On the discrepancy in simultaneous observations of $C_{T^2}$ by \textbf{scintillometers}, sonics and unmanned aircraft

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On the discrepancy in simultaneous observations of $C_T^2$ by scintillometers, sonics and unmanned aircraft

Previous results: LITFASS-2003

Meijninger et al. 2006
Why? On the discrepancy in simultaneous observations of $C_T^2$ by scintillometers, sonics and unmanned aircraft

Previous results: LITFASS-2003

$C_n^2$ $\uparrow$ $C_T^2$ $\uparrow$ $C_n^2$ $\uparrow$

$H_{\text{LAS-MWS}}$ $[\text{W m}^{-2}]$

$H_{\text{source-area}}$ $[\text{W m}^{-2}]$

$y = 1.07x$

$R^2 = 0.83$

$H_{\text{landuse}}$

Meijninger et al. 2006
Why? On the discrepancy in simultaneous observations of $C_T^2$ by scintillometers, sonics and unmanned aircraft

Previous results: LITFASS-2003

$C_n^2$ $C_n^2$ $C_n^2$

$C_T^2$ $C_T^2$ $C_T^2$

MOST

$H$ $H$

Fraction landuse $\bar{H} < \bar{H}$

Meijninger et al. 2006
How? On the discrepancy in simultaneous observations of $C_T^2$ by scintillometers, sonics and unmanned aircraft

New campaign: LITFASS-2009

$z_{\text{eff}} = 63$ m

$z_{\text{eff}} = 43$ m
On the discrepancy in simultaneous observations of $C^2_T$ by scintillometers, sonics and unmanned aircraft
On the discrepancy in simultaneous observations of $C_T^2$ by scintillometers, sonics and unmanned aircraft.
What? On the *discrepancy* in simultaneous observations of \( C_T^2 \) by scintillometers, sonics and unmanned aircraft

First results: LITFASS-2010

\[ C_T^2 \text{ aircraft} > C_T^2 \text{ EC} \]

Van den Kroonenberg *et al.* 2012
Conclusions so far...

LITFASS-2009

$C_I^2$ aircraft $\approx 2 \ C_I^2$ LAS

One day
“quick overview”

LITFASS-2010

$C_I^2$ aircraft $\approx 2 \ C_I^2$ EC

No $C_I^2$ LAS
This study
On the discrepancy of $C_T$

- More days
- More validation data (EC & LAS)
- Normalizing to $z = 50$ m

Elaborate data processing
- Saturation correction
- $C_n^2 \rightarrow C_T^2$: Humidity correction
- Synchronising averaging times
- Path-weighting function of LAS
- Mathematical methods
Elaborate data processing normalizing to $z = 50$ m
Results

normalizing to $z = 50$ m

$C_T^2 \text{[K}^2 \text{m}^{-2}\text{]}$

![Graph showing data from LITFASS-2009 and LITFASS-2010](image)

**LITFASS-2009**

**LITFASS-2010**

- EC 50m
- EC 90m
- LAS 43.3m
- LAS 63.3m
- aircraft
Elaborate data processing

$C_n^2$: Saturation correction

- **Clifford correction method**
  - *Kleissl et al.* 2010
  - *Clifford et al.* 1974

- **LAS:**
  - 43 m: +16%
  - 63 m: +11%
Elaborate data processing

\[ C_n^2 \rightarrow C_T^2: \textbf{Humidity correction} \]

\[ C_n^2 = A_T C_T^2 + A_{Tq} C_{Tq} + A_q C_q^2 \]

1. Extra Microwave Scintillometer (MWS)
   two wavelength method
   - \( \text{cov}(\ln I_{LAS}, \ln I_{MWS}) \) (Lüdi et al, 2005)
   - \( R_{Tq} \) (Hill)

2. Extra EC (Moene, 2003)
   - \( R_{Tq}, \sigma_T \) and \( \sigma_q \)
   - \( R_{Tq}, \beta \)
   - \( \beta \)

LITFASS-2009
@ 43 m

LITFASS-2009
LITFASS-2010
@ 43 m
@ 63 m
Elaborate data processing

\[ C_n^2 \rightarrow C_T^2: \text{Humidity correction} \]

\[ C_n^2 = A_T C_T^2 + A_{Tq} C_{Tq} + A_q C_q^2 \]

1. Extra MWS
   - two wavelength method
     - cov(ln \( I_{LAS} \), ln \( I_{MWS} \))
     - \( R_{Tq} \)

2. Extra EC
   - \( R_{Tq}, \sigma_T \) and \( \sigma_q \)
   - \( R_{Tq}, \beta \)
   - \( \beta \)

LAS: +5%
(relative to standard Bowen correction)
Elaborate data processing
Synchronizing averaging times

Normally:
10 or 30 min
approx. 2 min

LAS:
- 43m: -1%
- 63m: -4%
- uncertain

LITFASS-2009
This study

On the discrepancy of $C_T$

- Other days
- Extra validation with EC
- Normalizing to $z = 50$ m
- Elaborate data processing
  - Saturation correction
  - $C_n^2 \rightarrow C_T^2$: Humidity correction
  - Synchronising averaging times
  - Path-weighting function of LAS
  - Mathematical methods
  - Effect of flight speed

$C_T^2$ aircraft

$\approx 2C_T^2$ LAS

$C_T^2$ LAS +15%

$C_T^2$ LAS +5%

$C_T^2$ LAS 0%
Elaborate data processing path weighting function LAS
Elaborate data processing path weighting function LAS

LITFASS-2009
UAV: −6%

LITFASS-2010
UAV: +10%
Elaborate data processing
other mathematical methods

- **Standard procedure**
  van den Kroonenberg *et al.* 2012
- **Spectrum procedure**
- **Wavelet procedure**
  Moene & Gioli 2008

UAV: −14%
UAV: −4%
This study
On the discrepancy of $C_T$

- Other days
- Extra validation with EC
- Normalizing to $z = 50$ m

Elaborate data processing
- Saturation correction
- $C^n_T \rightarrow C^2_T$: Humidity correction
- Synchronising averaging times
- Path-weighting function of LAS
- Mathematical methods

$C_T^2 \text{ aircraft } \approx 2C_T^2 \text{ LAS}$

$C_T^2 \text{ LAS } +15\%$

$C_T^2 \text{ LAS } +5\%$

$C_T^2 \text{ LAS } 0\%$

$C_T^2 \text{ aircraft } \pm 10\%$

$C_T^2 \text{ aircraft } \pm 15\%$
Results

EC 50m  
EC 90m  
LAS 43.3m,  
LAS 63.3m,  
aircraft,

\[ C_T^2 \text{[K}^2 \text{m}^{-2/3}] \]


LITFASS-2009  LITFASS-2010
Results
all corrections/processing implemented
Effect of translation speed of sensor

- High-resolution LES of LITFASS area ($\Delta x = 3.1$ m, $\Delta z = 2$ m)

- Virtual sensors at different speeds:
  - $0$ ms$^{-1}$: virtual sonic
  - $5$-33 ms$^{-1}$: virtual UAV
  - $\infty$ ms$^{-1}$: virtual LAS

- Does structure parameter depend on choice of platform translation speed?
Effect of translation speed of sensor

Extra variance due to temporal development of turbulence
Conclusions

- $C_T^2$ aircraft > $C_T^2$ LAS > $C_T^2$ EC also valid at other days

- More elaborate data processing does not decrease differences significantly

- Additional experiments are needed to better understand line-mean $C_T^2$ and link with scintillometer signal