Technische Universität Braunschweig

Institute of Aerospace Systems

Aircraft Speed Variations and Sensible Heat Flux Measurements

Sabrina Martin[1] and Jens Bange[2]

[1] Technische Universität Braunschweig, [2] Eberhard Karls Universität Tübingen

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Outline

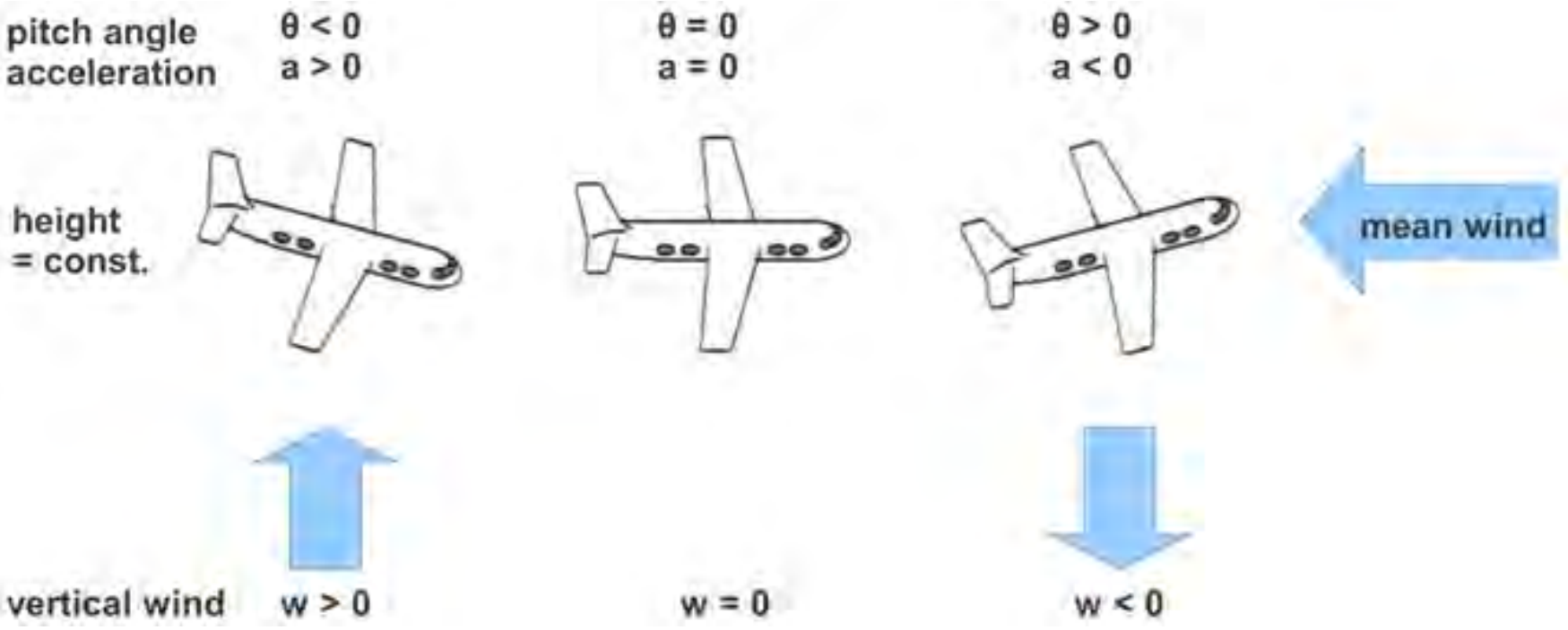
- Publication by Crawford et al. 1993
- Vertical wind and ground speed
- Time and space average
- Airborne systems
- Results
- Conclusions

Publication by Crawford et al. 1993

- correlation between aircraft speed and vertical wind velocity
  $\Rightarrow$ time average is inappropriate for EC flux computations
  $\Rightarrow$ space average (ground speed correction to the time average)
- correction highly variable, depending on turbulent flow and aircraft
- speed connection more important as airplane size is reduced

Airplane	$\overline{H_s/H_t}$	σ	Variance for 50% of data
Twin Otter (5225 kg)	1.01	0.02	1%
Long-EZ (550 kg)	1.00	0.11	10%

Vertical Wind and Ground Speed



Time and Space Average

time average:

$$H_t = \overline{\rho} c_p \overline{w'\theta'}$$

$$\phi_i' = \phi_i - \overline{\phi}$$

$$\overline{\phi} = \frac{1}{N}\sum \phi_i$$

space average:

(Crawford, 1993, BLM)

$$H_s = c_p \left(\frac{\overline{\rho w \theta S}}{\overline{S}} - \frac{\overline{\rho w S}\ \overline{\theta S}}{\overline{S}^2} \right)$$

$$\phi_i^* = \phi_i - [\phi]$$

$$[\phi] = \frac{1}{X}\sum \phi_i \Delta x = \frac{1}{\overline{S}T}\sum \phi_i S_i \Delta t$$

Application for different airborne systems.

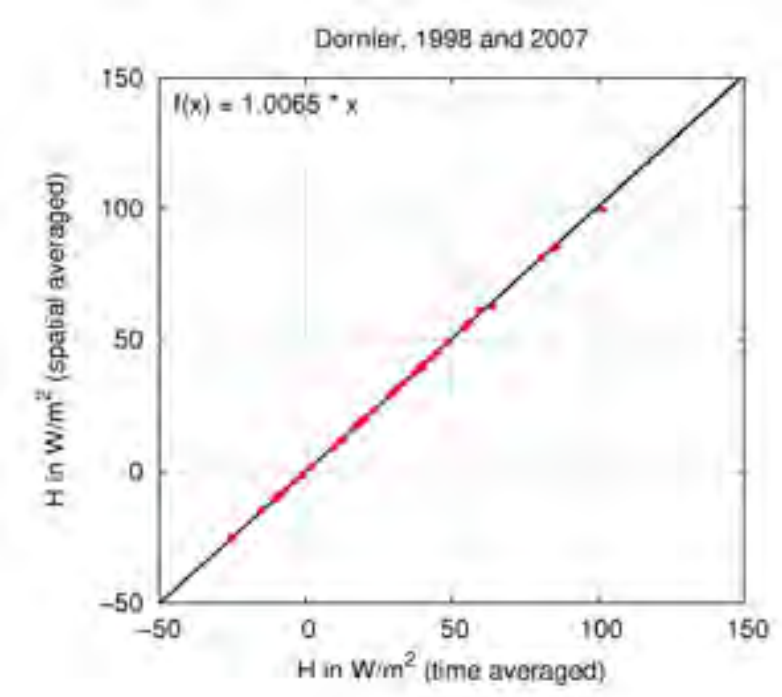
Airborne Systems

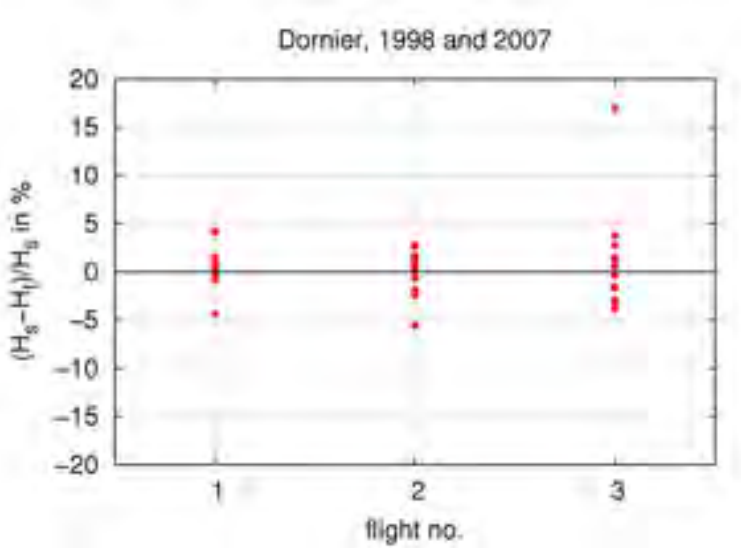
Dornier Do 128-6
cruising speed: 62 m/s
weight: 4350 kg
wingspan: 16 m

Helipod & Helicopter
cruising speed: 40 m/s
weight: 1700 kg
wingspan: 10 m

UAV M^2AV
cruising speed: 22 m/s
weight: 6 kg
wingspan: 2 m

Dornier Do 128-6

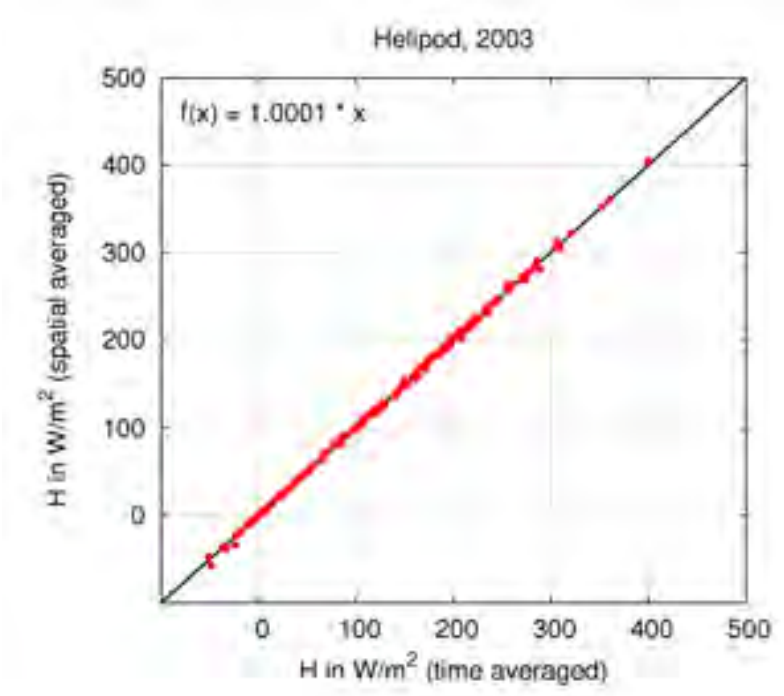


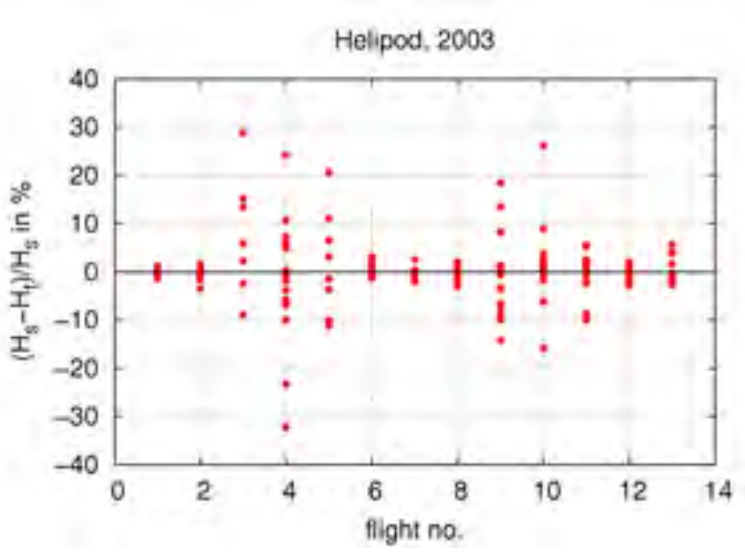


- 44 flight legs
- variance mostly below 5%
- mean (absolute) variance: 1.83%
- $H_s > H_t$

Airplane	$\overline{H_s/H_t}$	σ
Twin Otter	1.01	0.02
Long-EZ	1.00	0.11
Dornier	1.00	0.04
Helipod		
M^2AV		

Helipod

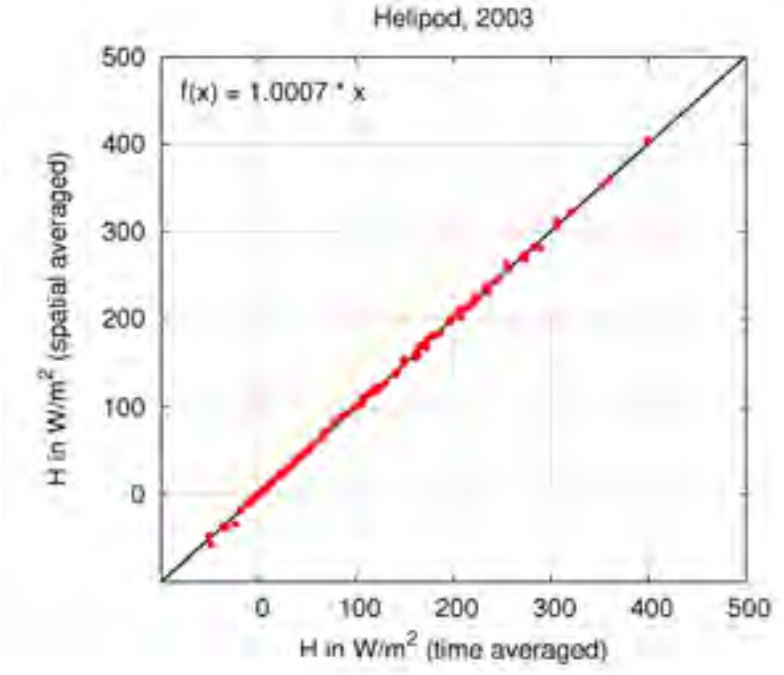


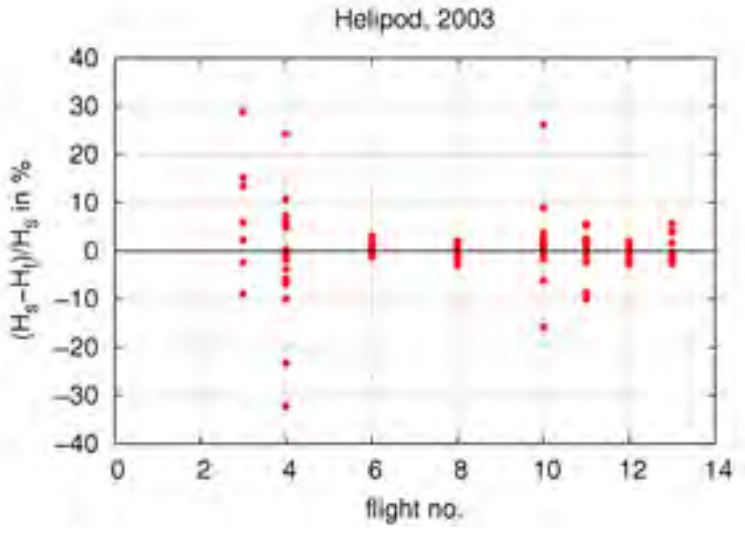


- 178 flight legs
- variance up to 30%
- mean (absolute) variance: 3.58%
- $H_s > H_t$

Airplane	$\overline{H_s/H_t}$	σ
Twin Otter	1.01	0.02
Long-EZ	1.00	0.11
Dornier	1.00	0.04
Helipod	1.01	0.07
M^2AV		

Helipod: Flights around Noon

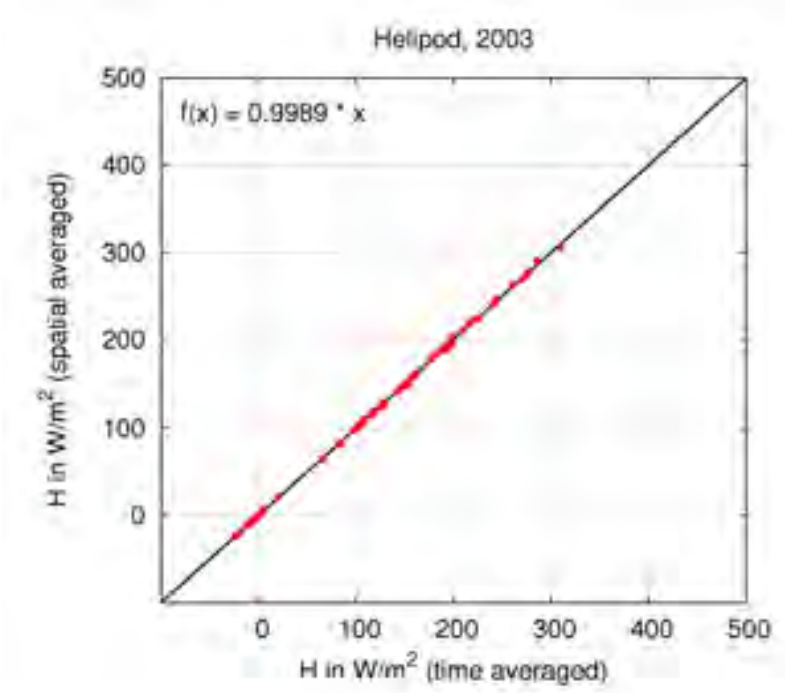


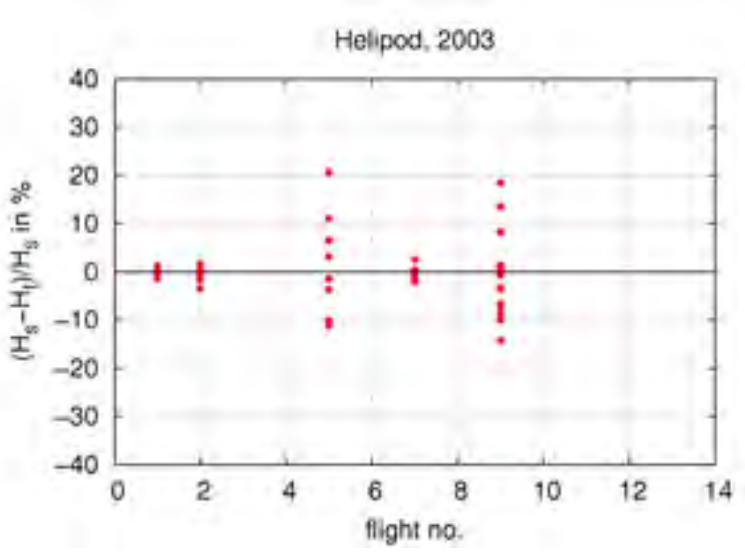


- 115 flight legs
- mean (absolute) variance: 3.77% ↑
- $H_s > H_t$

Airplane	$\overline{H_s/H_t}$	σ
Twin Otter	1.01	0.02
Long-EZ	1.00	0.11
Dornier	1.00	0.04
Helipod	1.01	0.08 ↑
M^2AV		

Helipod: Morning and Evening Flights

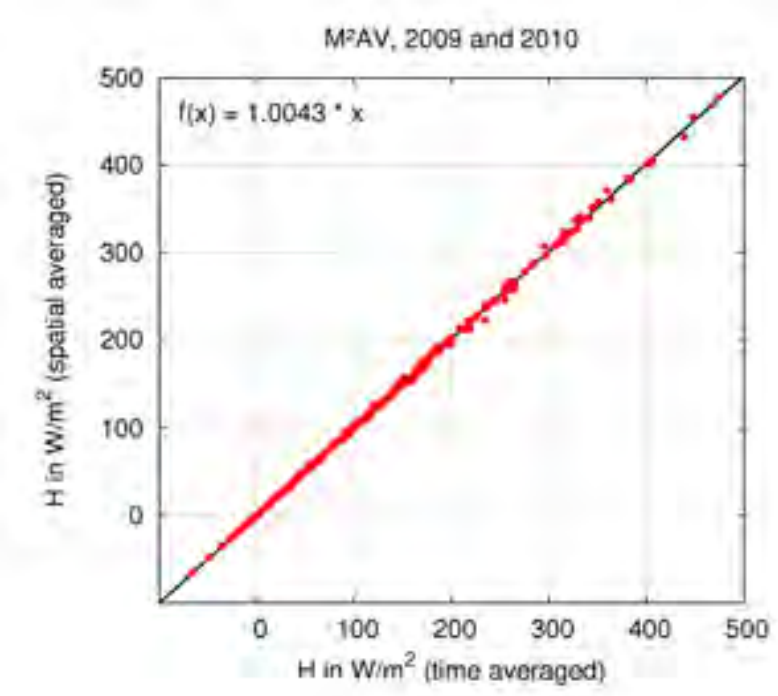


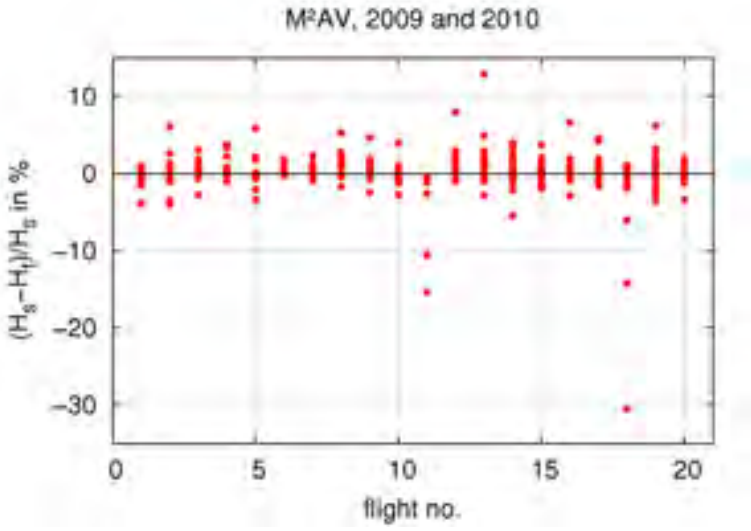


- 63 flight legs
- mean (absolute) variance: 3.23% ↓
- $H_s < H_t$

Airplane	$\overline{H_s/H_t}$	σ
Twin Otter	1.01	0.02
Long-EZ	1.00	0.11
Dornier	1.00	0.04
Helipod	1.00 ↓	0.06 ↓
M^2AV		

UAV M^{2}AV

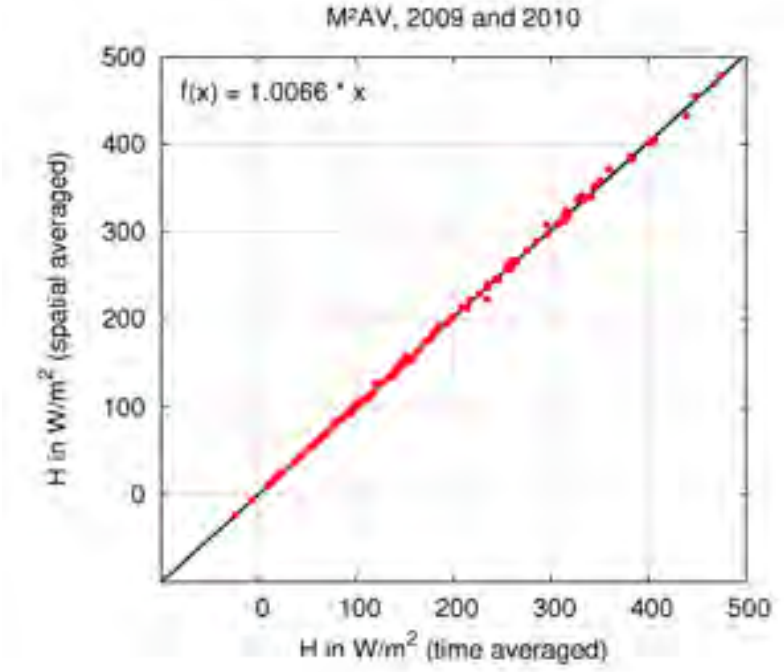


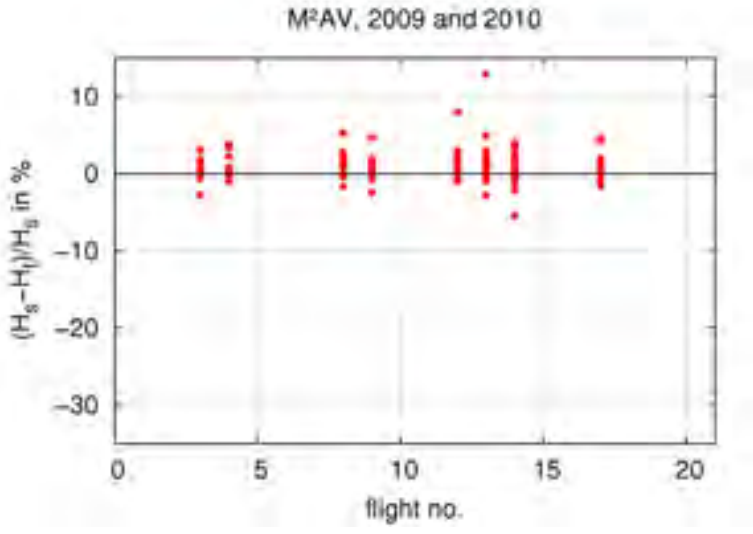


- 288 flight legs
- variance mostly below 10%
- mean (absolute) variance: 1.59%
- $H_s > H_t$

Airplane	$\overline{H_s/H_t}$	σ
Twin Otter	1.01	0.02
Long-EZ	1.00	0.11
Dornier	1.00	0.04
Helipod	1.01	0.07
M^{2}AV	1.00	0.03

UAV M^{2}AV: Flights around Noon

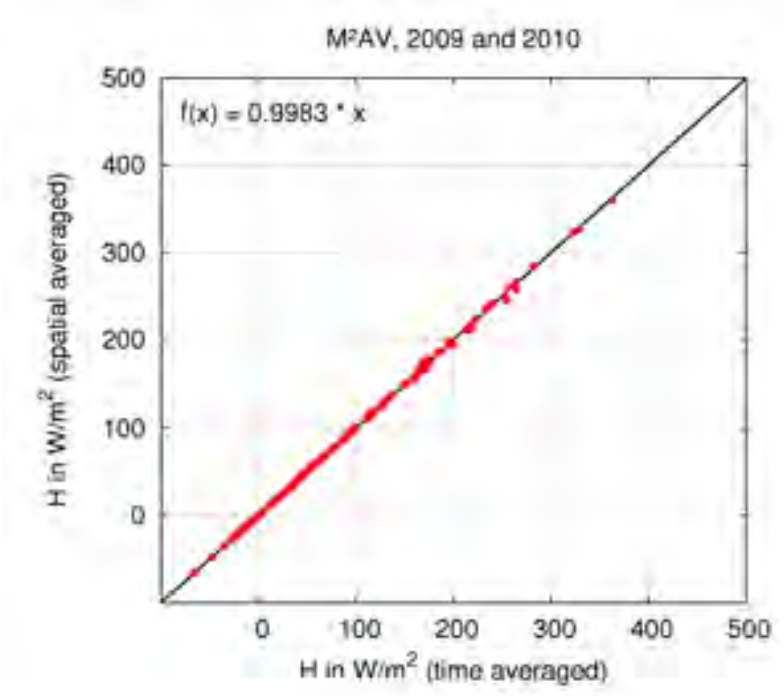


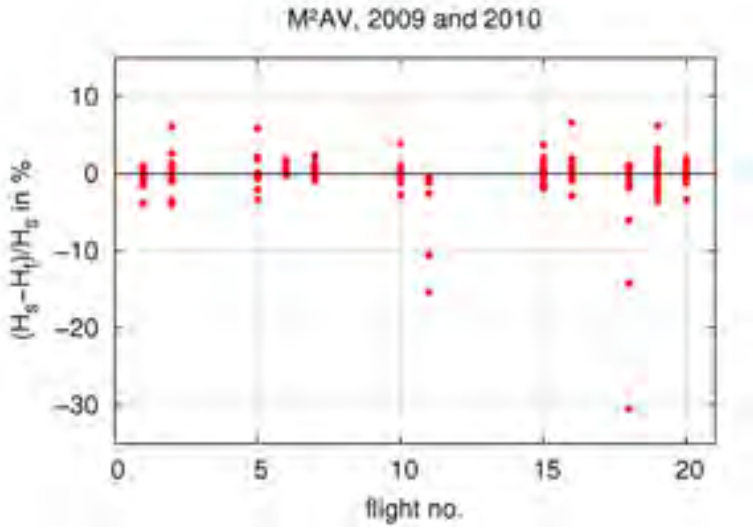


- 114 flight legs
- mean (absolute) variance: 1.60% ↑
- $H_s > H_t$

Airplane	$\overline{H_s/H_t}$	σ
Twin Otter	1.01	0.02
Long-EZ	1.00	0.11
Dornier	1.00	0.04
Helipod	1.01	0.07
M^{2}AV	1.01 ↑	0.02 ↓

UAV M^{2}AV: Morning and Evening Flights





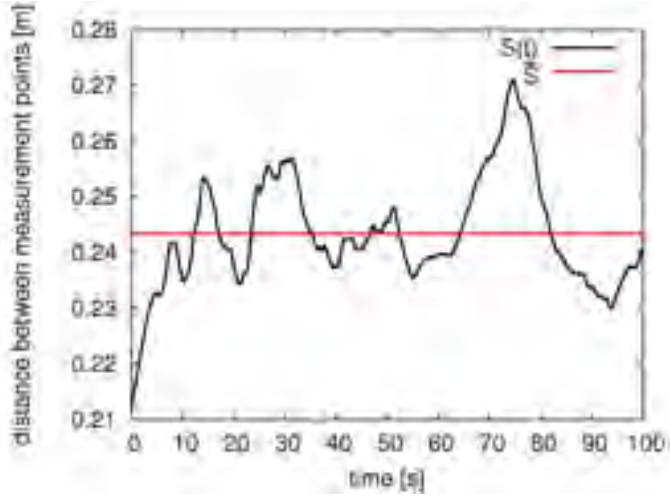
- 174 flight legs
- mean (absolute) variance: 1.53% ↓
- $H_s < H_t$

Airplane	$\overline{H_s/H_t}$	σ
Twin Otter	1.01	0.02
Long-EZ	1.00	0.11
Dornier	1.00	0.04
Helipod	1.01	0.07
M^{2}AV	1.00	0.03

Aircraft Speed Variations

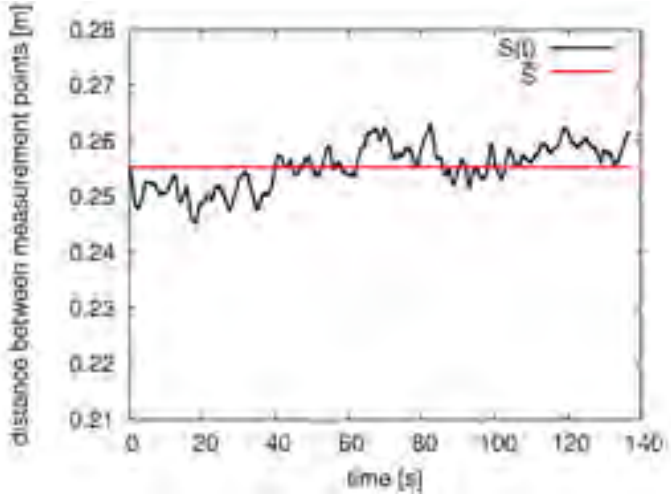
Distance between measurement points.

12 July 2010, 11:22 - 11:24 UTC



Variations up to 6 cm.

11 July 2010, 5:04 - 5:06 UTC



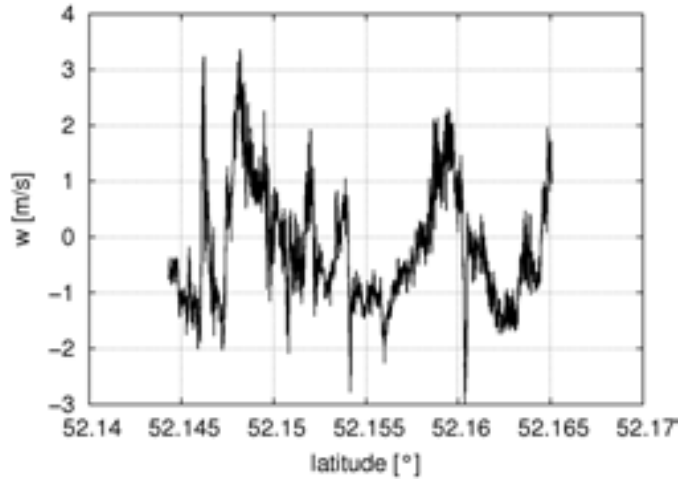
Variations up to 1 cm.

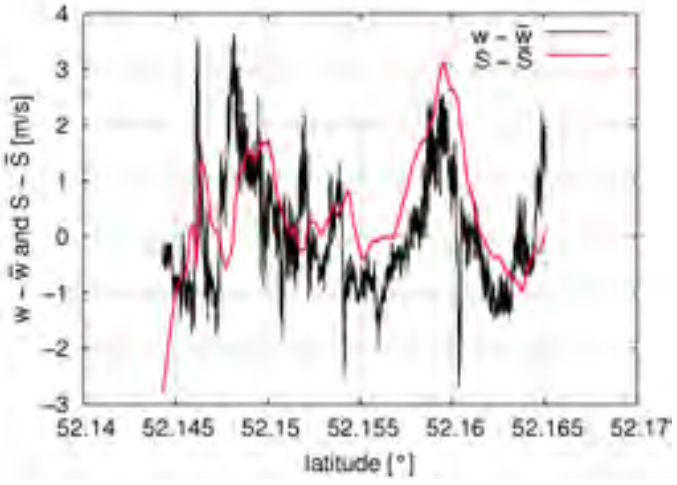
Summary and Conclusions

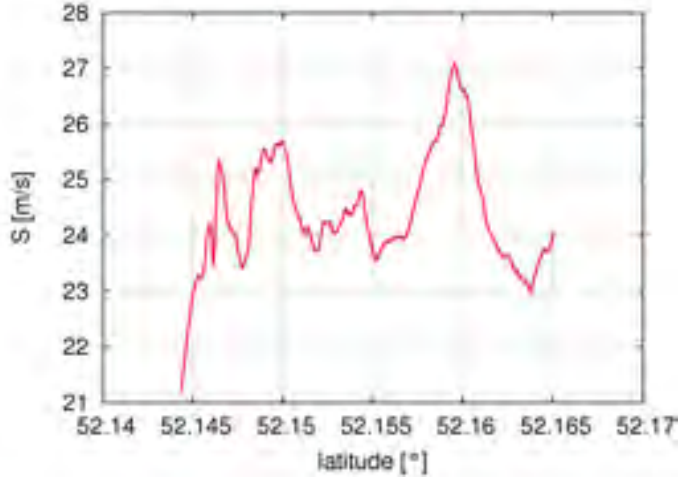
- aircraft speed variations influence EC flux computations
- ground speed correction to the time average is necessary
- variance between H_s and H_t depends on aircraft and turbulent flow
- reduced airplane size $\not\rightarrow$ increased variance
- strong convection $\rightarrow$ increased variance
- advice: space average for airborne flux measurements

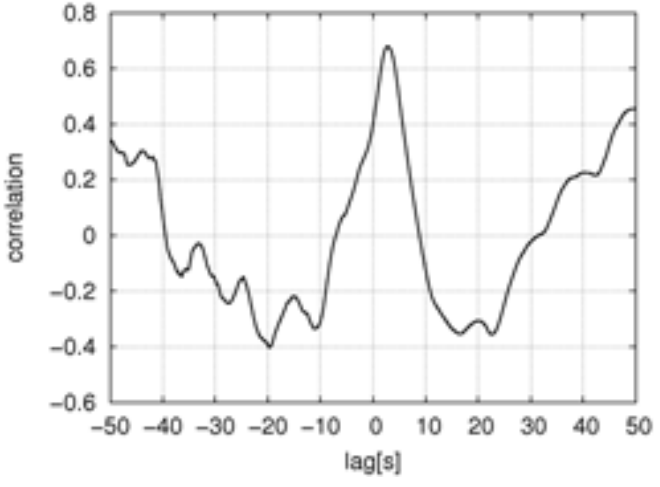
Airplane	$\overline{H_s/H_t}$	σ
Twin Otter (5225 kg)	1.01	0.02
Dornier (4350 kg)	1.00	0.04
Helipod (1700 kg)	1.01	0.07
Long-EZ (550 kg)	1.00	0.11
M^2AV (6 kg)	1.00	0.03

12 July 2010, 11:22 - 11:24 UTC









Strong convection: high correlation between S and w

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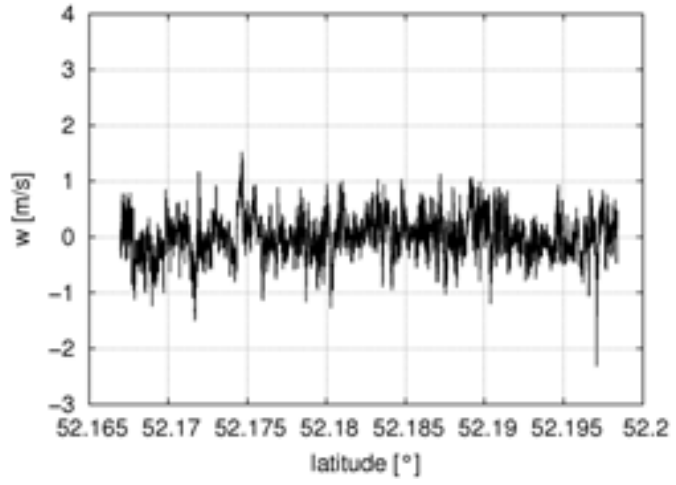

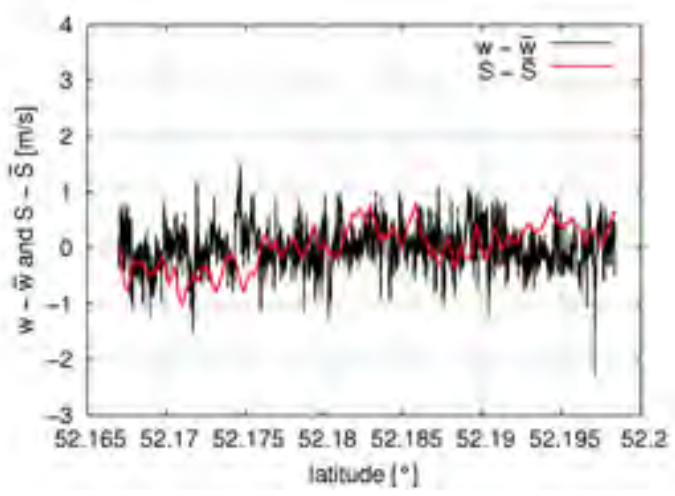

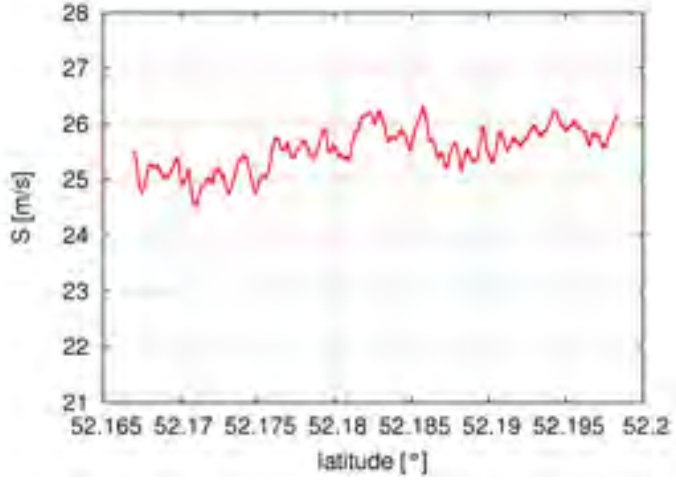

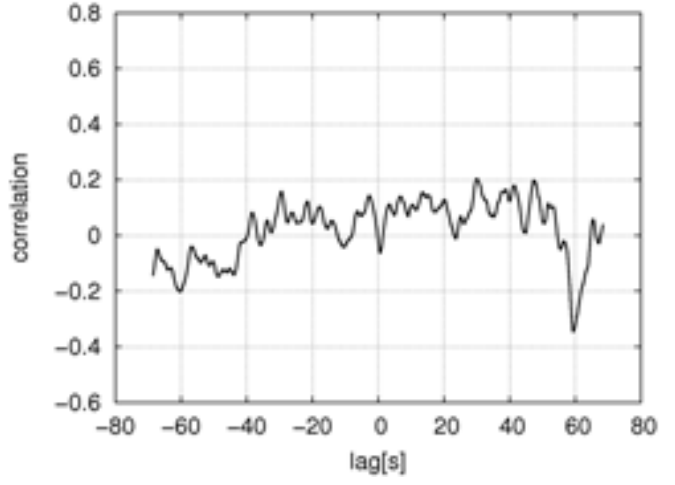

Weak convection: low correlation between S and w