Towards a Better Understanding of the Early Morning Boundary Layer Transition, Using Observations of Small Unmanned Aerial Vehicles (UAV)

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Outline

1. Experiment description EMBoLT2013 / Motivation
2. Instrument: Multi-purpose Airborne Sensor Carrier (MASC)
3. Measurement strategy: Vertical profiling and Constant Altitude Profiling (CAP)
4. Measurement results (selection)
5. Scaling and further analysis
6. Summary and Outlook

Early Morning Boundary Layer Transition Experiment EMBoLT2013

→ **Idea: Low-cost, single UAV experiment to investigate Early Morning Boundary Layer Transition, right in our backyard**

→ **Flight Overview:**

Date dd.mm.yy	Place	NoF	time [min]	start [UTC]	end [UTC]	Flight pattern
08.05.13	Schnittlinger Berg	4	105	0515	0835	Vpro 500 m, Racetracks
06.06.13	Kirchentellinsfurt	5	60	0540	0732	Vpro 300 m, CAP
19.06.13	Schnittlinger Berg	9	133	0440	1000	Vpro 500 m, Racetracks
05.07.13	Kirchentellinsfurt	8	99	0505	0840	Vpro 300 m, CAP
23.07.13	Kirchentellinsfurt	8	85	0505	0850	Vpro 300 m, CAP
14.08.13	Kirchentellinsfurt	7	99	0605	0935	Vpro 500 m, CAP
05.09.13	Kirchentellinsfurt	8	98	0605	0930	Vpro 500 m, CAP

→ **49 flights at two locations and seven days are taken into account**

MASC: Multi-purpose Airborne Sensor Carrier

operated at **University of Tübingen**

(I told the designer, that I don't care about the colour, as long as it is well visible ...)

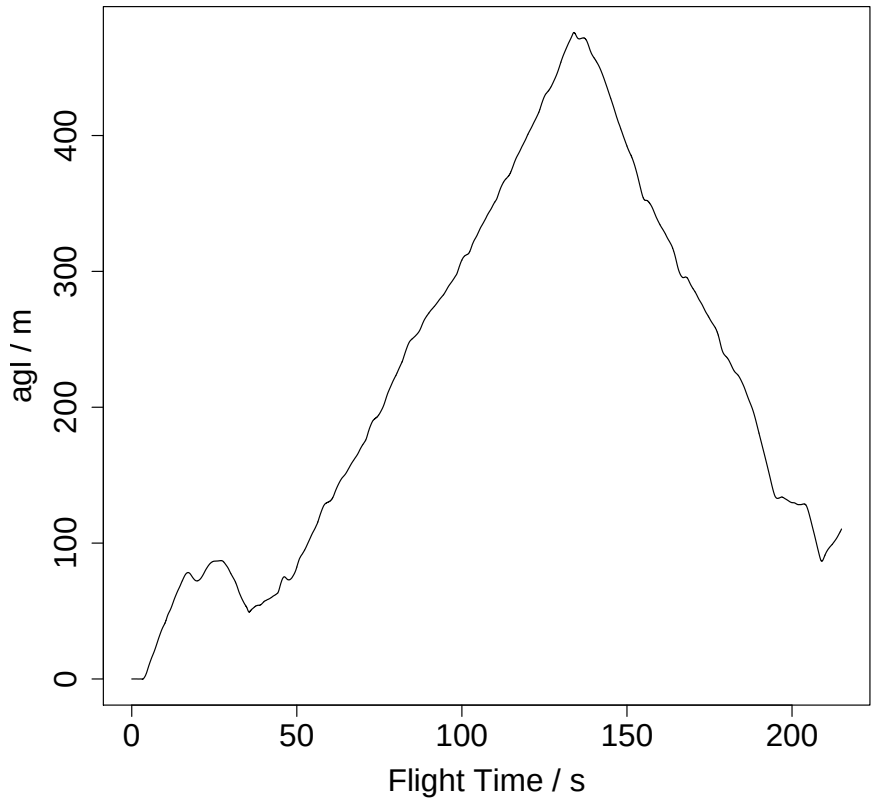
wingspan:	2.7...3.5 m
total weight:	$<$ 6 kg
incl. sci. payload:	1.5 kg
cruising speed:	25 m/s
endurance:	$\approx$ 1 hour
electrical engine	
autopilot:	U Stuttgart

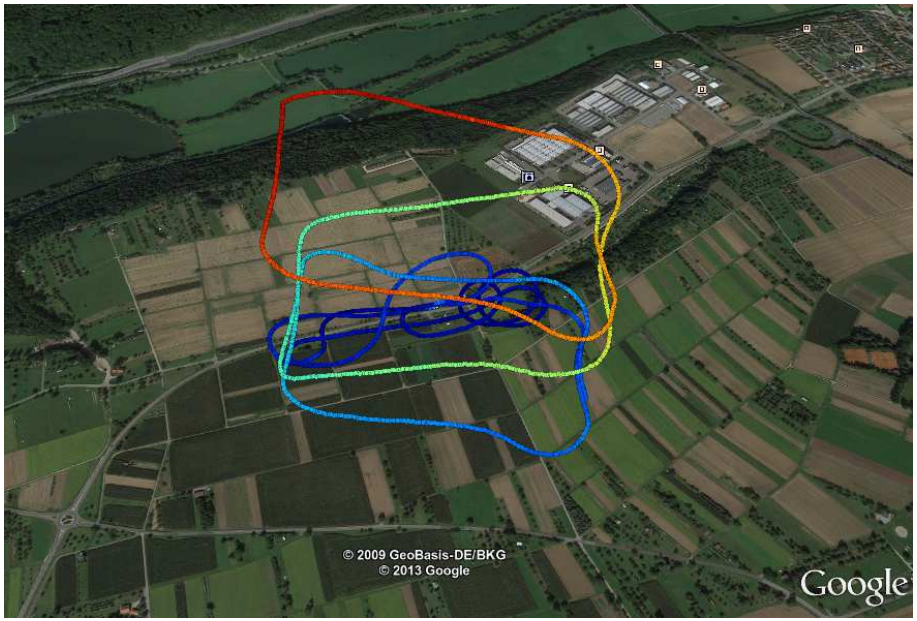
Measurements:

- 3D wind vector
- air temperature
- water vapour
- 100 Hz sampling rate
- data link to ground station

Morning transition of the ABL: momentary profiles

Vertical profiles of PTU and 3D wind vector, square pattern ascend

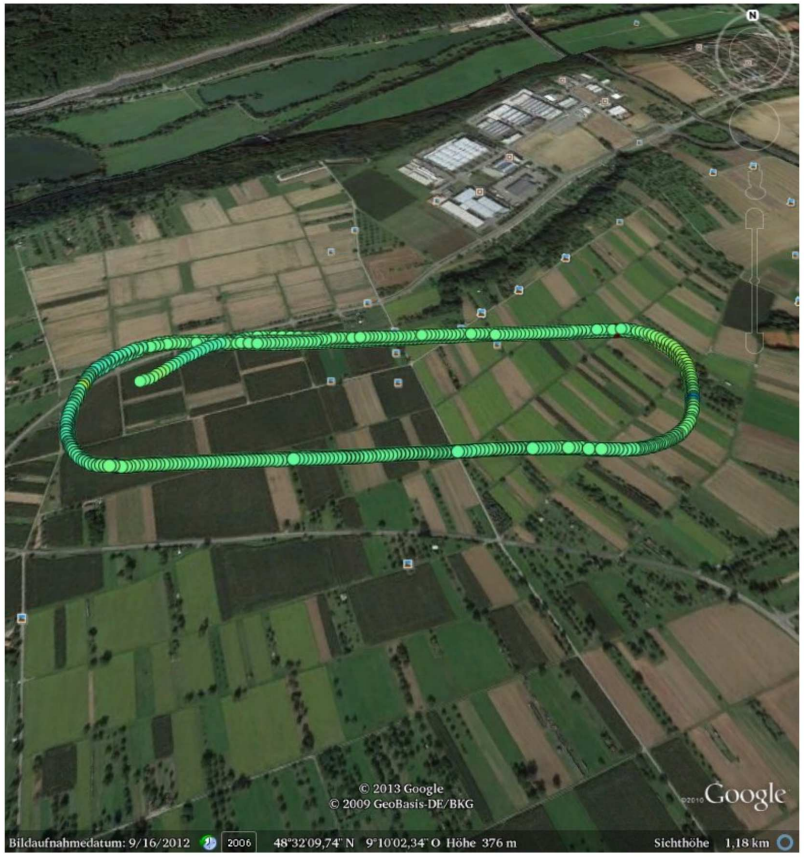




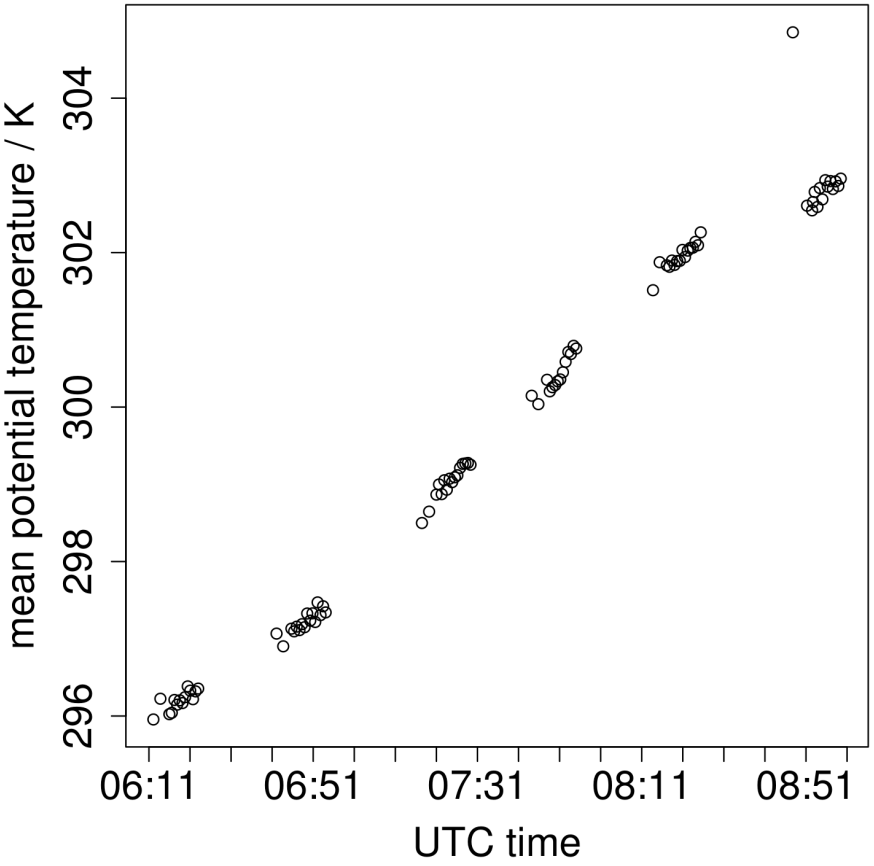
due to CAA limits: vertical profile above a very small horizontal area

Morning transition of the ABL: CAP

1 km long straight and level flight legs at 100 m altitude above ground level (agl)



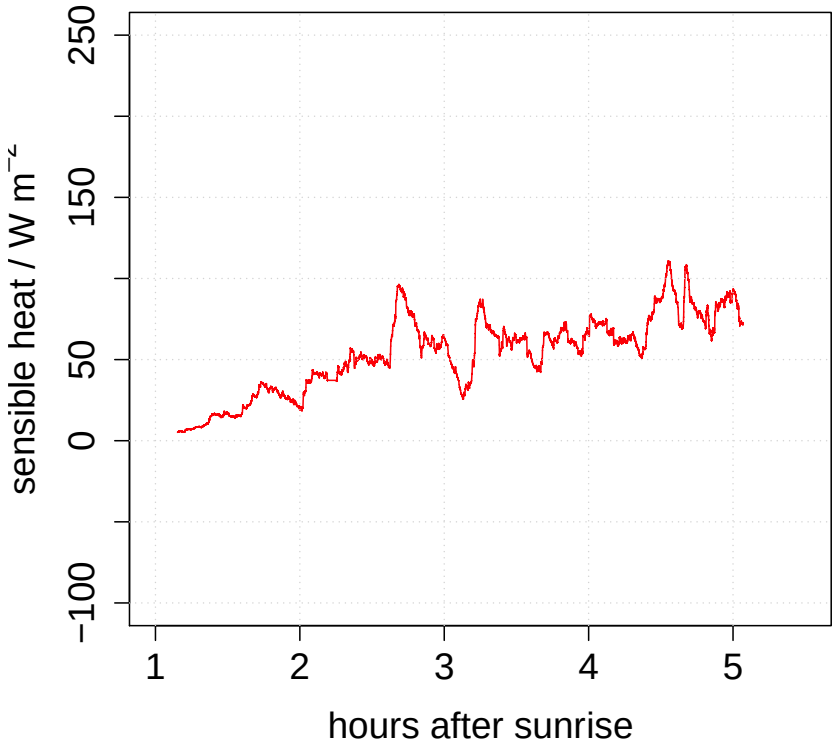
→ CAP
(constant-altitude profiling during transition, see *Bange et al, 2007*)



CAP provides vertical profiles of averaged data, plus fluxes of sensible and latent heat

Morning transition of the ABL: surface heat flux

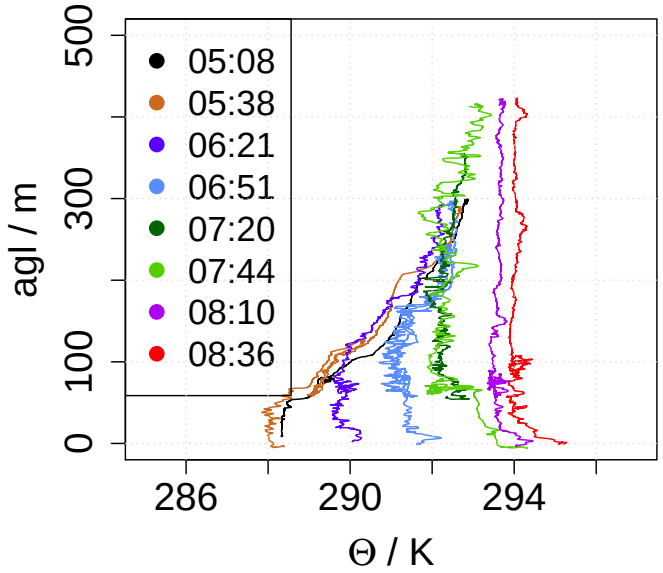
Additional surface flux from sonic anemometer at 2 m above ground level

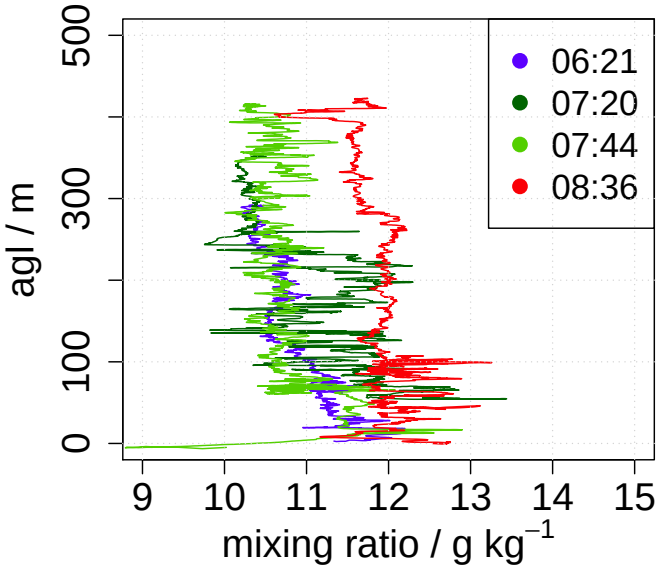


Instrument was installed on 14 Aug and 05 Sep 2013 in Kirchentellinsfurt.
Averaging time for sensible heat flux 10 minutes, to compare to UAV flights.

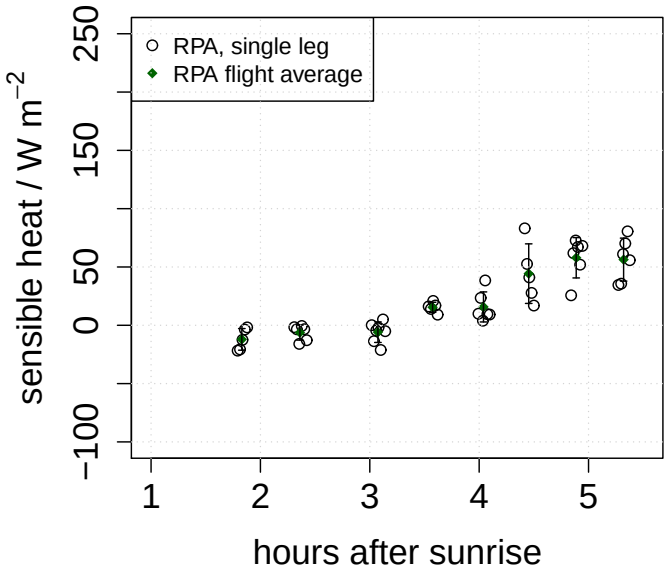
Morning transition of the ABL: 05 July 2013

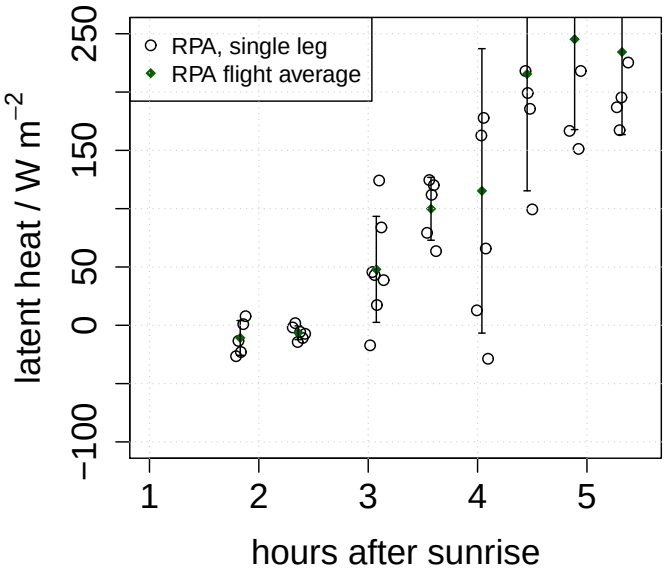
Vertical profiles:





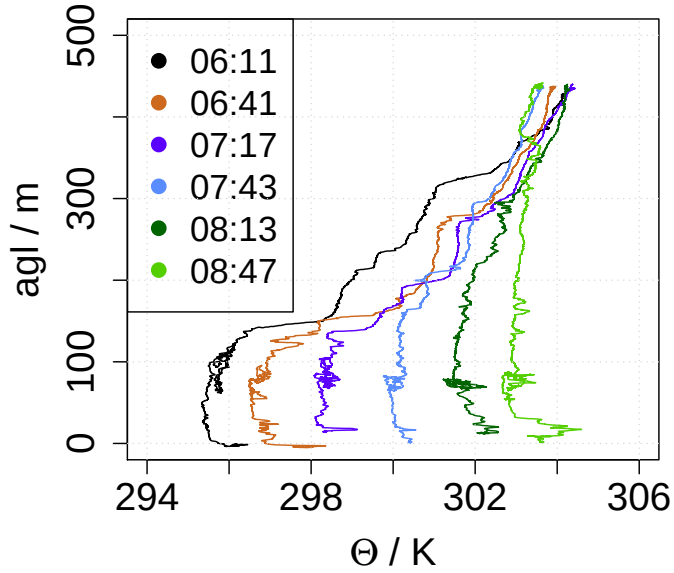
CAP, fluxes:

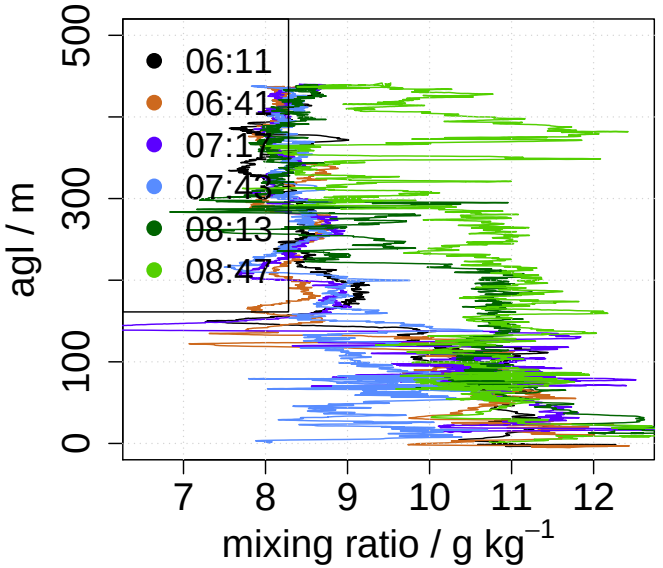




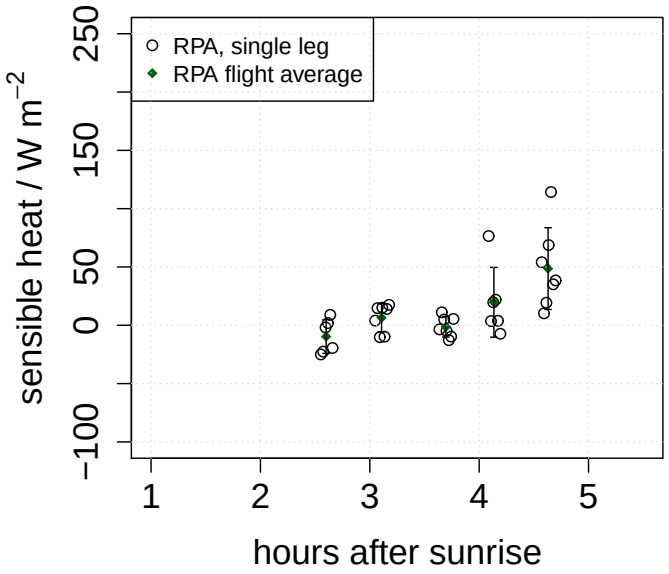
Morning transition of the ABL: 23 July 2013

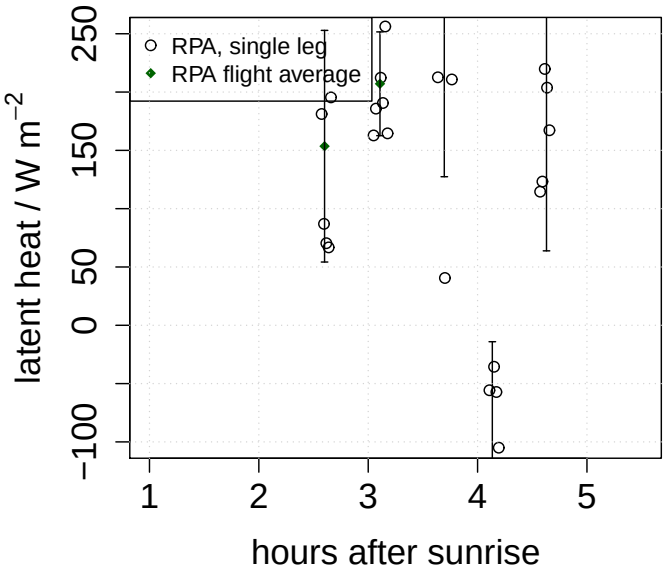
Vertical profiles:





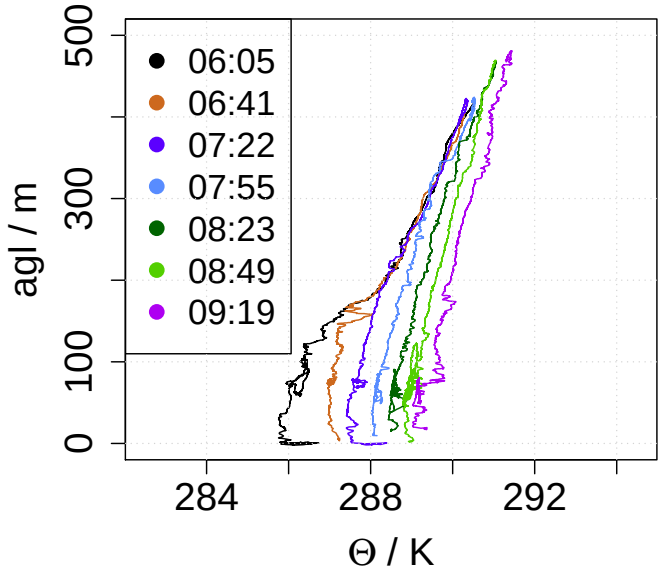
CAP, fluxes:

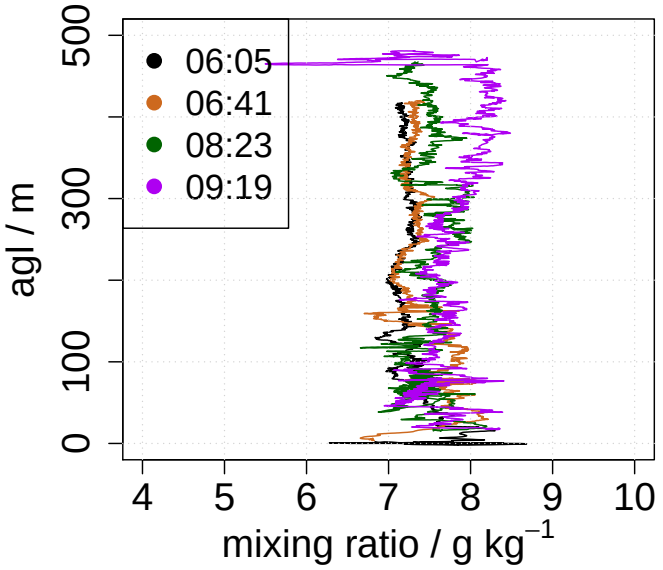




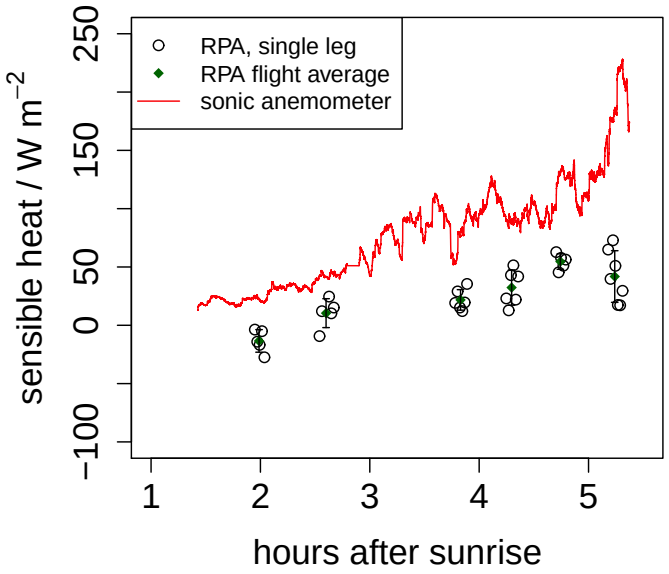
Morning transition of the ABL: 14 August 2013

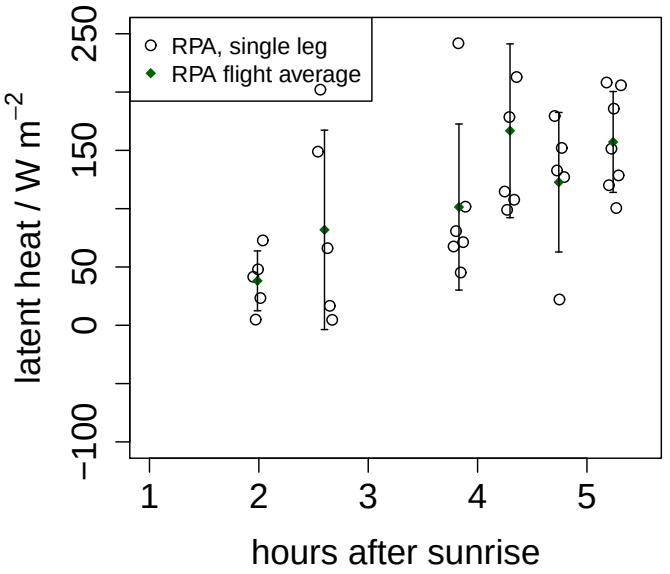
Vertical profiles:





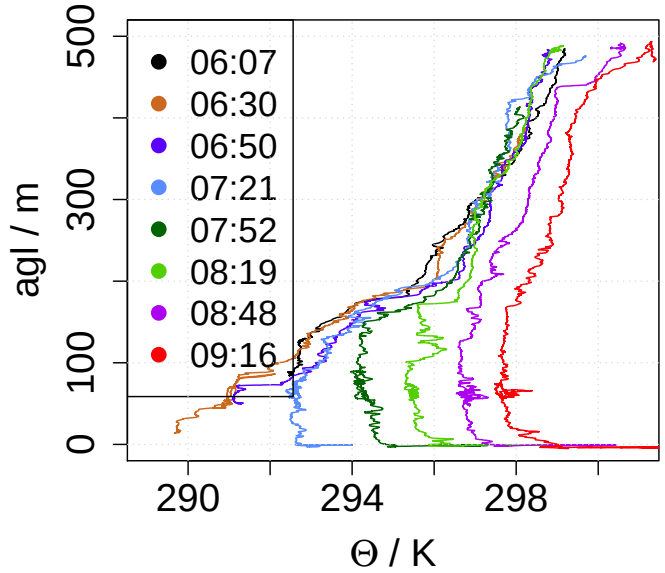
CAP, fluxes:

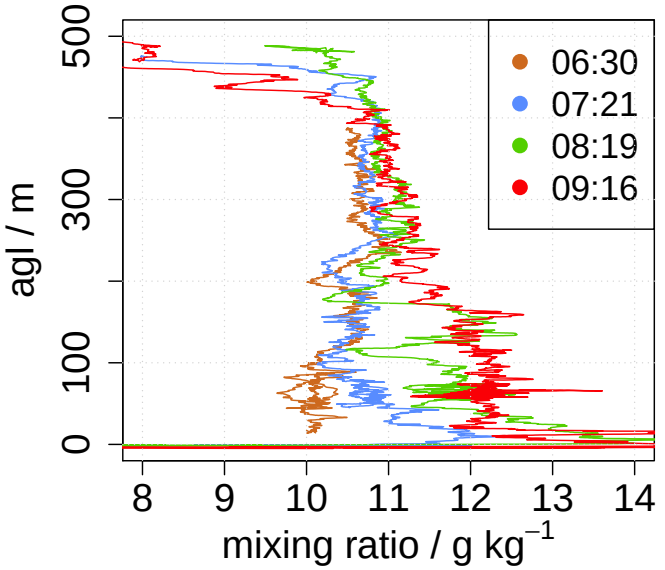




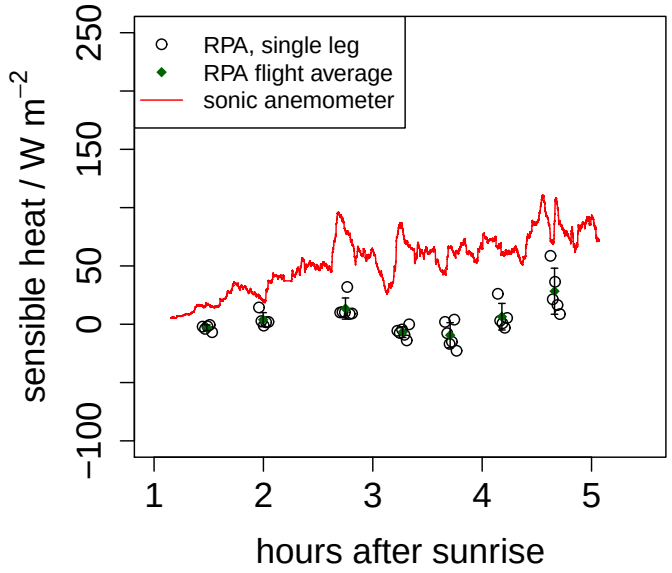
Morning transition of the ABL: 05 September 2013

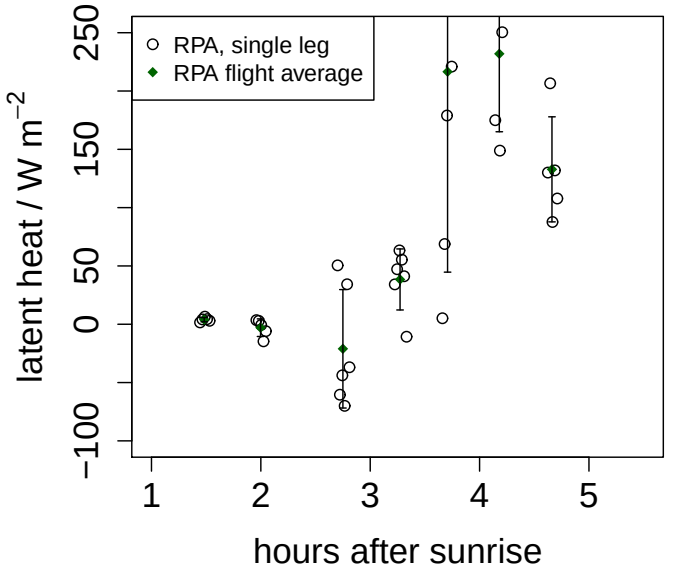
Vertical profiles:



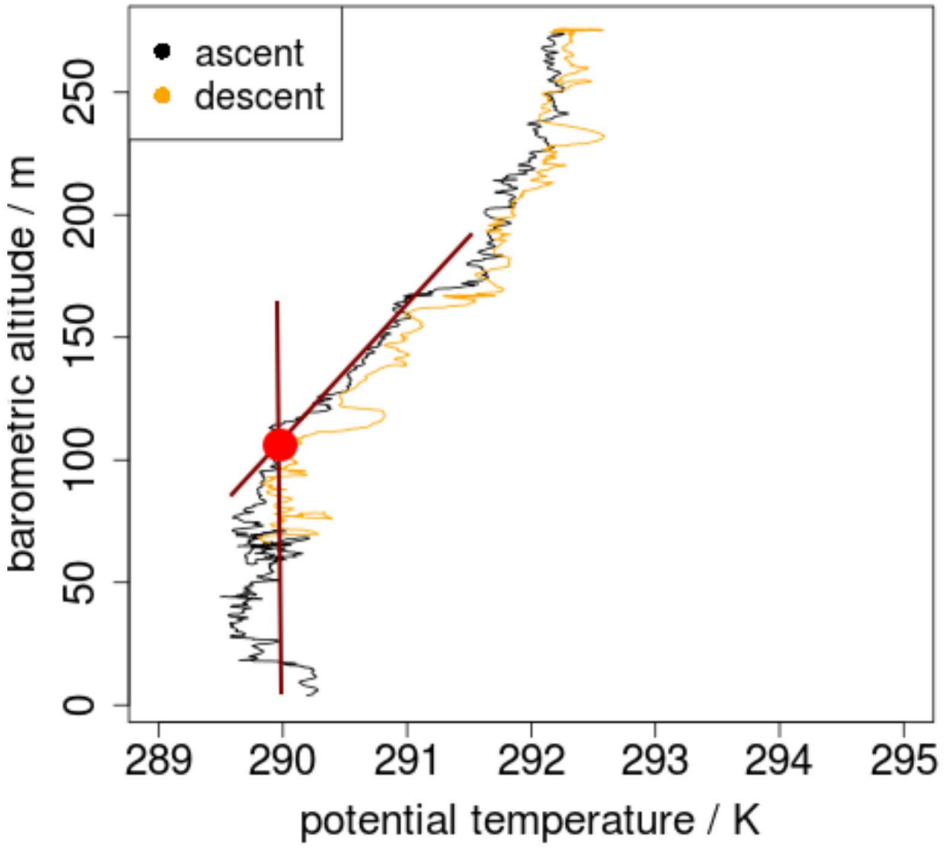


CAP, fluxes:

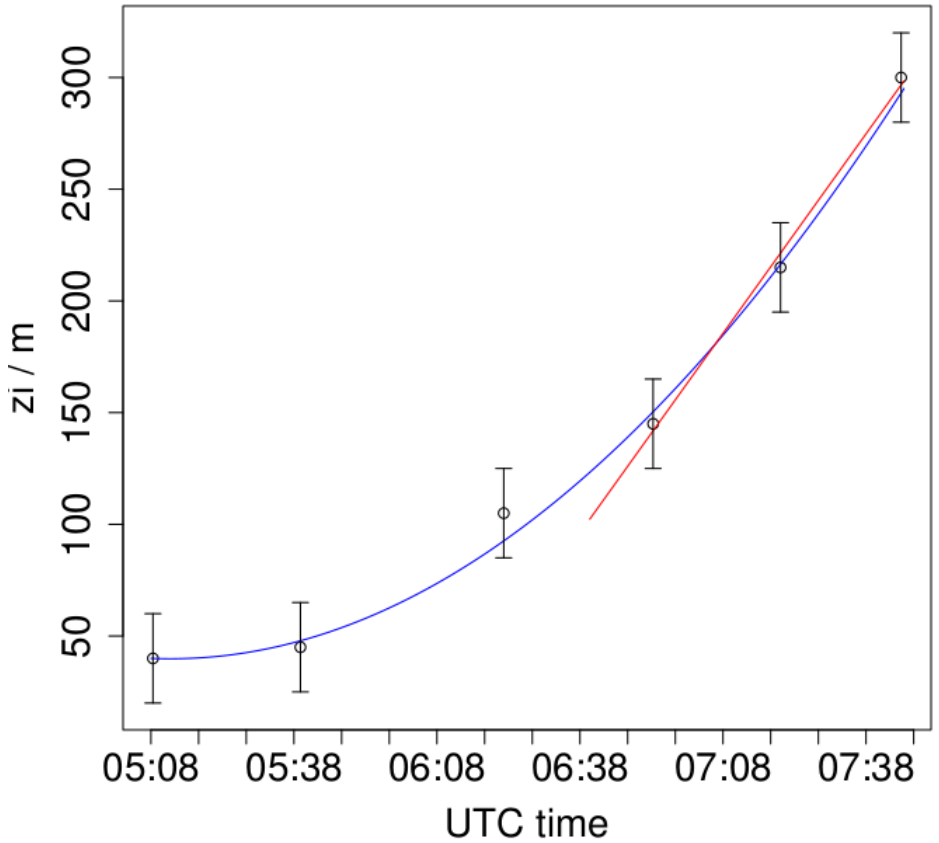




Scaling parameters: Boundary Layer Depths z_i

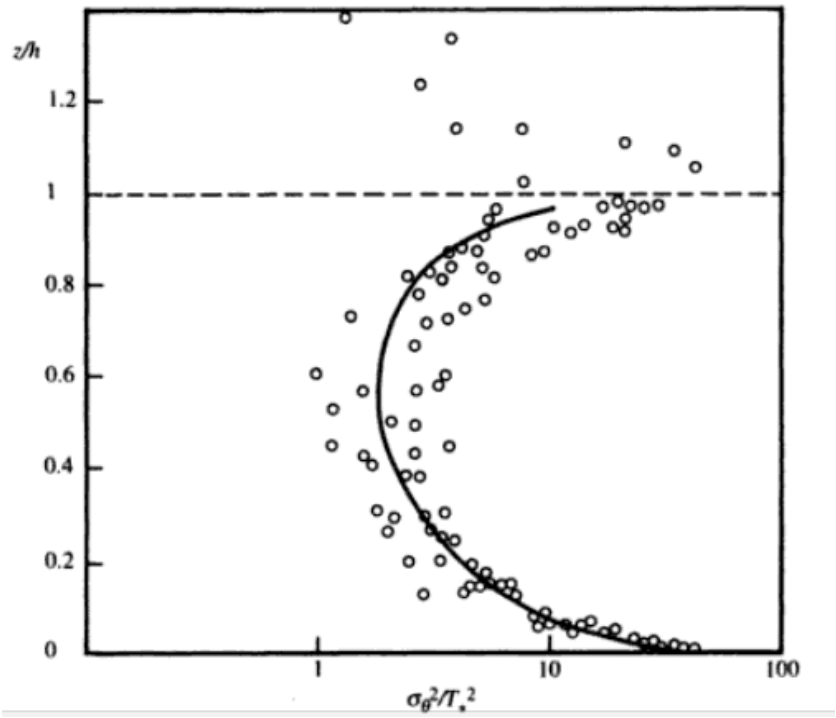


the height of the SCBL was detected from momentary profiles



... which was almost linearly increasing in time

Scaling parameters: Convection velocity w_* , Θ_*



Garrat(1994)

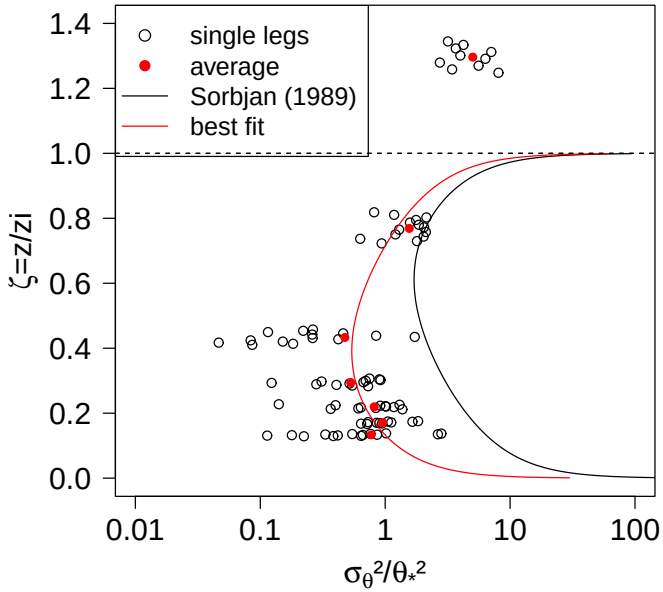
Deardorff scales can be found, using surface flux $\langle w'\Theta' \rangle_0$ from sonic anemometer

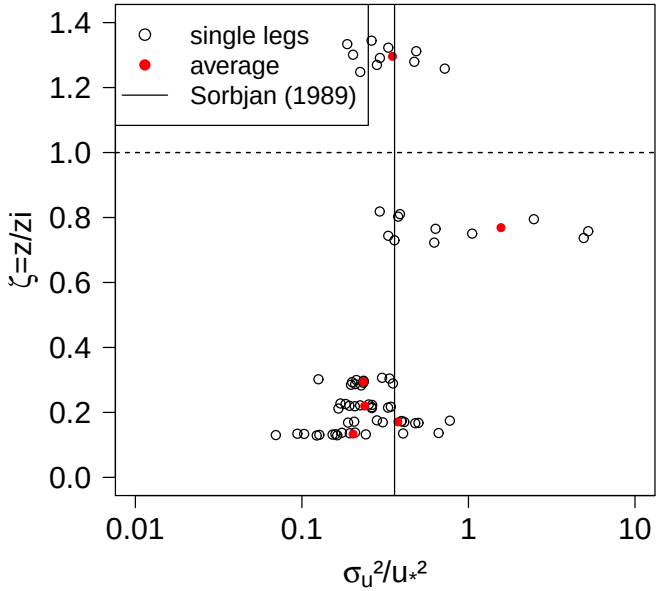
$$w_* = \left[\frac{g}{\overline{\Theta}} z_i \langle w'\Theta' \rangle_0 \right]^{1/3}$$

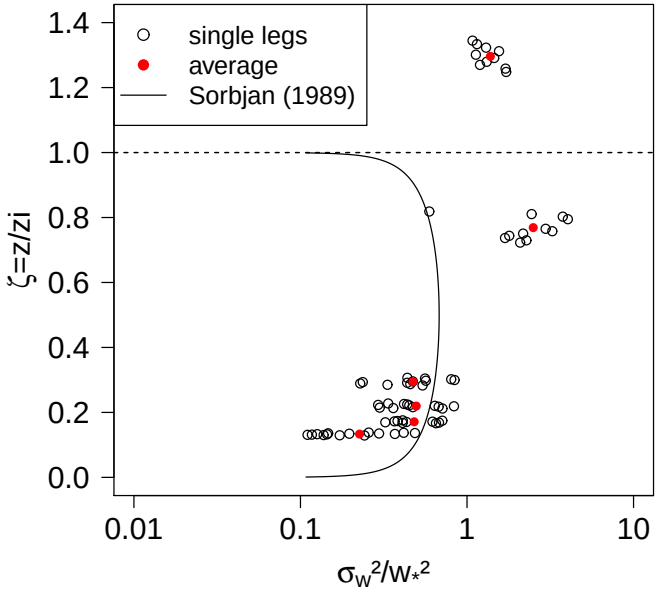
$$\Theta_* = \frac{\langle w'\Theta' \rangle_0}{w_*}$$

- Which theories / formulations for the CBL are valid in the early morning transition?
- Which parameters can be found in literature and fit with the experiment?

Scaled variances: 14 August 2013



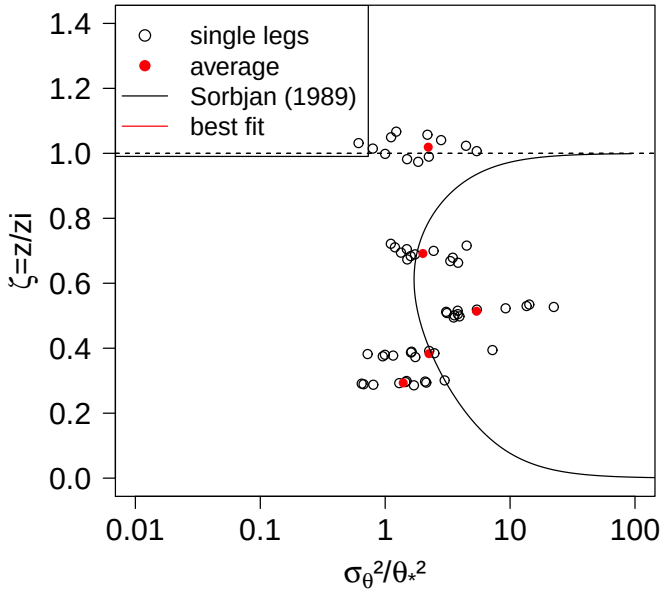




Scaled variances of Θ, u and w were calculated and compared to literature:

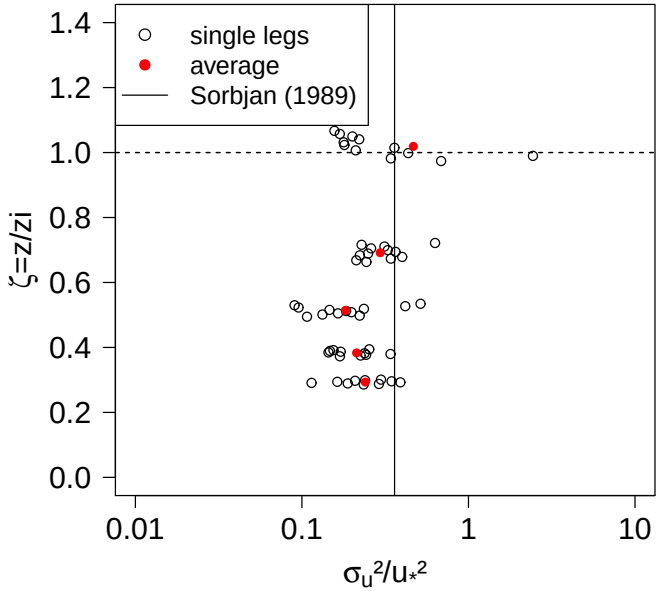
- Observations maybe comparable to mixed layer theories
- but scaling parameters differ a lot

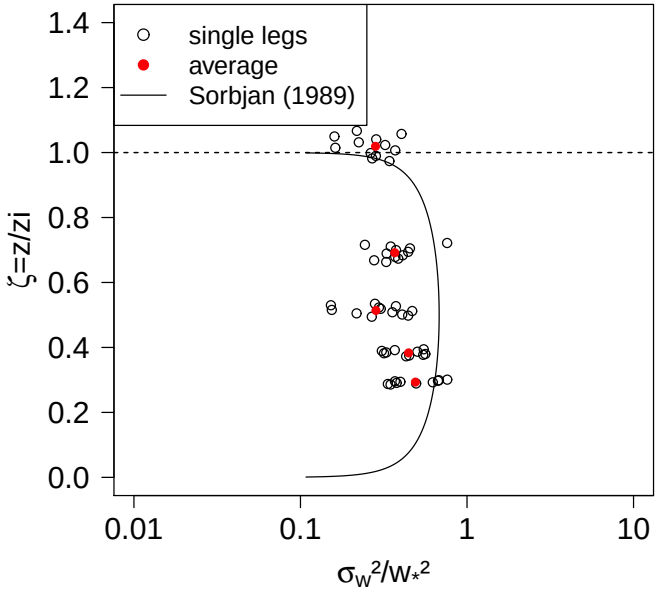
Scaled variances: 05 September 2013



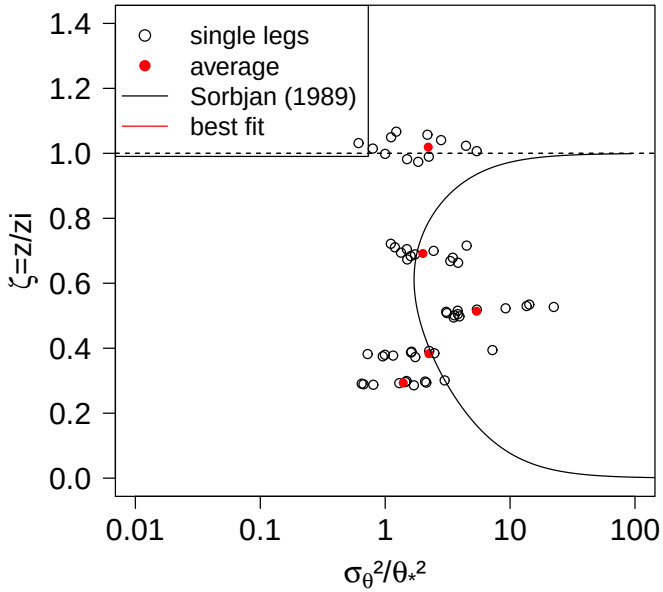
Second day of observations

- Non-textbook conditions give non-textbook results
- No clear relationship can be derived on this day





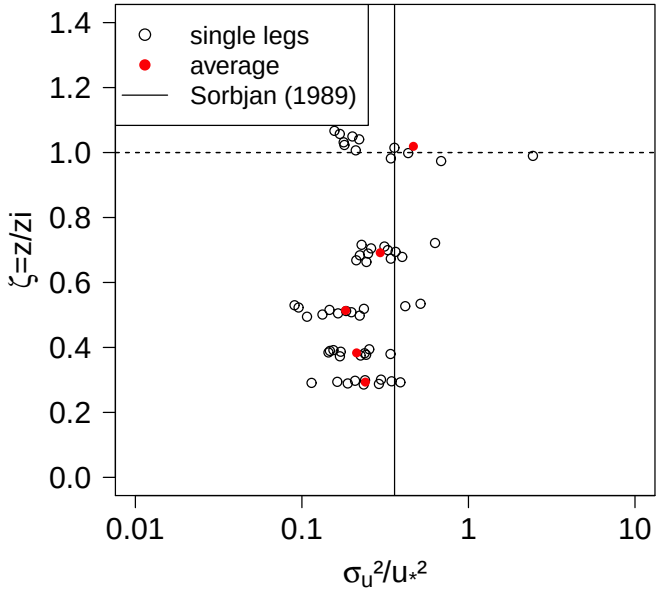
Scaled variances: 05 September 2013

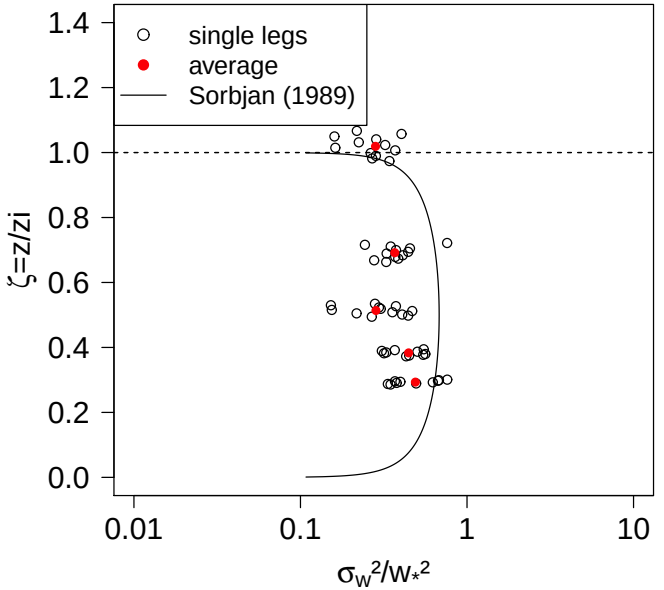


Possible reasons:

- high water vapour content
- strong entrainment
- remaining weak stability after mixing
- heterogeneous terrain
- flight legs too short

More experiments and data are necessary





Thank you for your attention!