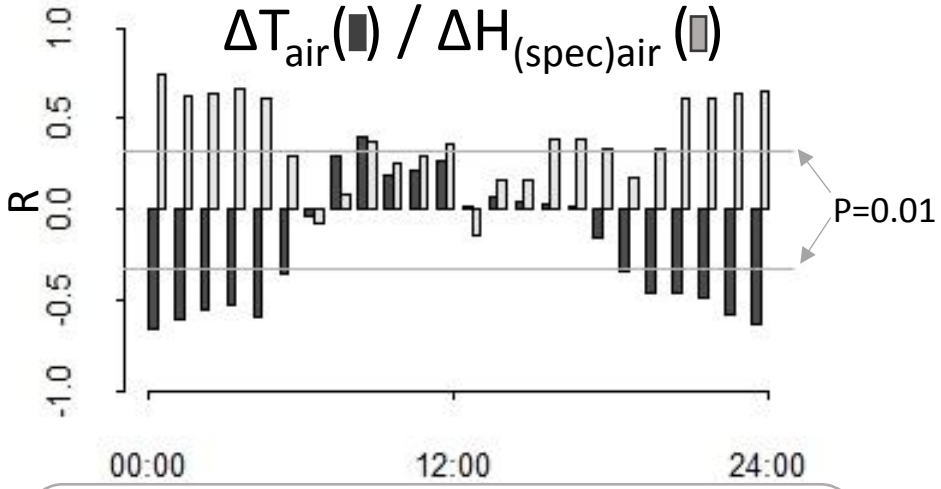


Correlation between:

Courtyard - Street
ΔT_{air} and $\Delta H_{(spec)air}$



Sap Flow and
ΔT_{air}(▮) / $\Delta H_{(spec)air}$ (▯)

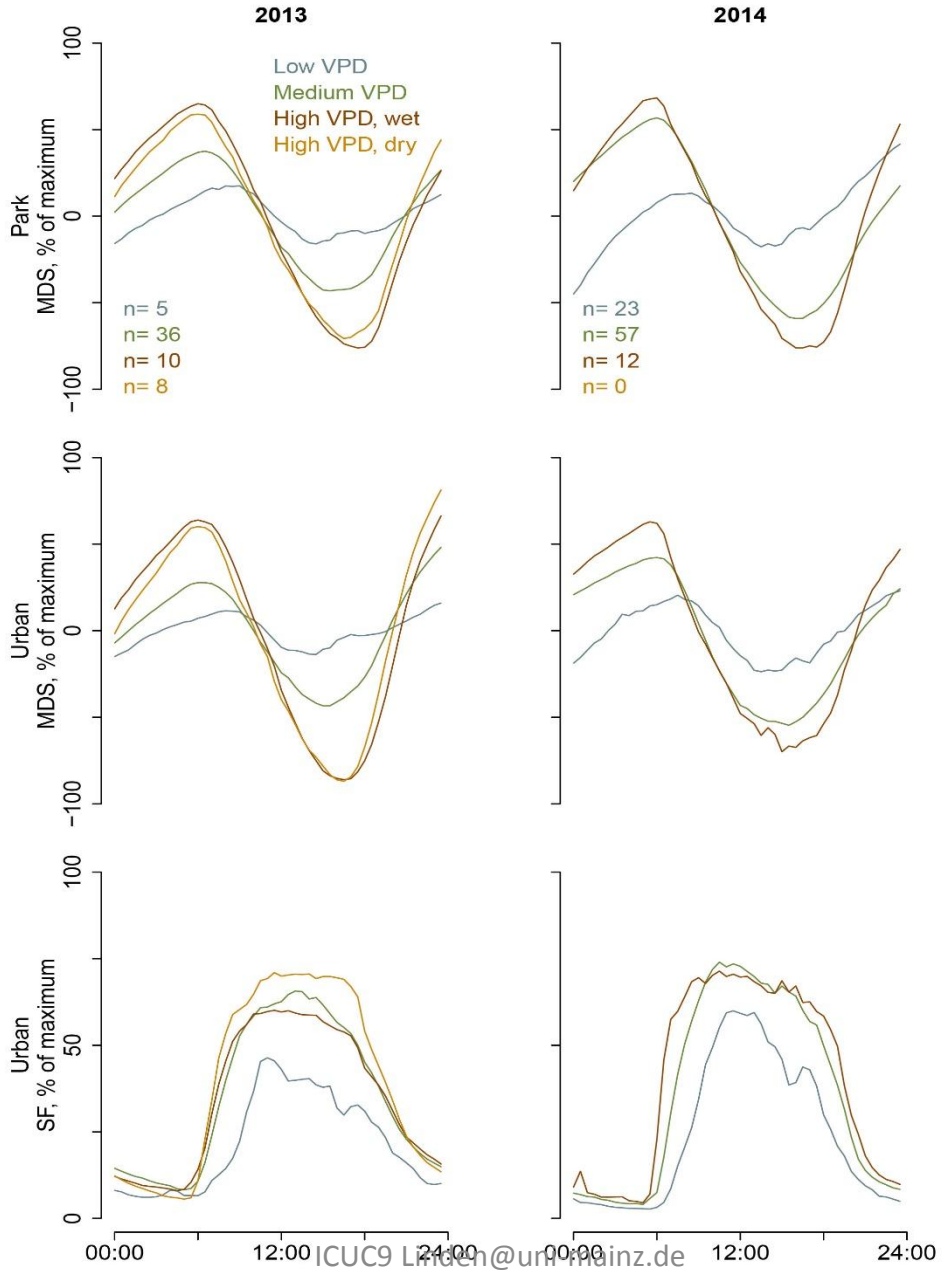


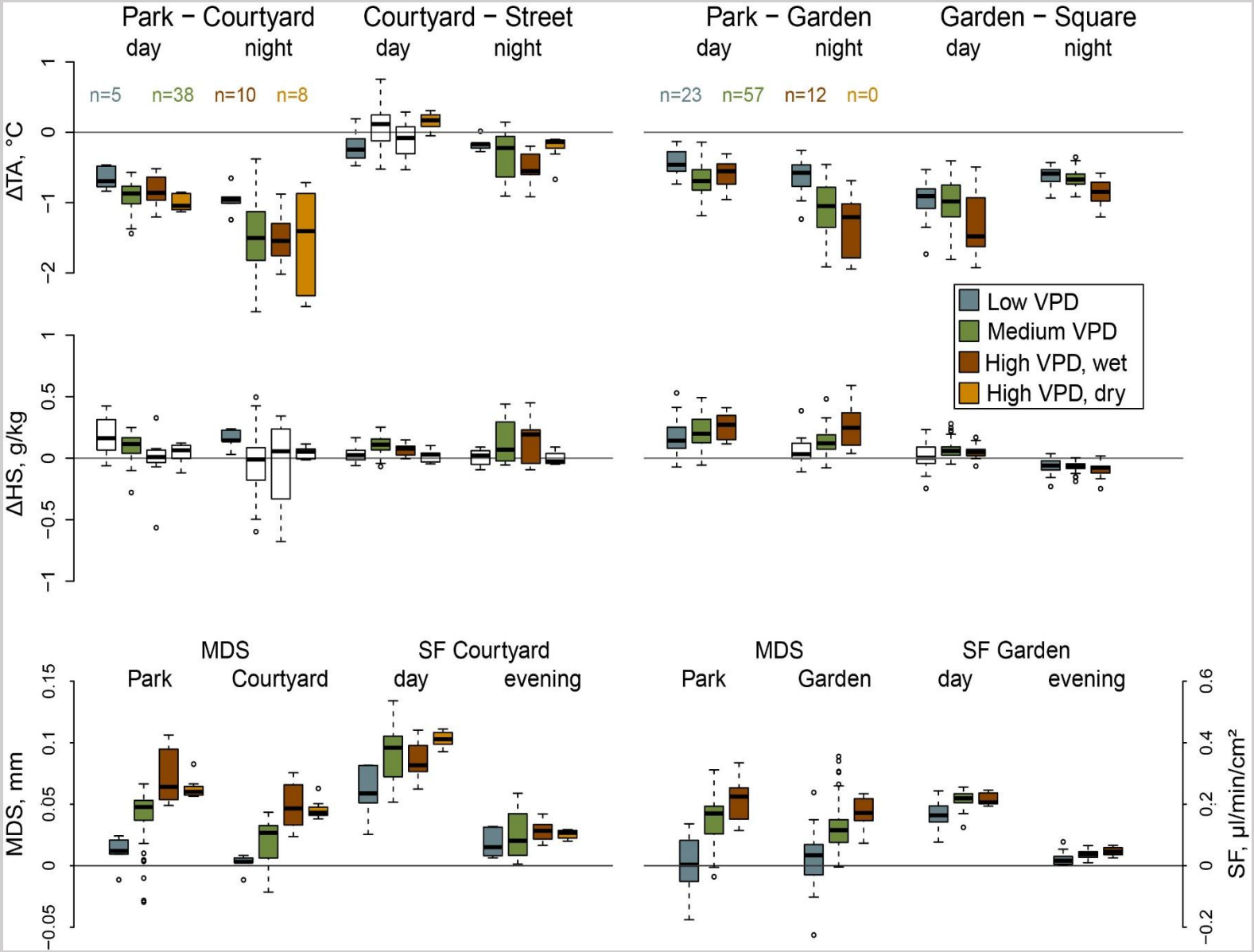
Stronger cooling = higher humidity → transpiration cooling

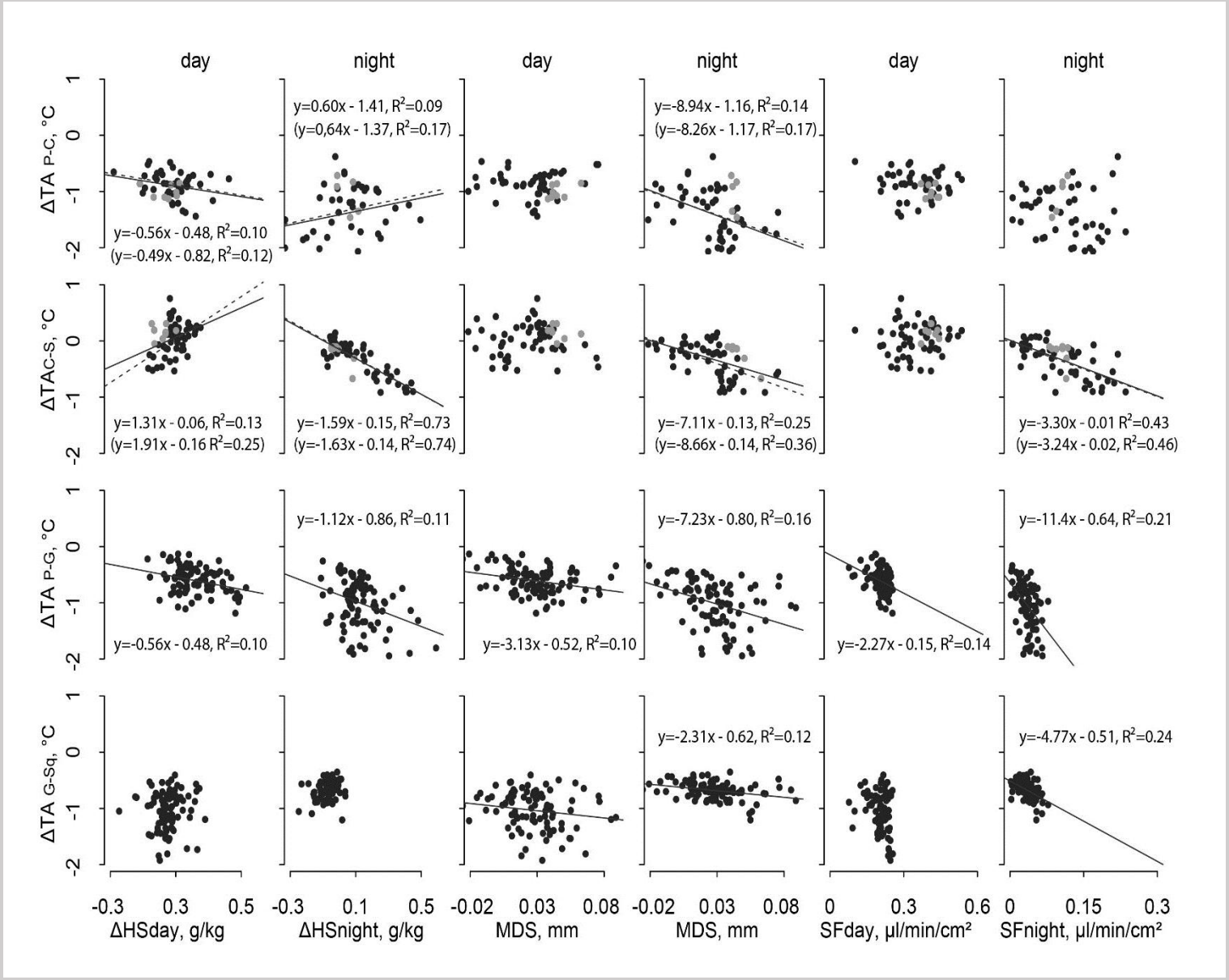
Stronger transpiration→ vegetated location cooler and more humid

Nocturnal transpiration cooling

	VPD_L	VPD_M	VPD_{Hwet}	VPD_{Hdry}
TA, °C	18,4	19,8	23,6	26,3
Wind speed, ms^{-1}	1.8	1.5	1.5	1.8
VPD, kPa	0,64	1,1	1,8	1,8
HR, %	67.4	55.3	48.7	42.7
Solar radiation, % of daily max.	20	47	59	65


2013
2014
Low VPD
Medium VPD
High VPD, wet
High VPD, dry
Park
MDS, % of maximum
n= 5
n= 36
n= 10
n= 8
n= 23
n= 57
n= 12
n= 0
Urban
MDS, % of maximum
Urban
SF, % of maximum
100
0
−100
50
00:00
12:00
24:00


Park − Courtyard
Courtyard − Street
Park − Garden
Garden − Square
day
night
n=5
n=38
n=10
n=8
n=23
n=57
n=12
n=0
ΔTA, °C
ΔHS, g/kg
Low VPD
Medium VPD
High VPD, wet
High VPD, dry
MDS
Park
Courtyard
SF Courtyard
evening
Garden
SF Garden
MDS, mm
SF, µl/min/cm²


day
night
day
night
day
night
ΔTA P-C, °C
y=0.60x - 1.41, R²=0.09
(y=0,64x - 1.37, R²=0.17)
y=-8.94x - 1.16, R²=0.14
(y=-8.26x - 1.17, R²=0.17)
y=-0.56x - 0.48, R²=0.10
(y=-0.49x - 0.82, R²=0.12)
ΔTAC-S, °C
y=1.31x - 0.06, R²=0.13
(y=1.91x - 0.16 R²=0.25)
y=-1.59x - 0.15, R²=0.73
(y=-1.63x - 0.14, R²=0.74)
y=-7.11x - 0.13, R²=0.25
(y=-8.66x - 0.14, R²=0.36)
y=-3.30x - 0.01 R²=0.43
(y=-3.24x - 0.02, R²=0.46)
ΔTA P-G, °C
y=-1.12x - 0.86, R²=0.11
y=-7.23x - 0.80, R²=0.16
y=-11.4x - 0.64, R²=0.21
y=-0.56x - 0.48, R²=0.10
y=-3.13x - 0.52, R²=0.10
y=-2.27x - 0.15, R²=0.14
ΔTA G-Sq, °C
y=-2.31x - 0.62, R²=0.12
y=-4.77x - 0.51, R²=0.24
-0.3 0.3 0.5
ΔHSday, g/kg
-0.3 0.1 0.5
ΔHSnight, g/kg
-0.02 0.03 0.08
MDS, mm
-0.02 0.03 0.08
MDS, mm
0 0.3 0.6
SFday, µl/min/cm²
0 0.15 0.3
SFnight, µl/min/cm²