MOMENTUM, SENSIBLE HEAT AND CO_2 CORRELATION COEFFICIENTS : WHAT CAN WE LEARN FROM 20 YEARS OF EDDY COVARIANCE MEASUREMENTS?

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Introduction

Context

- ICOS candidate site located inside a mixed temperate forest
- How does long term variability of measurement height and canopy height affect turbulent fluxes?

Content

- Spatio-temporal evolution of canopy aerodynamic distance (*z-d*)
- Spatio-temporal evolution of correlation coefficients (r_{uw}, r_{wT}, r_{wc}).
- Relation between these parameters.

Theory

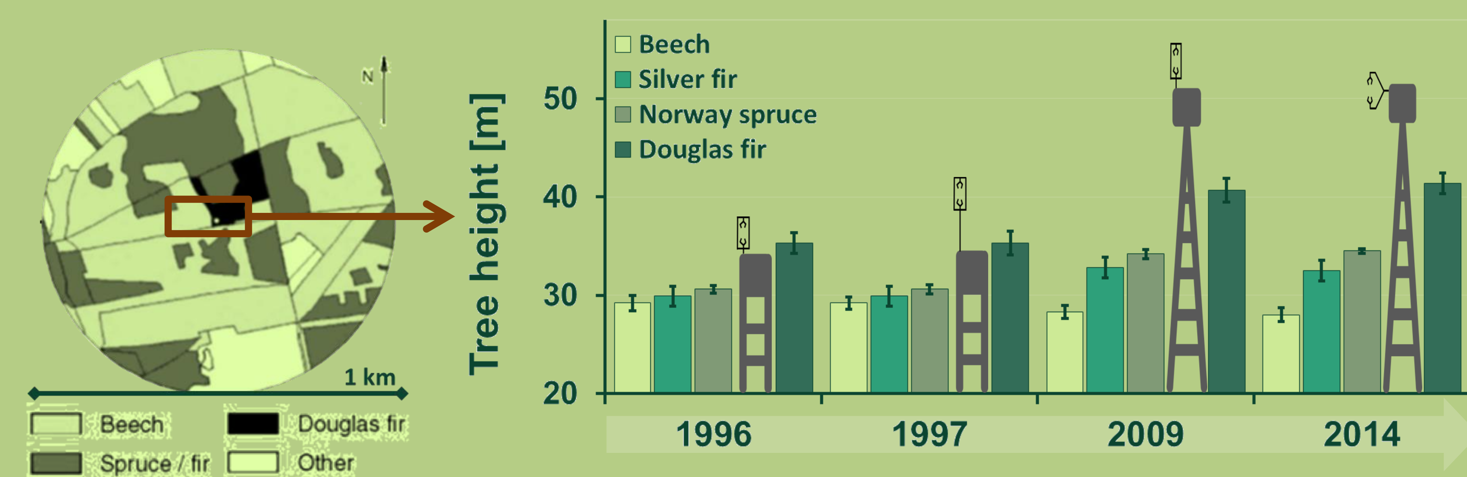
- $z-d$ = sonic anemometer height (z) – displacement height (d)
- Correlation coefficients :

$$r_{uw}=\frac{\overline{u'w'}}{\sigma_u\sigma_w}\quad;\quad r_{wT}=\frac{\overline{w'T'}}{\sigma_w\sigma_T}\quad;\quad r_{wc}=\frac{\overline{w'c'}}{\sigma_w\sigma_c}$$

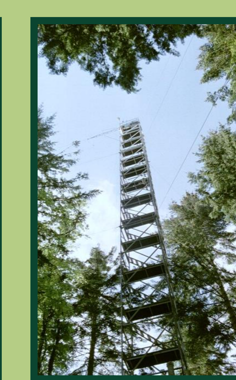
  - may be referred to as normalized covariances or transport efficiencies as they indicate how much *w* is related to *u*, *T* and *c*.
  - directly related to the similarity ratios and should therefore be constant in the inertial sublayer according to the similarity theory.

Site description

The Vielsalm Terrestrial Observatory

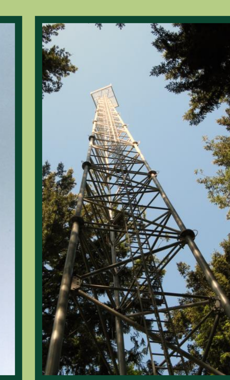


The mixed forest view from the top of the tower in the West direction in autumn 2014



Start! **The scaffolding** 36m in 1996

Too short! **→A mast** +4m in 1997



Tree growth! **→New tower** +12m in 2009

ICOS! **→New sonic** −1m in 2014

Method

Canopy aerodynamic distance estimation

NEW

- **Principle: comparing observed and theoretical sensible heat cospectra**

Observed cospectrum:

- Mean cospectrum in wave number domain by year and azimuthal direction sector.

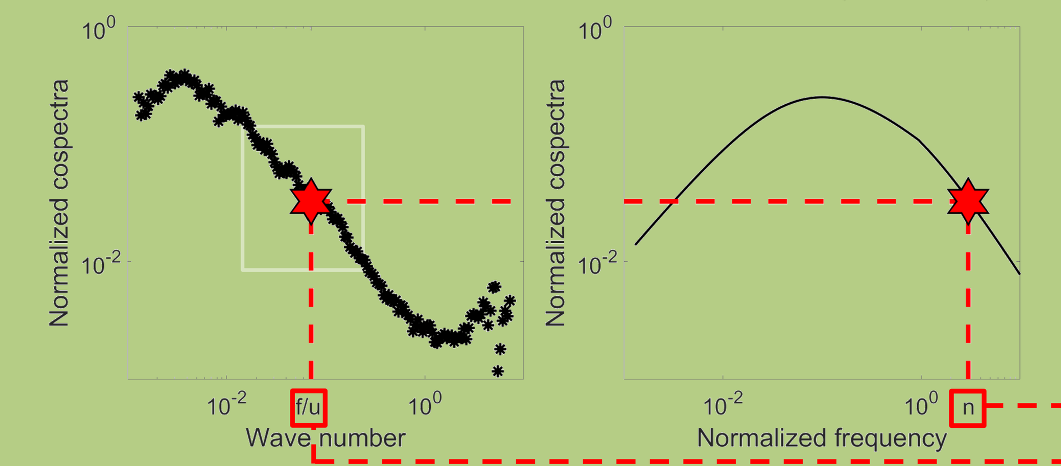
Theoretical cospectrum:

- Kaimal's function with site specific parameters:

$$\frac{fCo_{wT}(f)}{\overline{w'T'}}=\frac{a\,n}{(1+b\,n)^c}$$

Ratio between:

- Expected normalized frequencies and observed wave numbers.



$$z-d=\frac{n}{f/u}$$

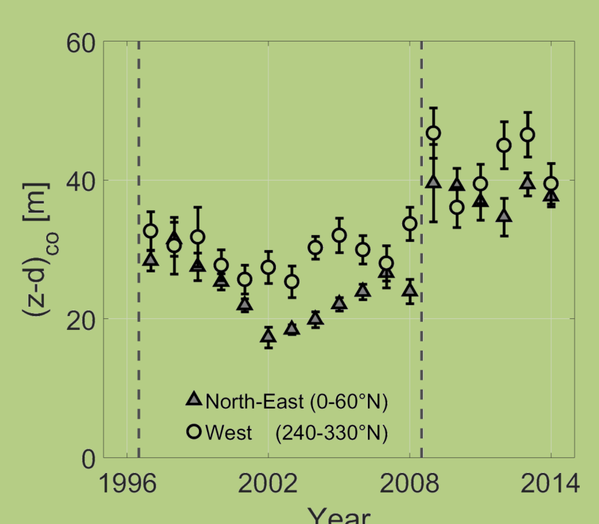
$$n=(z-d)\frac{f}{u}$$

Validation:

- Confrontation of the results obtained to the observed changes in measurement height (*z*) and canopy height (*d*) (not presented)

Results

Canopy distance (*z-d*)

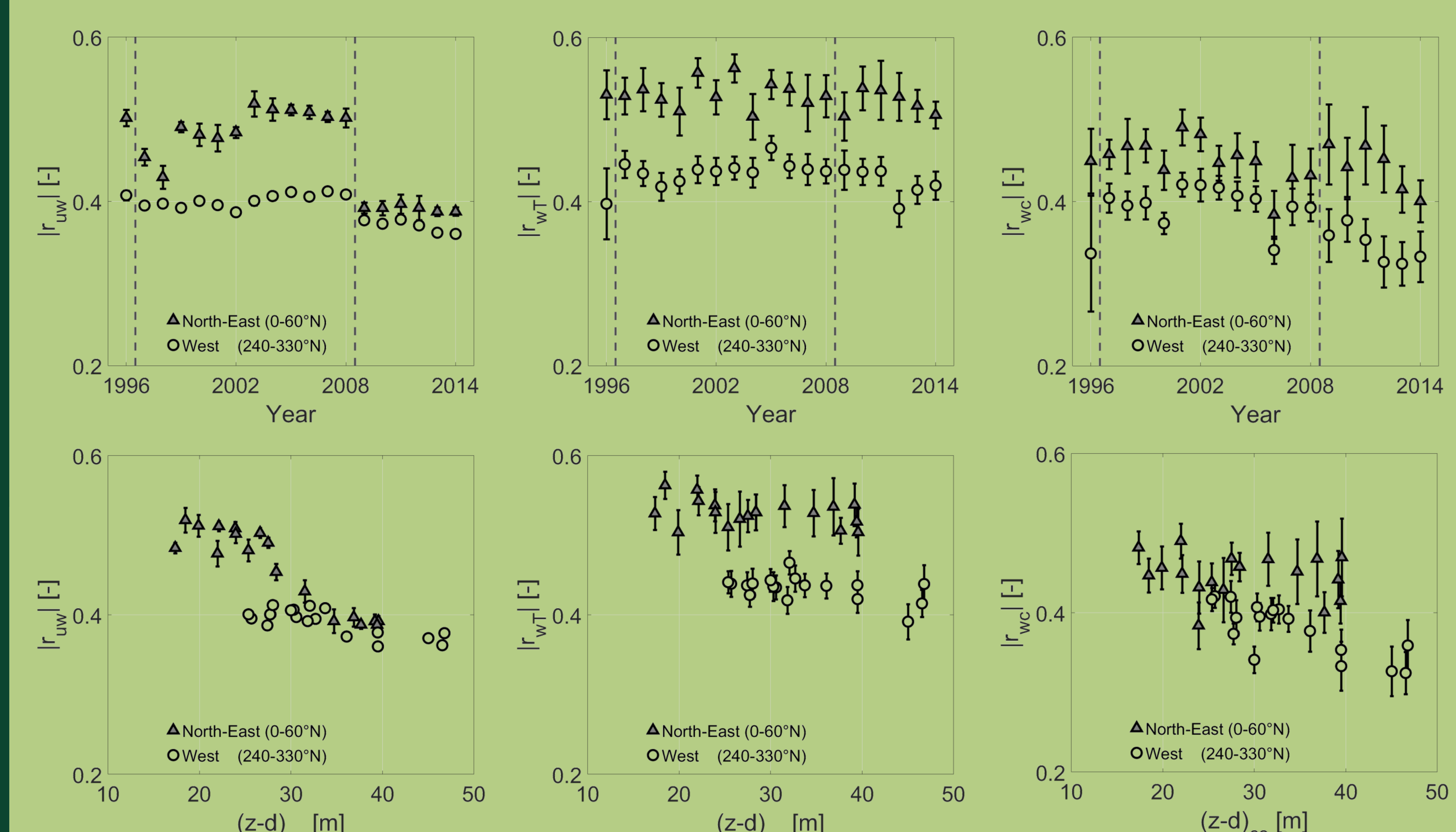


Discussion

- **1997–2002:** *z-d* decrease due to vegetation growth.
- **2002–2004:** *z-d* increase due to thinning.
- **2004–2008:** unexplained *z-d* increase: measurements too close to the canopy?
- **2009:** 14 (±6) m increase (+12 meter in reality).

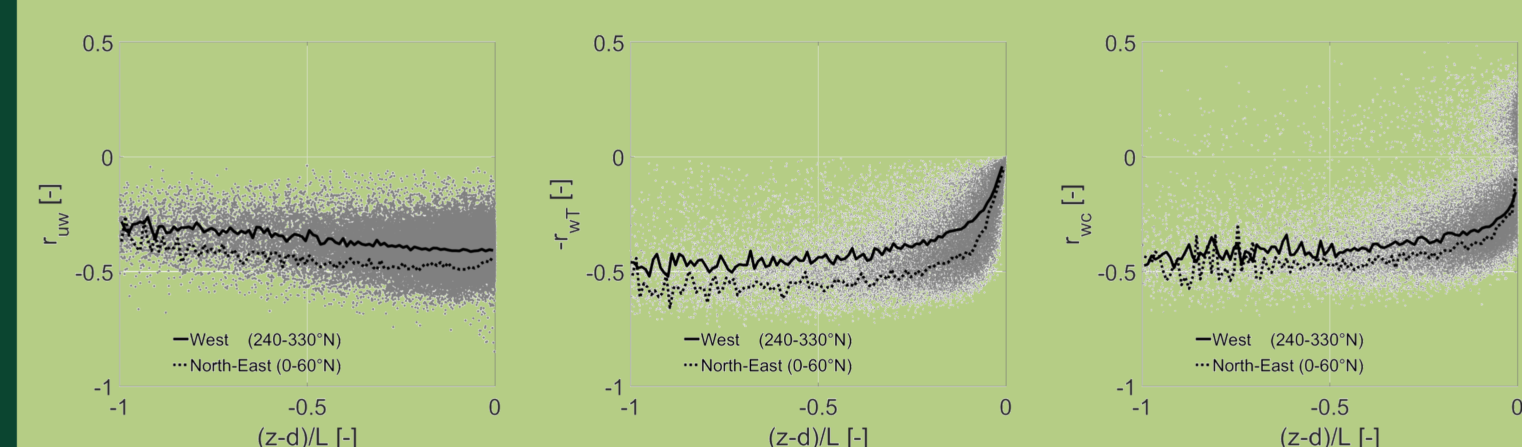
→ *z-d* spatial and temporal dynamics is fairly well reproduced. However *z-d* is slightly overestimated.

Correlation coefficients and *z-d*



- r_{uw} (neutral conditions): pronounced temporal dynamics (NE especially). r_{wc} and r_{wT} (unstable conditions): no temporal dynamics.
- r_{uw}, r_{wc} and r_{wT} : pronounced spatial dynamics.
- Significant relation between *z-d* and r_{uw} confirming measurements were made in the roughness sublayer.
- No relation between *z-d* and r_{wc} or r_{wT} likely due to a more homogeneous distribution of sources.

Spatial variability in r_{uw}, r_{wc} and r_{wT}?



- The spatial variability does not depend on stability as it is observed for all stabilities. It is less pronounced for $\boldsymbol{r_{wc}}$ than for $\boldsymbol{r_{wT}}$.
- For $\boldsymbol{r_{uw}}$ it is (at least partly) explained by canopy aerodynamic distance, while it is not the case for $\boldsymbol{r_{wc}}$ and $\boldsymbol{r_{wT}}$.
- For $\boldsymbol{r_{wc}}$ and $\boldsymbol{r_{wT}}$, it could be partly explained by a mechanical effect as they are related to the similarity ratio σ_w/u_*. This effect could be due to the roll present at the limit between tall Douglas firs and beeches.

$$r_{uw}=\left(\frac{\sigma_u}{u_*}\frac{\sigma_w}{u_*}\right)^{-1}\quad;\quad r_{wT}=\left(\frac{\sigma_T}{T_*}\frac{\sigma_w}{u_*}\right)^{-1}\quad;\quad r_{wc}=\left(\frac{\sigma_c}{c_*}\frac{\sigma_w}{u_*}\right)^{-1}$$

- However it is not sufficient as the effect is less pronounced for r_{wT} than for r_{wc}. None of the classical explanations (differences in sources and sinks distribution, active role of the temperature, large turbulence structures, occurrence of cloud passages) was completely satisfactory.

Conclusion

- An original method has been developed in order to estimate canopy aerodynamic distance (*z-d*).

→ The method correctly detects the *z-d* variability observed at a long term eddy covariance site.

- Momentum transport efficiency (r_{uw}) is strongly linked to *z-d*.

→ Characteristic of the roughness sublayer.

- Heat and CO_2 correlation coefficients (r_{uw}, r_{wc}, r_{wT}) independent of *z-d*.

→ The differences between azimuthal direction sectors in r_{wc}, and r_{wT} can not be explained by *z-d*.

- How to explain the spatial variability observed in r_{wc}, and r_{wT} (and at a lesser extent r_{uw})?

→ Hypothesis were raised but no completely satisfactory explanation was found.

- The canopy aerodynamic distance variability impact on the fluxes themselves remains to be explored as the footprint composition changed.

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