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Transpiration of urban trees and its impact on nocturnal cooling in Gothenburg, Sweden

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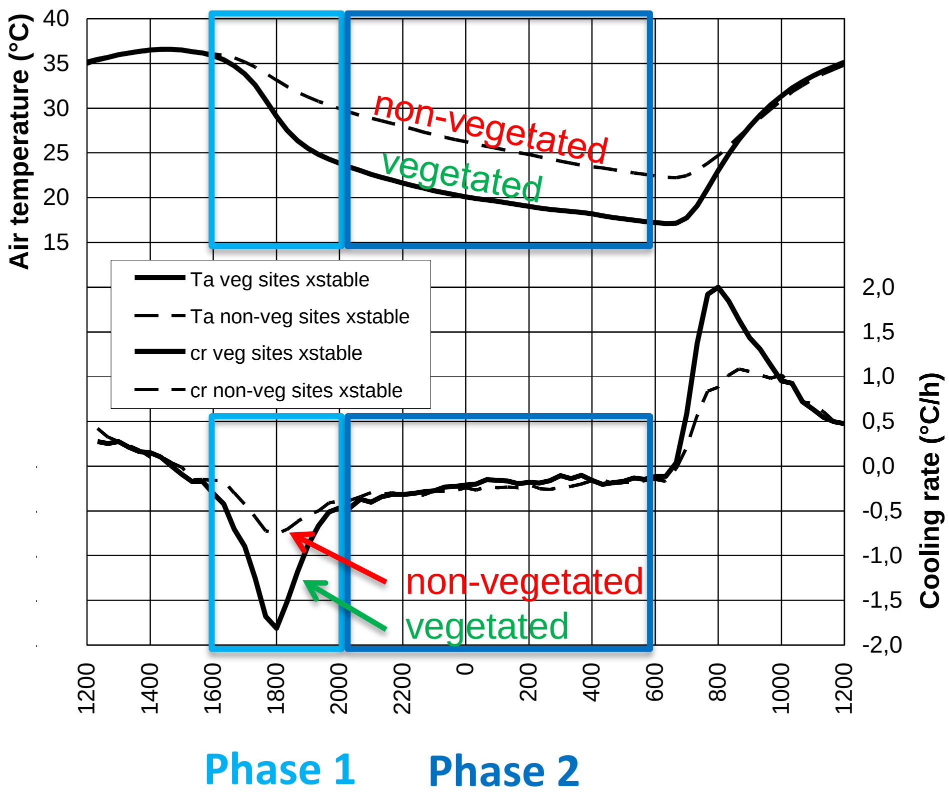
RESEARCH CONTEXT. Urban trees

- Urban trees – a common mitigation strategy in climate-sensitive planning
- Urban environment – tree growing conditions and stress factors different from those in forests
- To provide a cooling effect, trees need to remain healthy in the stressful urban environment

RESEARCH CONTEXT. Night-time tree transpiration?



Phase 1 (around sunset)

- Site specific, intensive cooling
- Holmer et al. 2013: more intensive cooling in vegetated than non-vegetated sites in Ouagadougou, Burkina Faso

Phase 2 (starting 2-3 h after sunset)

- Spatially homogeneous, less intensive cooling
- Holmer et al. 2013: similar cooling rates at vegetated and non-vegetated sites in Ouagadougou

Holmer B,Thorsson S, Linden J (2013) Evening evapotranspirative cooling in relation to vegetataion and urban geometry in the city of Ouagadougou, Burkina Faso. Int J Climatol 33: 3089-3105

OBJECTIVES

- Quantify the magnitude and diurnal variations of transpiration of the most common urban tree species in a high latitude city of Gothenburg, Sweden

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- Analyse the influence of meteorological conditions and surface permeability on the transpiration of urban trees

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- Quantify the magnitude and diurnal variations of transpiration of the most common urban tree species in a high latitude city of Gothenburg, Sweden
- Analyse the influence of meteorological conditions and surface permeability on the transpiration of urban trees
- Find out whether the transpiration of urban trees contributes to daytime or nocturnal cooling

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MEASUREMENTS. Instruments

- LiCor XT-6400 Portable Photosynthesis System – an open system measuring gas exchange between leaf and air using an infrared gas analyser
  - leaf transpiration rate (***E_L***, mmol m^{-2} s^{-1})
  - stomatal conductance (***g_s***, mmol m^{-2} s^{-1})

- *T_a* and RH (→ cooling rates) measured simultaneously with two TinyTag Plus 2 instruments:
  - at the measurement site, under one of the trees
  - at a reference site in a non-vegetated street canyon

- Energy loss per unit ground area (***Q_E***, W m^{-2}) due to tree transpiration was calculated by scaling up *E_L* using measured leaf area index (**LAI**)
- Note: for more information on LAI measurements in urban areas, see Jenny Klingberg's presentation this afternoon, session UCP11

MEASUREMENTS. Study sites

- Seven most common tree species in Gothenburg: common lime (linden), English oak, Norway maple, Silver birch, Horse chestnut, European beech, Japanese cherry

- Street and park trees, different growing conditions (but no irrigation)

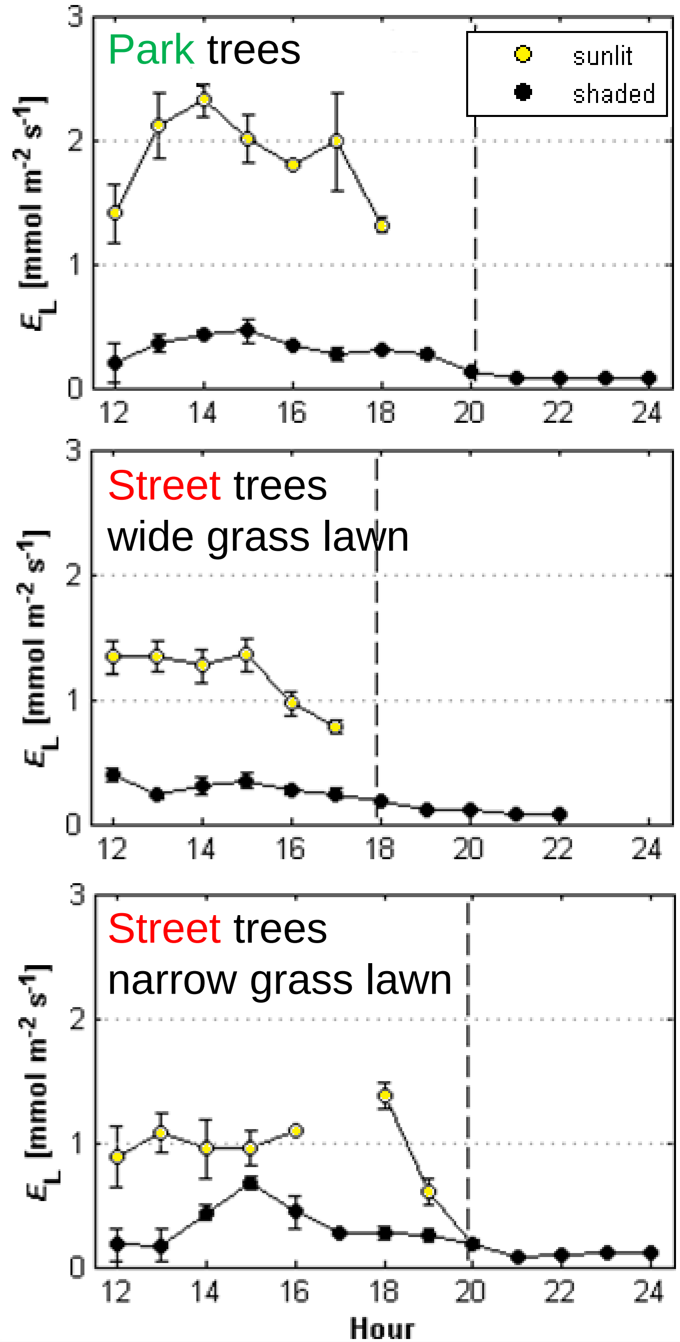
- 4-6 tree individuals per site, 8 leaves per tree (4 sunlit and 4 shaded)

- Daytime and night-time measurements on warm, sunny summer days (2012-13)

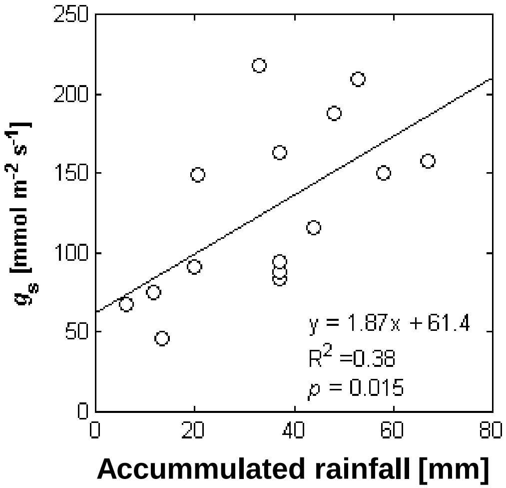
- Linden trees: three sites, continuous hourly measurements from noon until a few hours after sunset

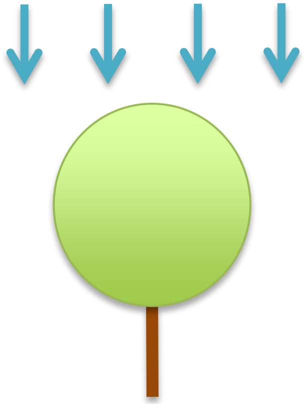
RESULTS. Diurnal course of transpiration (linden, *T. europaea*)

- E_L of sunlit leaves was on average 3x higher than of shaded leaves
- Park trees transpired more intensively than street trees
- Transpiration dropped significantly before sunset due to decreasing VPD and incoming solar radiation, but remained active during the night (7% of midday E_L of sunlit leaves and 20% of those in shadow)



RESULTS. Influence of weather and surface permeability





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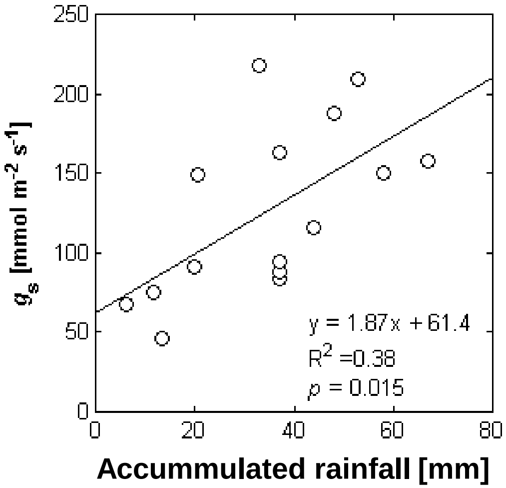

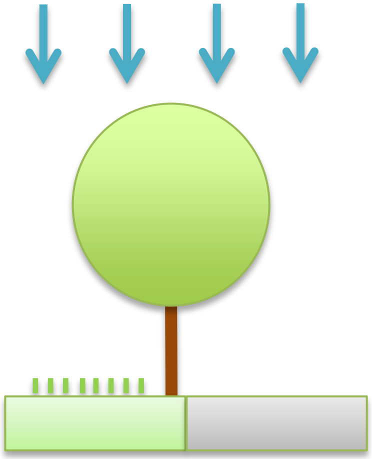

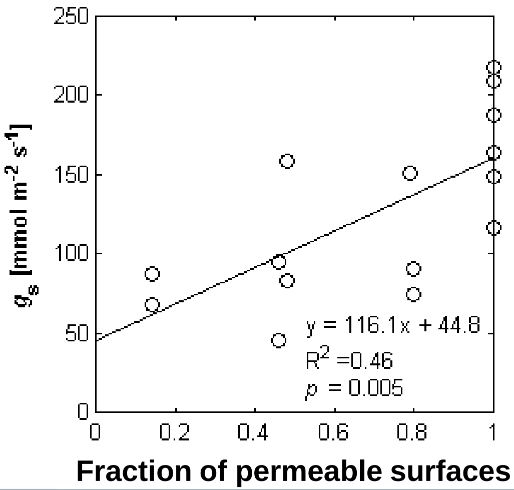

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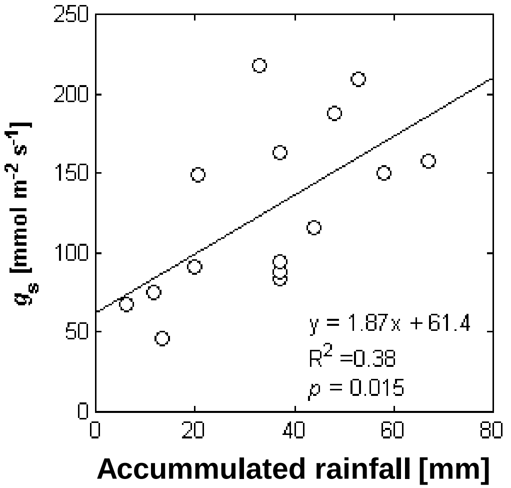
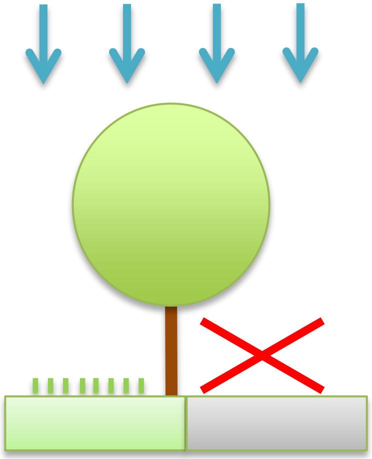
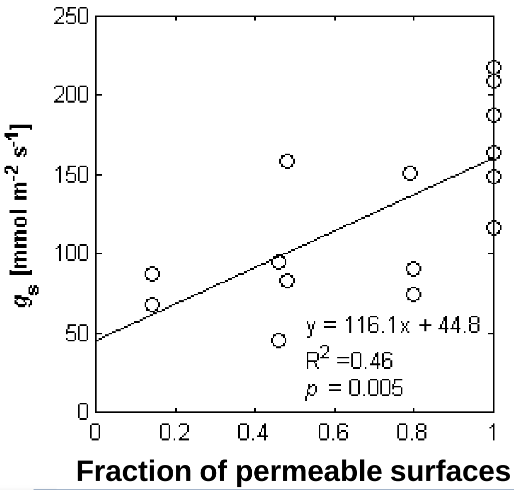




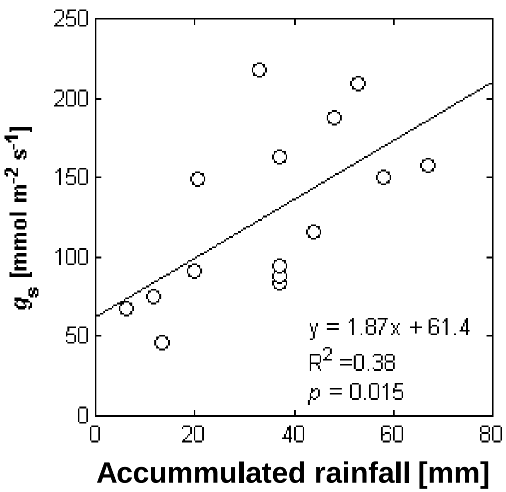


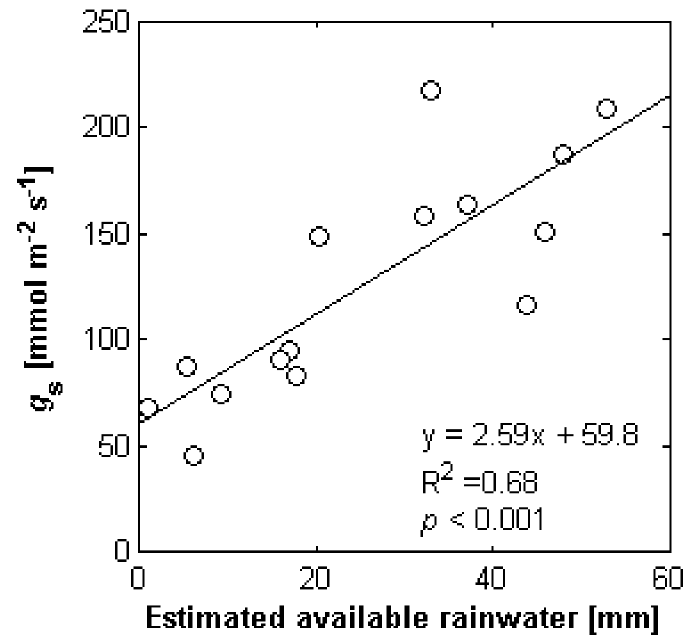
A simple estimation of available rainwater [mm]:

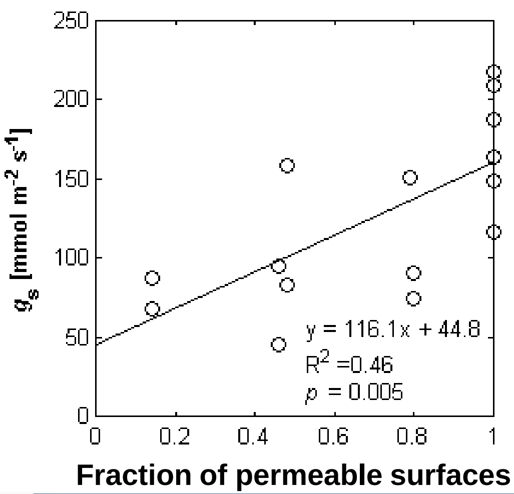
Accummulated rainfall **x** Fraction of permeable surfaces

– soil characteristics, interception, the extent of roots etc. are not accounted for
+ widely available data
+ no measurements needed

RESULTS. Influence of weather and surface permeability







Accummulated rainfall **x** Fraction of permeable surfaces

– soil characteristics, interception, the extent of roots etc. are not accounted for
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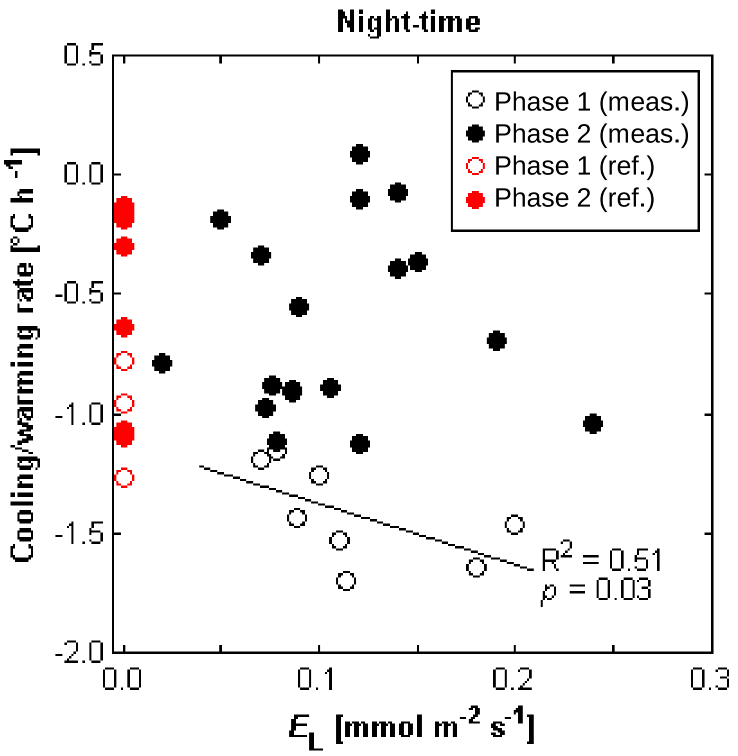
RESULTS. Estimated energy loss per unit ground area

Species, location	Date	Incoming solar radiation (midday, W m^{-2})	Energy loss due to tree transpiration, Q_E [W m^{-2}]	
			Midday	**Night-time**
Linden, park trees	11.07.2013	859	92	16
Linden, street trees, narrow grass lawn	20.07.2013	788	**72**	13
	22.08.2013	594	132	20
Linden, street trees, wide grass lawn	03.09.2013	572	206	30
	06.09.2013	609	174	18
English oak	12.07.2013	795	343	**38**
	28.08.2013	433	**390**	32
Silver birch	09.07.2013	812	230	**1.5**
	20.08.2013	528	190	26
Norway maple	20.08.2013	613	196	12
Horse chestnut	23.07.2013	799	171	32
	29.07.2013	635	260	31
European birch	26.07.2012	809	127	30
Japanese cherry	13.07.2013	780	244	25
	02.09.2013	610	260	35
Average		**682**	**206**	**24**

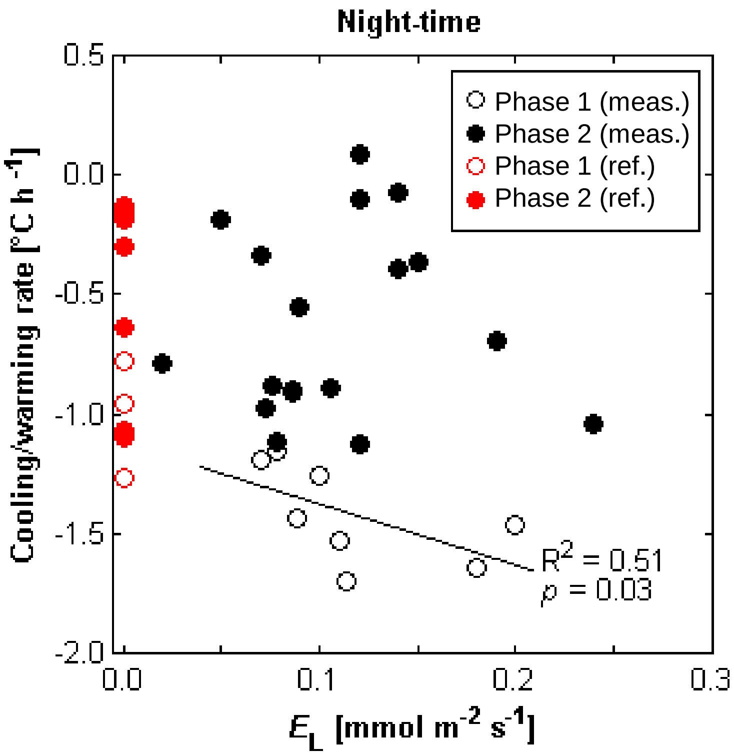
RESULTS. Transpiration vs daytime and nocturnal cooling

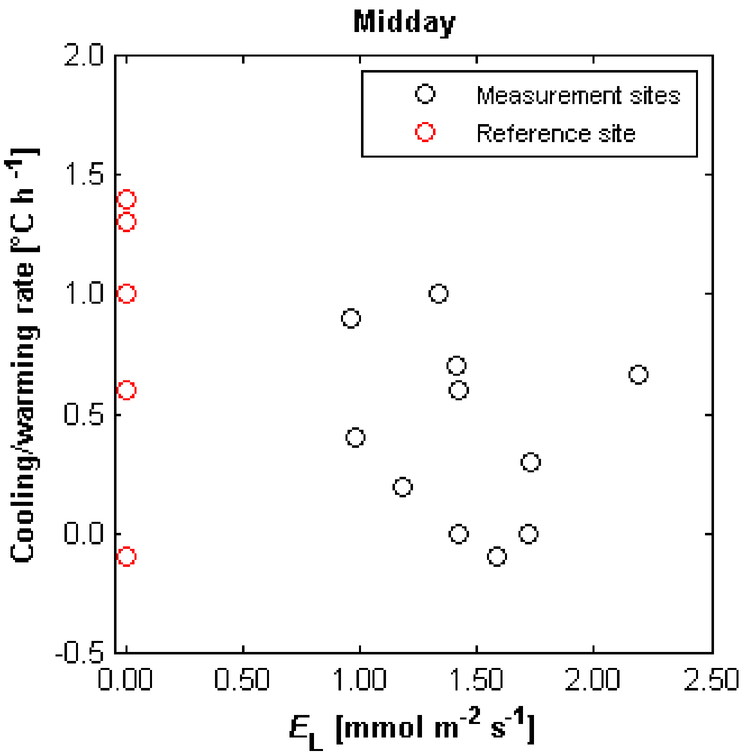


Phase 1 - More intensive cooling with increasing E_L
- Less intensive cooling at a non-vegetated reference site

Phase 2 - No correlation between cooling rate and E_L

RESULTS. Transpiration vs daytime and nocturnal cooling





Phase 1
- More intensive cooling with increasing E_L
- Less intensive cooling at a non-vegetated reference site

Phase 2
- No correlation between cooling rate and E_L

Midday
- No correlation between midday warming rate and E_l dispite strong transpiration

CONCLUSIONS

- **Poor growing conditions of trees** (impermeable surfaces surrounding the trees) **decrease their transpiration** and therefore cooling effect. A simple estimation of available rainwater, based on widely available data, explained 68% of variance in stomatal conductance

- **Night-time transpiration was active in all studied trees** and reached on average 7% and 20% of daytime E_L of sunlit and shaded leaves, respectively, with an estimated latent heat flux of 24 W per unit ground of vertically projected tree area

- A **significant correlation of transpiration rate with the cooling rate** of the air, as well as **less intensive cooling at a non-vegetated reference site**, indicated a contribution of tree transpiration to cooling around and shortly after sunset, but not later in the night

Thank you for your attention!

Research paper: Konarska J., Uddling J., Holmer B., Lutz M., Lindberg F., Pleijel H., Thorsson S., 2015. Transpiration of urban trees and its cooling effect in a high latitude city. Int J Biometeorol (*in press*)

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