

NVBM Symposium – 6 November 2009

Ontwikkelingen in de Scintillometrie



WAGENINGEN UNIVERSITY
METEOROLOGY AND AIR QUALITY

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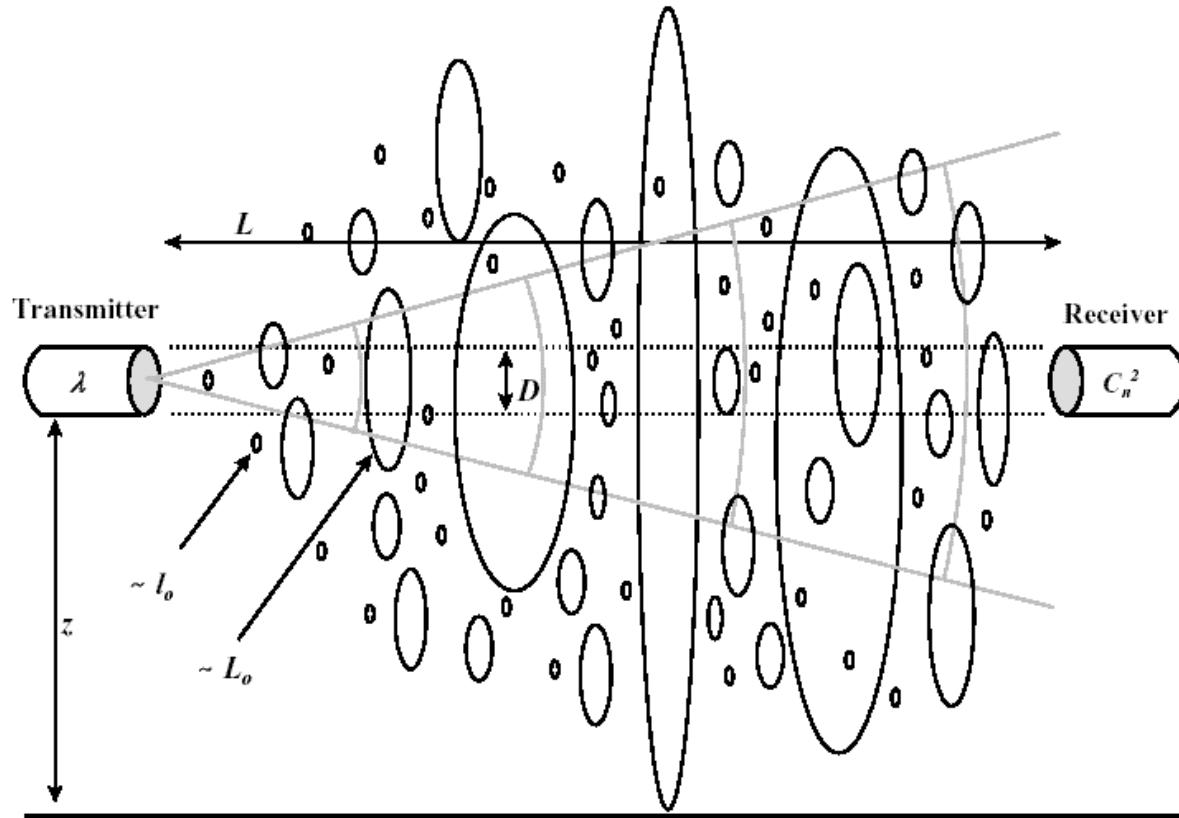
Enige Conclusies ter Introductie

- Scintillometers meten de verticale voelbare en latente warmtestroom over “grote” gebieden (schaal: 0.1 - 10km)
- Er zijn verschillende scintillometers voor diverse toepassingen (b.v.. lang vs kort pad en soort fluxen)
- Scintillometer methode is heel eenvoudig:
 - Methode kan worden toegepast door non-experts in micro-meteo
 - Instrumenten zijn makkelijk in onderhoud
 - Data processing is “eenvoudig”
- Scintillometer method is ook zeer complex:
 - Wave propagation theory in turbulent medium
 - Micro-meteorologie: Turbulentie in de oppervlaktelaag

What are Scintillations?



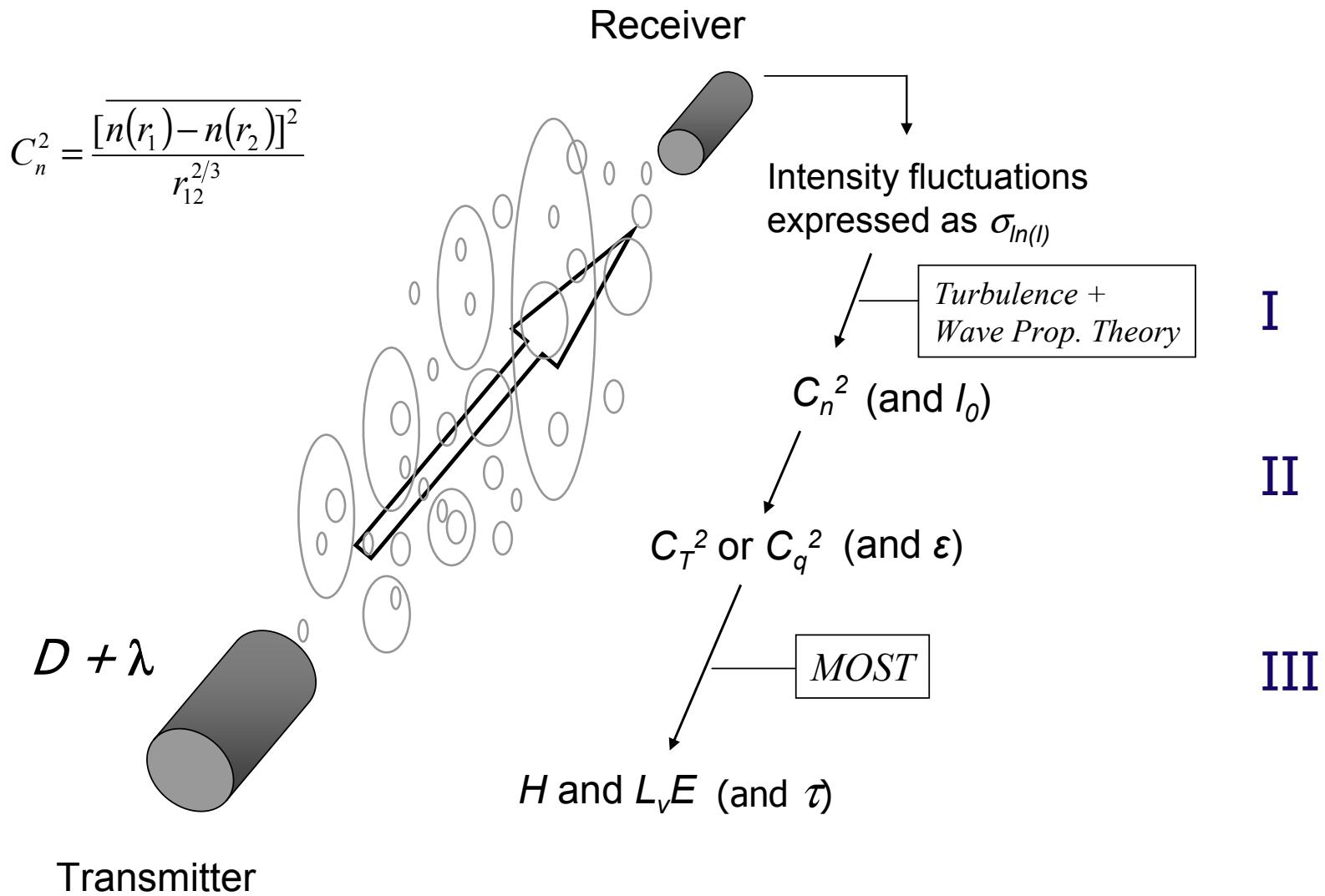
Scintillometer schematic + Length Scales



- Scintillometer length scales: **L** (path length), λ (wavelength), **F** (Fresnel length) = $(\lambda L)^{1/2}$, **D** (aperture), **z** (height)
- Turbulence length scales: **l_0** (inner length scale), **L_0** (outer length scale)

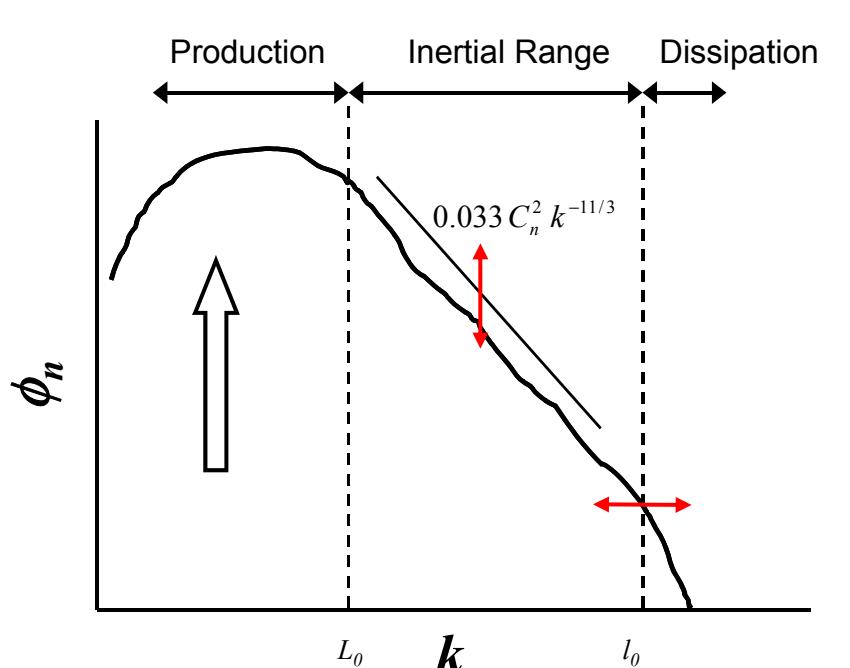


Scintillometry in a nutshell



I Wave Propagation Theory + Turbulence – Many eddies

Scintillometer Equation: $\sigma_{\ln(I)} = 16\pi^2 K^2 \int_0^\infty k \underbrace{\phi_n}_{\text{}} \sin^2 \left[\frac{k^2 x(L-x)}{2KL} \right] \left[\frac{4J_1^2(kDx/2L)}{(kDx/2L)^2} \right] dk dx$



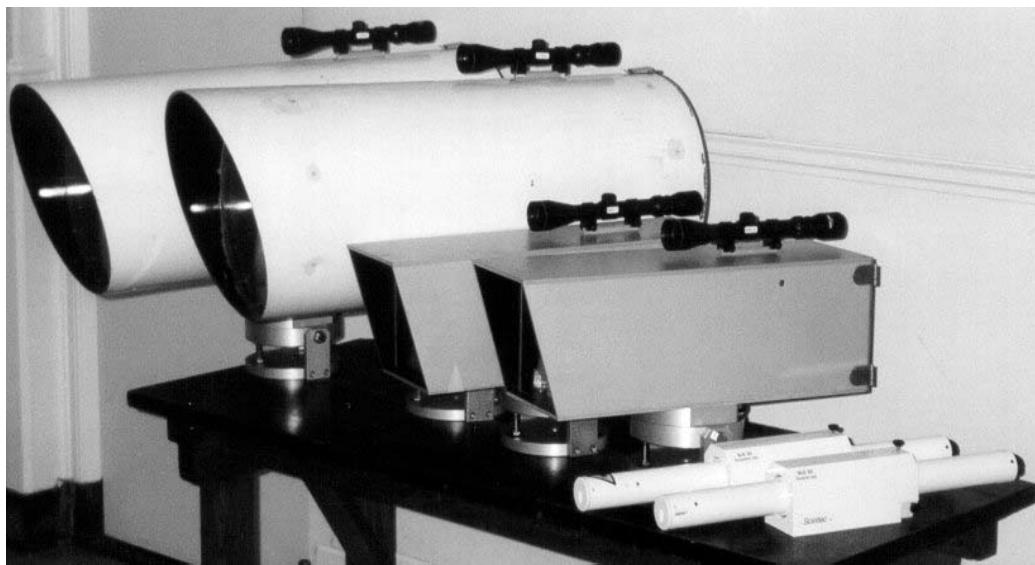
n-spectrum

Inertial Range – Kolmogorov
Dissipation Range - Hill

- Scintillometer sensitive to one eddy scale: largest of D or $F=(\lambda L)^{1/2}$
- If in Inertial range $\rightarrow \phi_n = 0.033 \underline{C_n^2} \underline{k^{-11/3}}$
- If in Dissipation range $\rightarrow \phi_n = 0.033 \underline{C_n^2} \underline{k^{-11/3}} f_A(kl_0)$



Scintillometer Types



Optical Scintillometers:

Temperature fluctuations $\rightarrow H$ (and u_*)

LAS – Large Aperture Scintillometer

XLAS – Extra large Aperture Scintillometer

DBLS – Displaced Beam Laser Scintillometer

Scintillometer types defined by:
 D and λ

RadioWave Scintillometers:

Humidity fluctuations $\rightarrow L, E$

MWS – Micro-Wave Scintillometer

Type	D	λ	L
LAS	15 cm	$\approx 1 \mu\text{m}$	1 - 5 km
XLAS	30 cm	$\approx 1 \mu\text{m}$	5 – 10 km
MWS	15 cm	$\approx 1 \text{ cm}$	1 -10 km
DBLS	2.5 mm	0.7 μm	100 m



Scintillometer work by MAQ



- People
- Current Research

People – “the Godfathers” (now pensionados)



Wim Kohsieck – KNMI/MAQ



Henk de Bruin – MAQ

People – the Builders



Bert Heusinkveld



Willy Hillen



Frits Antonysen



Kees van den Dries



People – the PhD's + PostDocs



Joost Nieveen



Wouter Meijninger



Arnold Moene



Oscar Hartogensis



Arjan van Dijk



Bram van Kesteren



Measure $H + L_v E$ directly at km-scale:

Optical-Millimetre wave System (OMS):

- Refractive index in millimeter-wave range dependent on water vapour *and* temperature



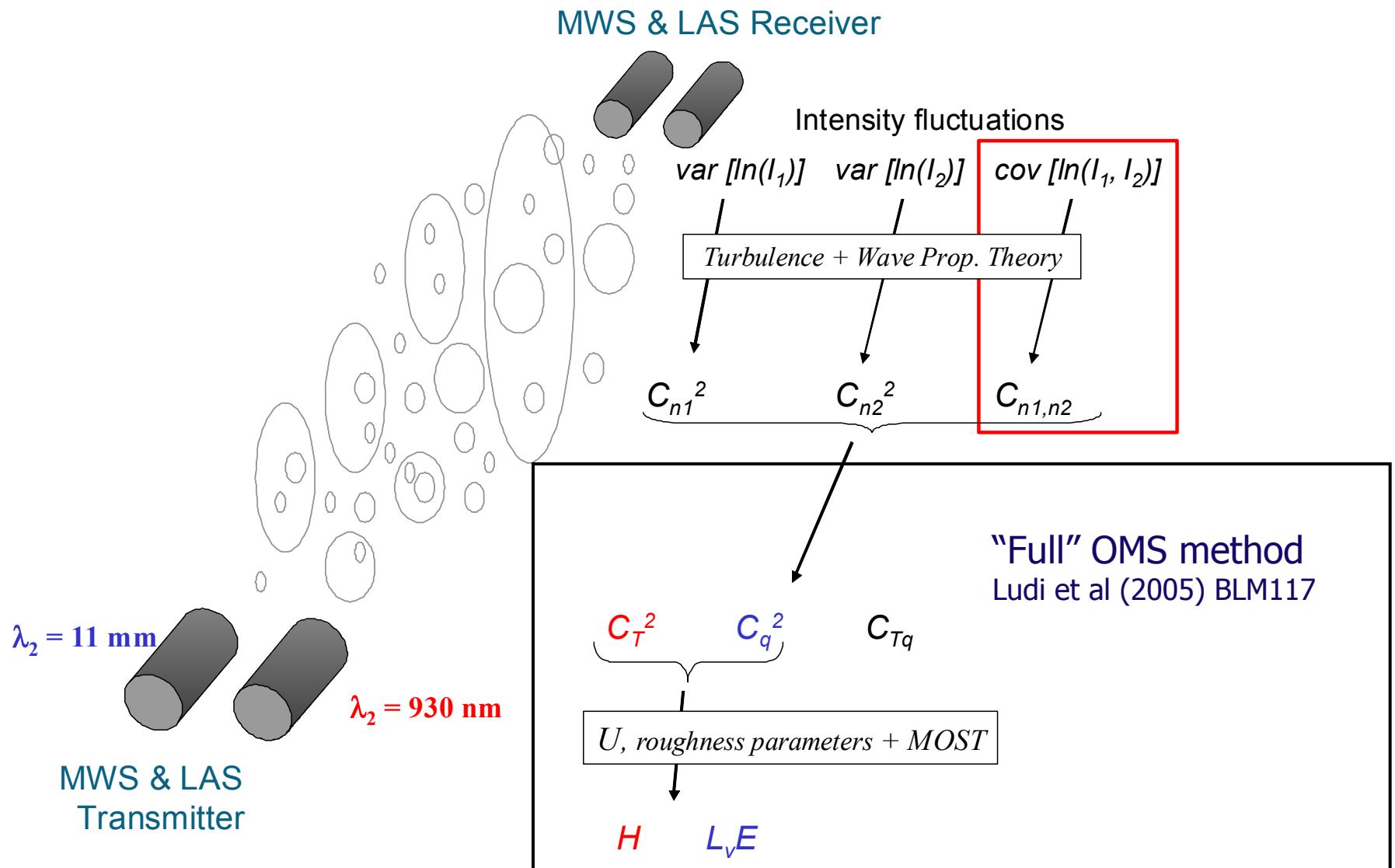
Measure $H + L_v E + u_*$ at field scale:

Short Path Scintillometer (SPS)

- combination of number of beams and or receivers
- additional measurements for evapotranspiration



OMS system – Third Equation – Full OMS method



Chilbolton Experiment – field site Rutherford Appleton Laboratory (RAL)



Chilbolton Experiment – field site Rutherford Appleton Laboratory (RAL)



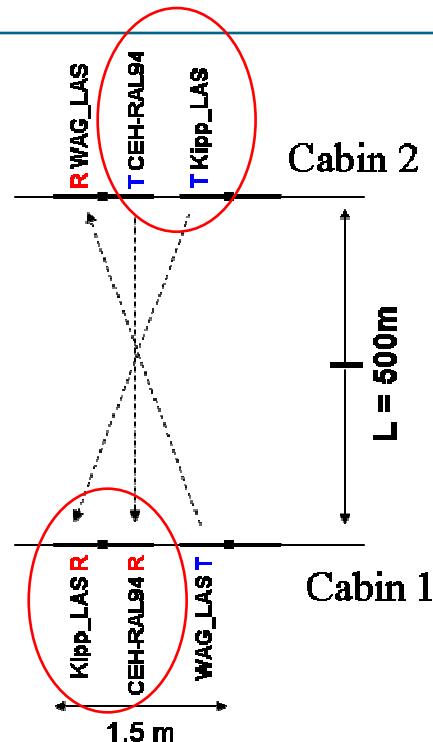
Chilbolton Experiment – the Site



- Open door laboratory
- Test range of 500m long
- 2 opposite cabins at 4m height



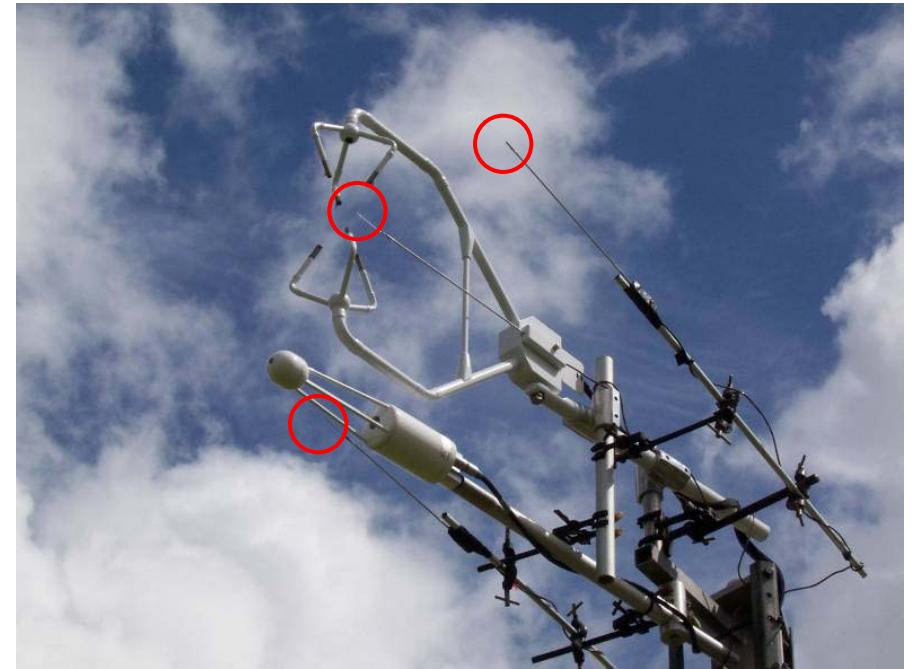
Chilbolton Experiment – Scintillometers



- **CEH-RAL94 MWS** – 94Ghz – GPS pulse to lock transmitter and receiver frequency
- **Kipp&Zn LAS** – 880nm - Fresnel lens to focus beam onto detector
- **Wageningen LAS** – 940nm – Concave mirror to focus beam onto detector
- datalog units in both cabins – 500Hz – GPS pulse to synchronize the signals



Chilbolton Experiment – local turbulence measurements



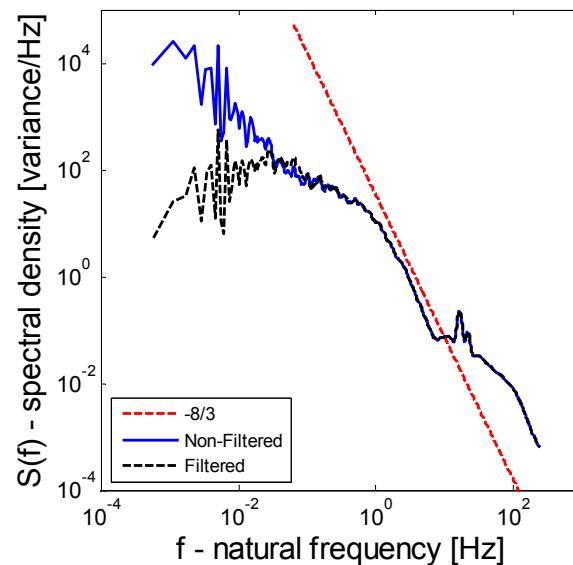
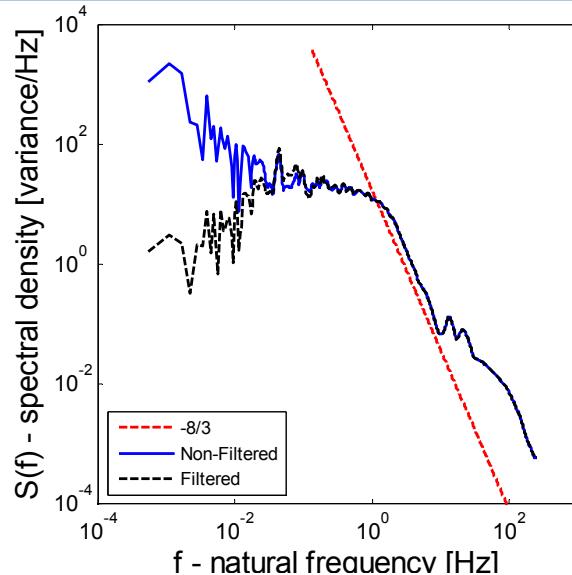
- CSAT3 sonic + LiCor 7500
- 3 fine wire thermocouples
- datalog unit – 20Hz



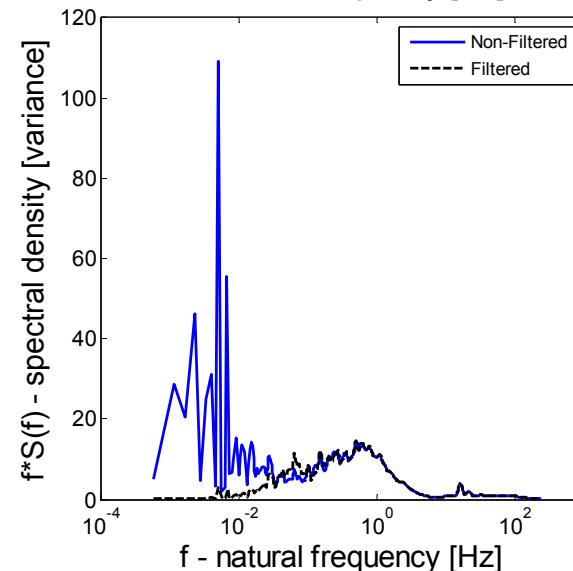
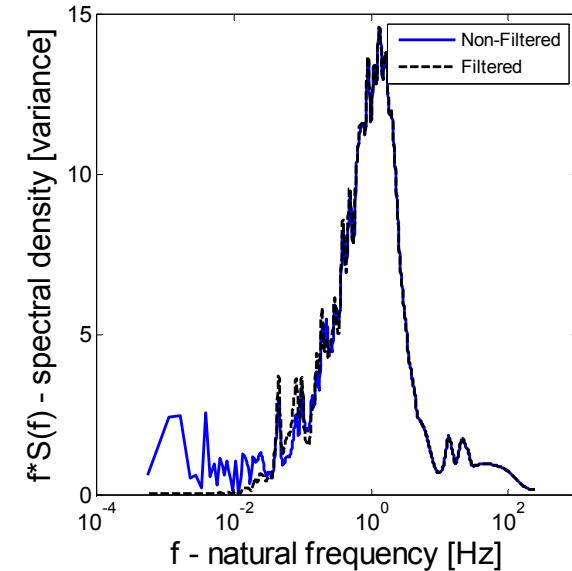
Reference for Fluxes and Structure parameters



Chilbolton Results – CEH-RAL94 Spectra



- Evidence of Absorption

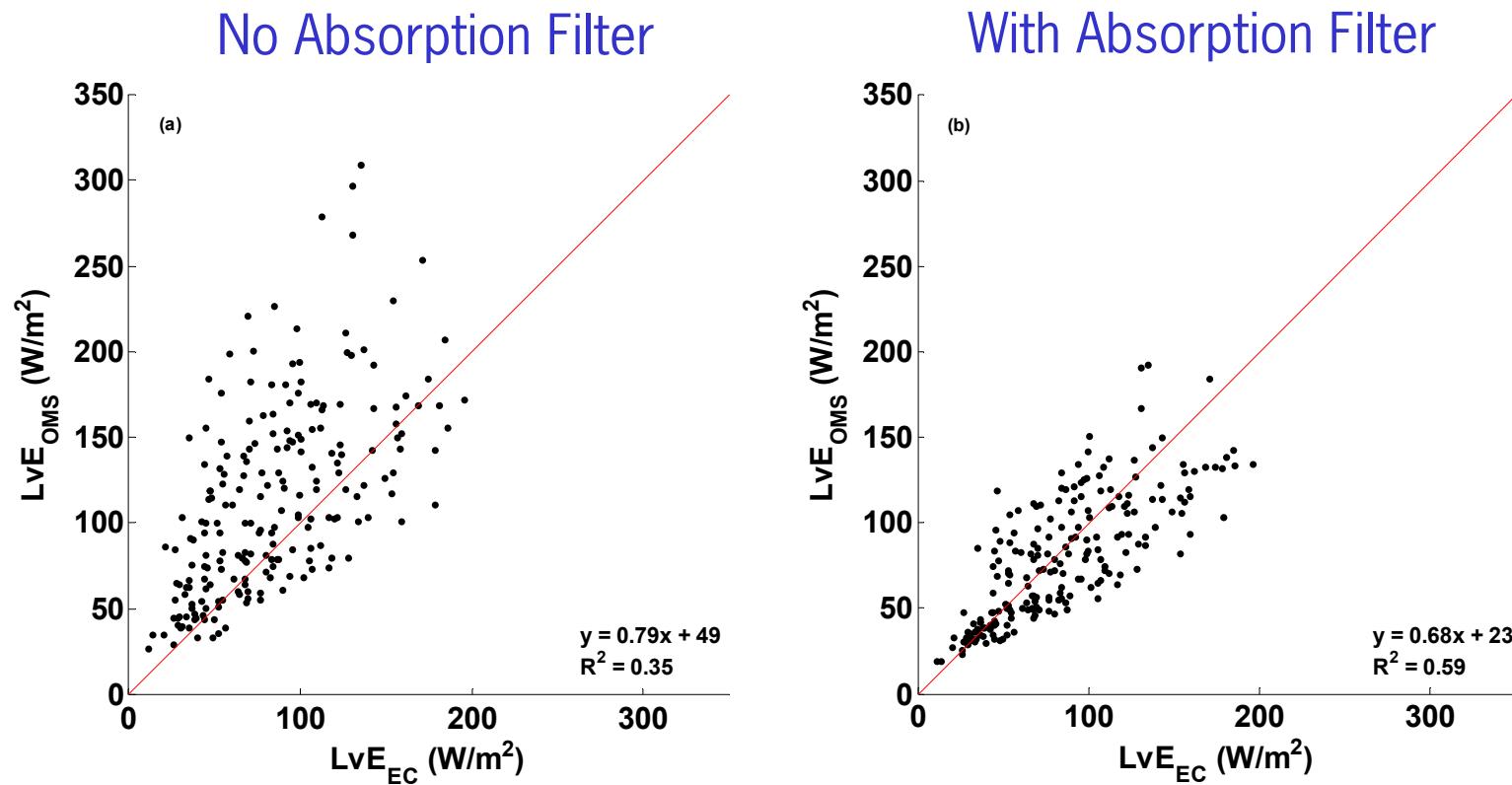


- “simple filter”: 10s moving average



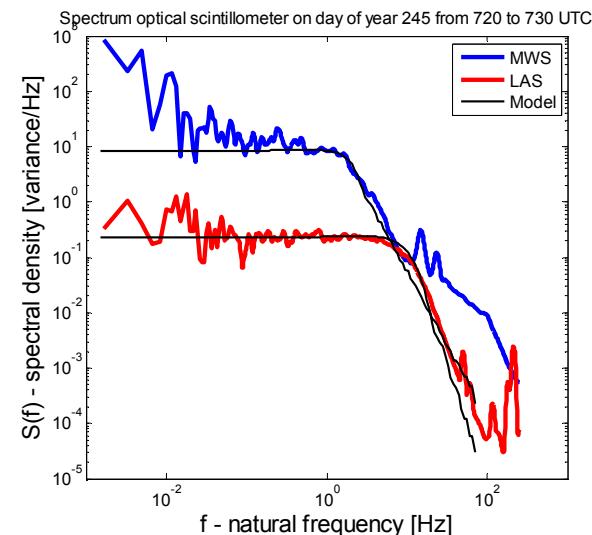
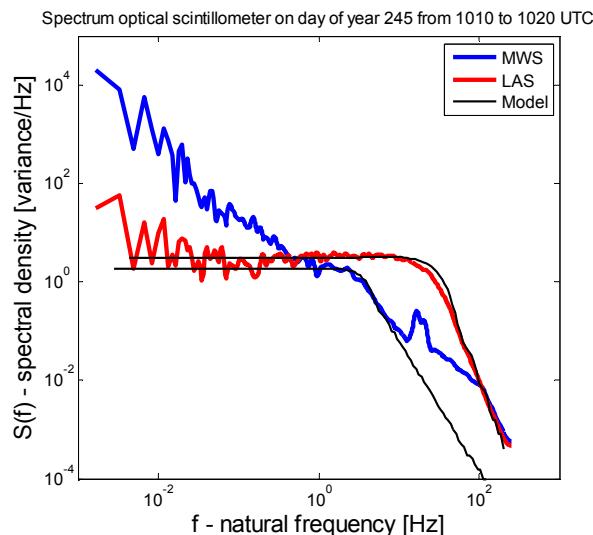
Chilbolton – OMS Evaporation

- OMS system: CEH-RAL94 MWS and Wag LAS
- 10s moving average filter for RAL94
- No C_{n1n2} used; R_{Tq} from EC system



Final Remarks

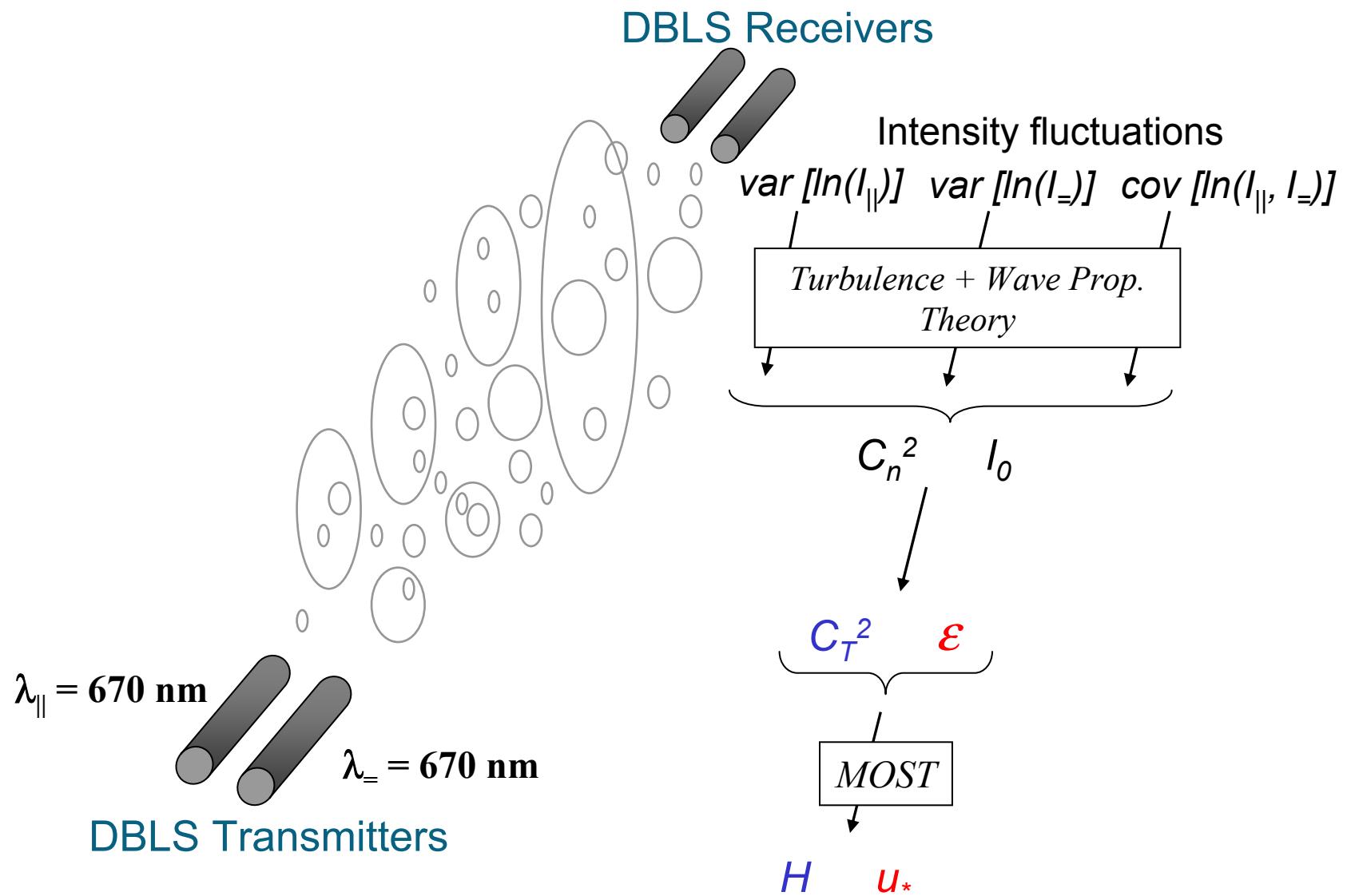
- First results of evaporation by the OMS system look “promising”.
- Further refinements we work on:
 - “Full” OMS method with $C_{n1,n2}$
 - Filtering LAS and MWS by routinely fitting theoretical to measured spectrum:



- Compare results with local turbulence measurements at structure parameter level.



Double Beam Laser Scintillometer (DBLS)



Combination Methods: Scinti–Variance + Scinti–Structure-Parameter

MOST framework: $F_x = \rho u_* q_{*x}$

Variance: $\sigma_x = \overline{(x(r_1) - \bar{x}(r_1))^2}$ $\frac{\sigma_x}{q_{*x}} = f_{xx}(z/L)$

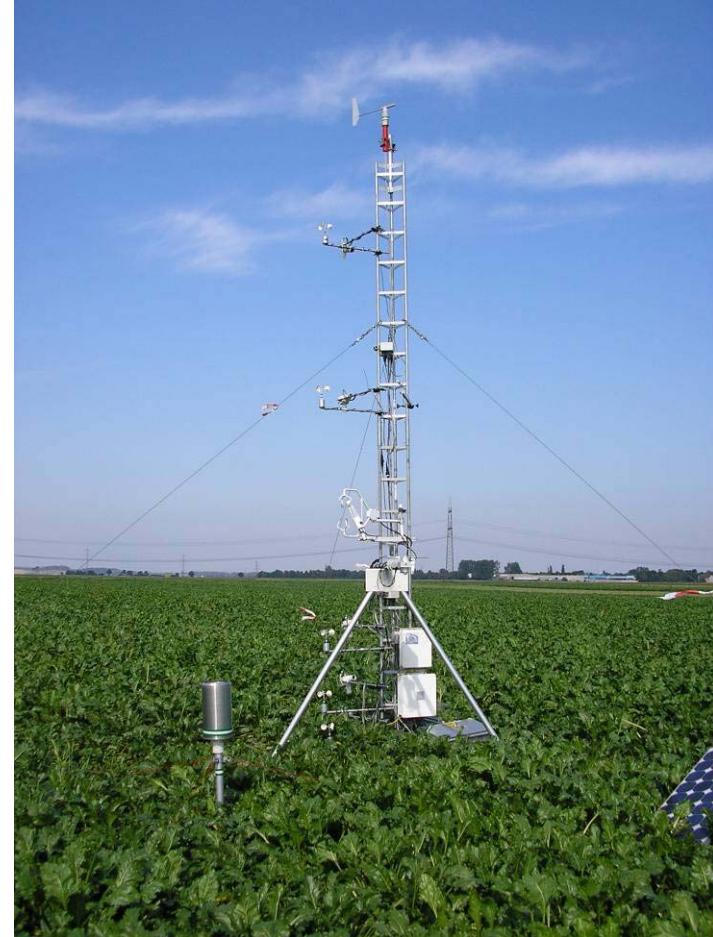
Structure parameters: $C_x^2 = \frac{\overline{(x(r_1) - x(r_2))^2}}{r_{12}^{2/3}}$ $\frac{C_x^2 z^{2/3}}{q_{*x}^2} = f_x(z/L)$

Scintillometer: \longrightarrow $u_* + L$ with $L = -\rho c_p \frac{T}{\kappa g} \frac{u_*^3}{H}$

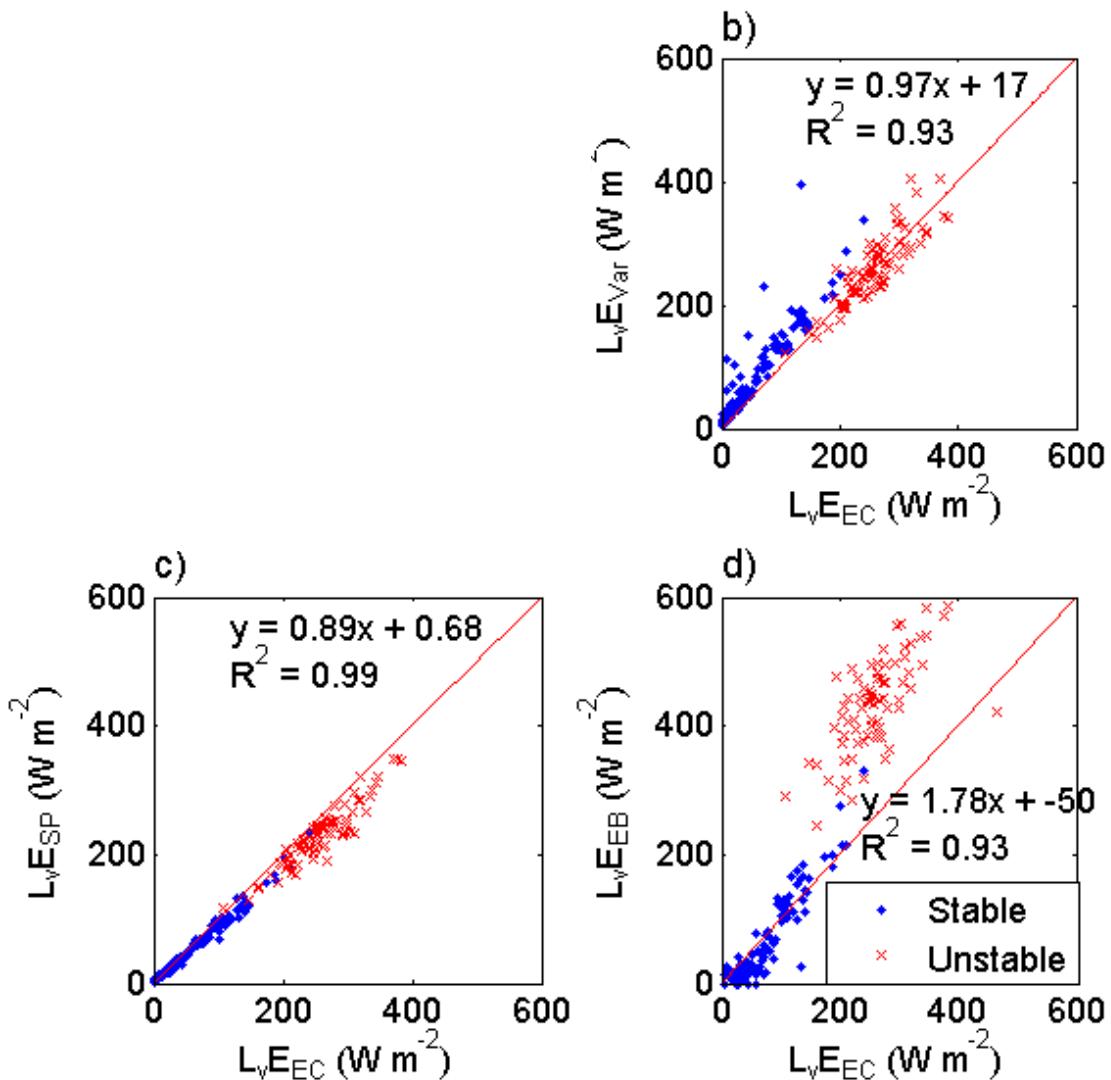
Scalar turbulence measurements: \longrightarrow $\sigma_T + \sigma_q + \sigma_{qCO2}$
 $C_T^2 + C_q^2 + C_{qCO2}^2$



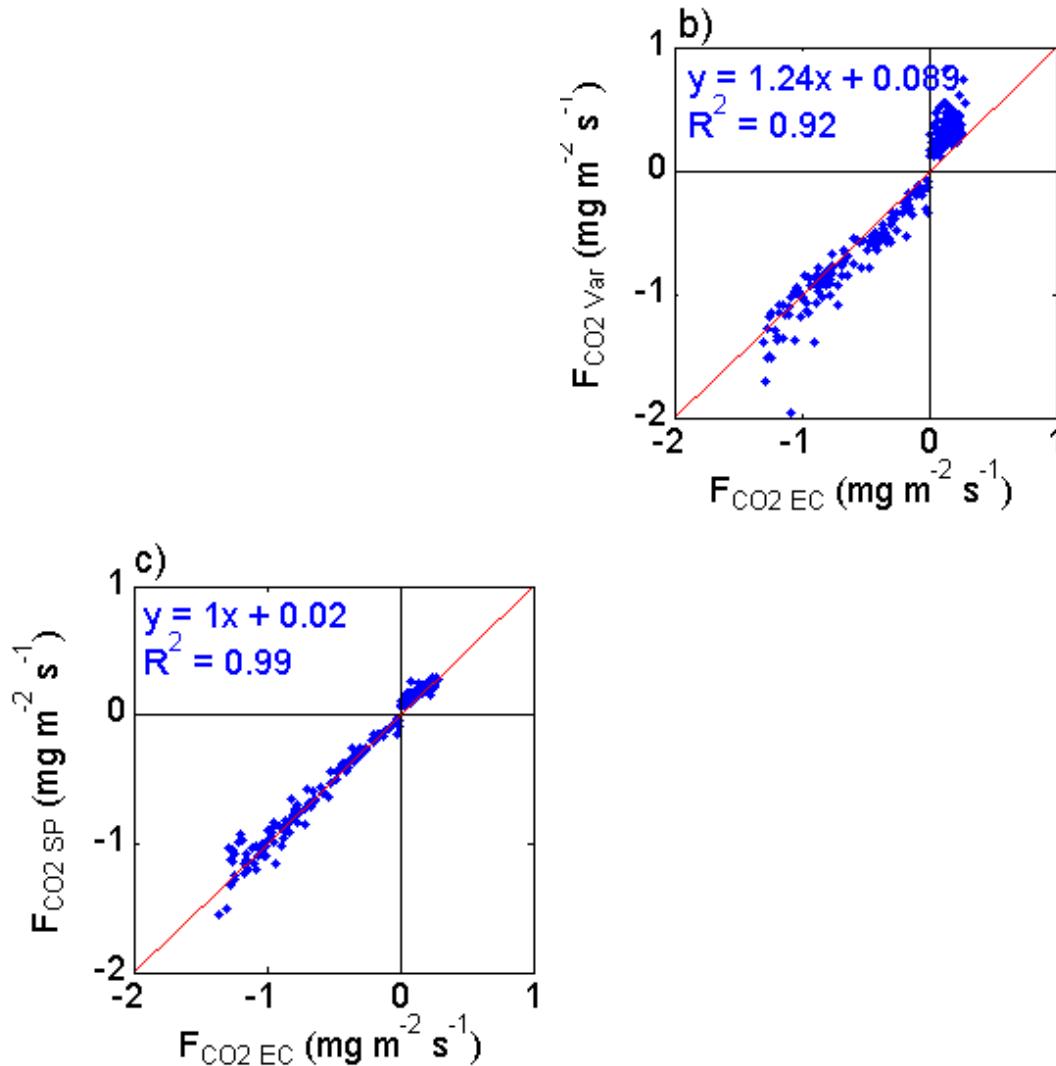
Merken Set-up



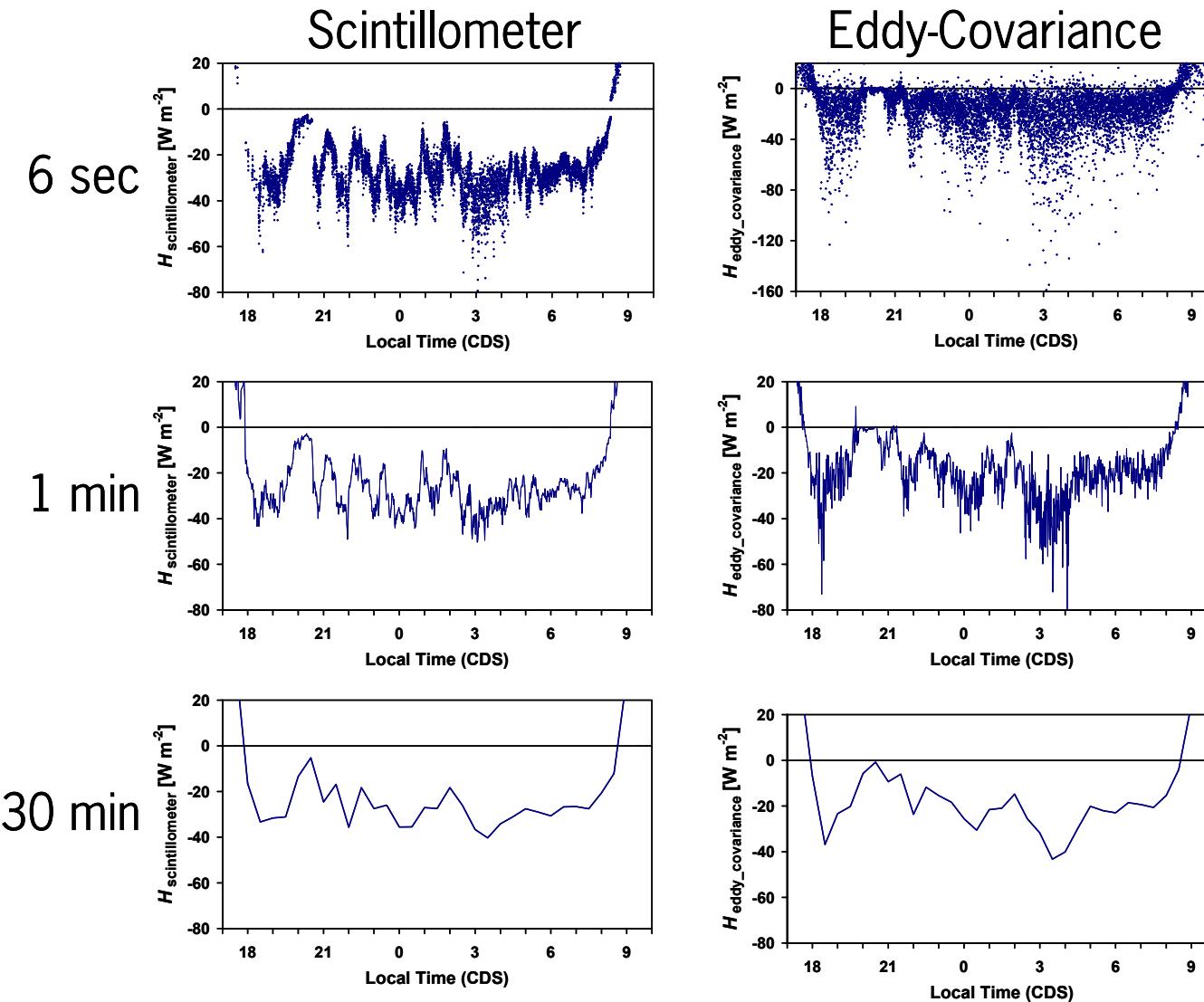
Combination-Methods – Long Interval (30min)



Combi-Methods – Long Interval (30min)



Space AND time averaging of turbulence



Objective

Test alternative methods to determine turbulent
 H_2O and CO_2 fluxes, which have a **faster statistical convergence** than the classical eddy-covariance method.



Combi-Methods – Short Intervals (1 min) – Temporal Variation

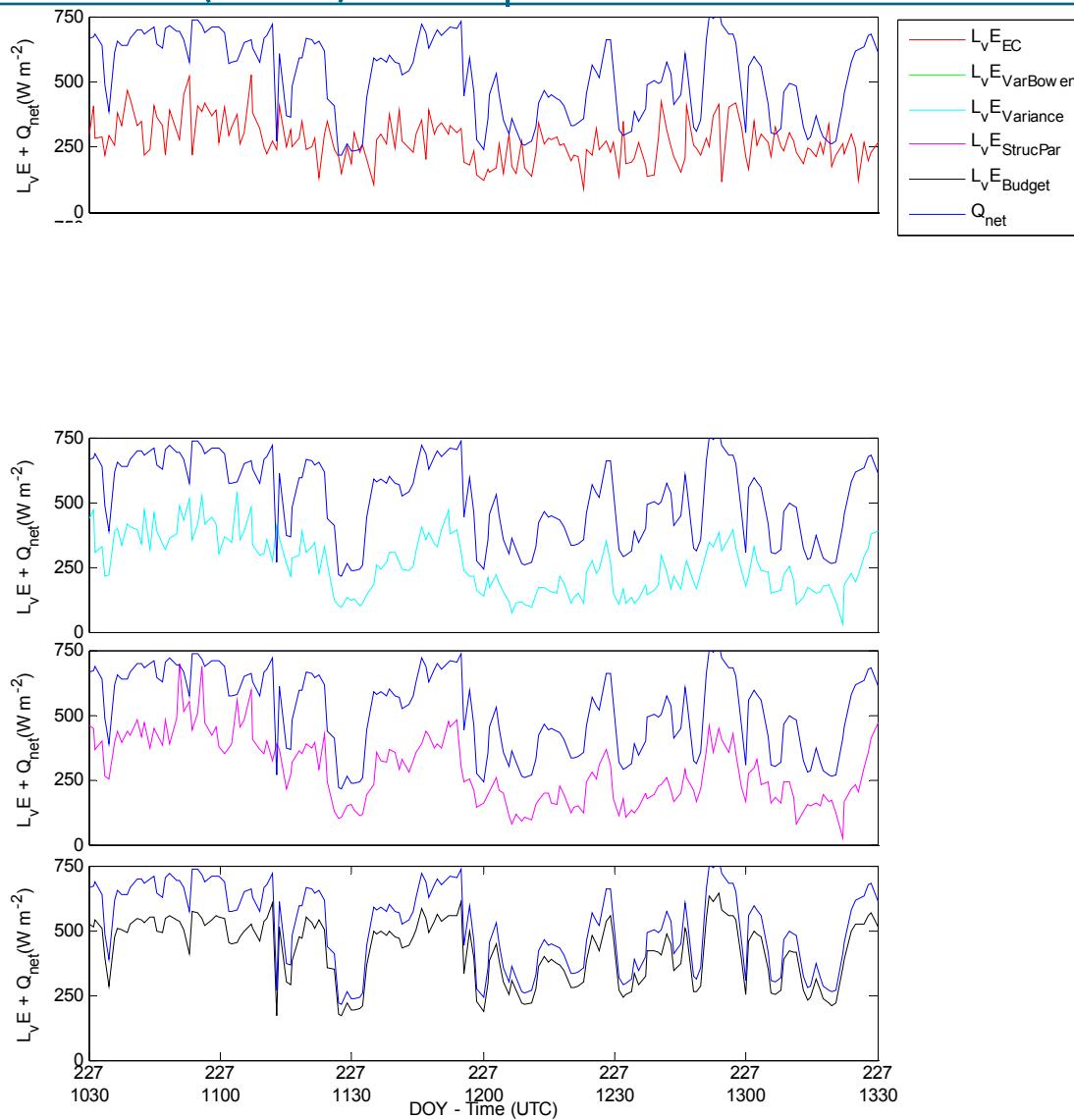
$L_v E$

EC

σ_x

C_x^2

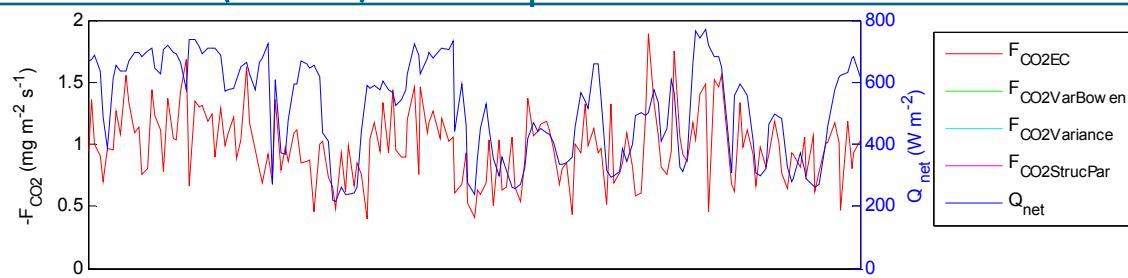
Energy balance



Combi-Methods – Short Intervals (1 min) – Temporal Variation

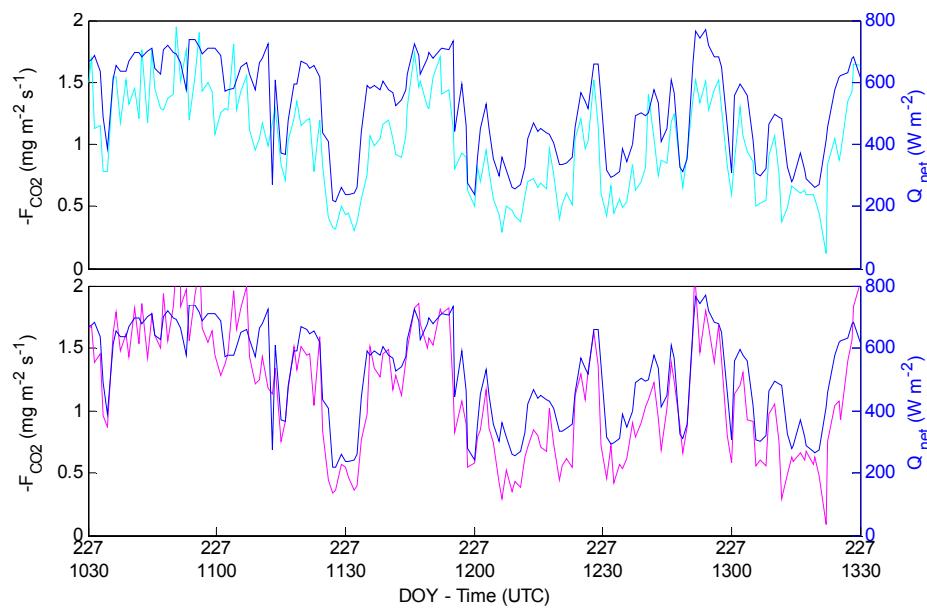
$-F_{CO_2}$

EC



σ_x

C_x^2



Conclusions

- Combined Methods work!
- Combined Method indeed gives much more reliable minute interval mass fluxes than EC
- Mr wrk ndd



KvK - WindVisions (2010-2014)

Wind and Visibility monitoring system at Schiphol Airport

WINDVISIONS

Wind and Visibility Monitoring System at Mainport Schiphol

O.K. Hartogensis, A.A.M. Holtlag, P. van den Brink, J.O. Haanstra, R. ten Hove, L.E.M. Smit, I. Holleman

Motivation

Due to its location near the sea, operations at Mainport Schiphol are very sensitive to changes in weather conditions. Given the anticipated climate change this sensitivity to local weather will increase, as extreme weather events are expected to occur more frequently and with increased intensity. The operations at Mainport Schiphol are especially sensitive to the local wind field and visibility (see Figures 1 and 2). Adverse wind and visibility conditions represent a safety hazard as well as economic losses due to additional delays, diversions and holdings. In order to maintain its position as a mainport, Schiphol has to anticipate to a changing climate such as more frequent adverse/ extreme weather conditions to become more "climate proof".



Figure 1: Strong crosswind conditions.



Figure 2: Poor visibility conditions.

Climate change is happening right now. This clear conclusion comes from the quintennial KNMI report of 2008 (KNMI (2008)) on the state of the current climate in the Netherlands. To better understand and anticipate the implications of climate change for Schiphol Mainport it is essential to improve local monitoring of wind and visibility as soon as possible.

Objective

The objective of this proposal is to develop a Wind and Visibility Monitoring System (WindVisions) at Mainport Schiphol. The system will consist of a vertically scanning remote sensing instrument, a so-called light or sound detecting and ranging instrument (LIDAR or SODAR), complemented by a horizontal long range wind sensor, a so-called cross-wind scintillometer. The area of interest to monitor is the landing and take-off course of airplanes ranging from the surface to about 300m height along the runway.

WindVisions will provide continuous measurements of the 3D wind field and visibility which will lead to better safety and efficiency of the operations at Mainport Schiphol



Figure 4: Scintillometers



Figure 3: SODAR

Methods

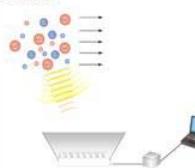


Figure 5: SODAR principle



Figure 6: Crosswind Scintillometer principle

- A **SODAR** emits short acoustic pulses into the atmosphere.
- The acoustic waves are backscattered at temperature inhomogeneities (turbulent eddies) in the air (see Figure 5).
- The Doppler frequency shift of the backscattered signal contains information on the **wind speed**.
- The amplitude of the backscattered signal contains information on **turbulence intensity**.

- A **scintillometer** consists of a transmitter and receiver.
- The transmitter emits a light beam over a horizontal path up to several km.
- The received intensity exhibits intensity fluctuations or "scintillations" due to turbulent eddies in the path.
- By using two receivers the cross-wind can be determined.
- The delay between the two received signals contains information on the **cross-wind**.
- The average received signal contains information on **visibility**.

Organization

The project is split in two phases. For the moment only funds have been requested for the first phase

First Phase:

- Definition study to find out which combination of sensors (SODARs/LIDARs and cross-wind scintillometers) suits best the proposed objectives of WindVisions.
- Conduct a first test with a cross-wind scintillometer together with a compact SODAR system at the KNMI tower of Cabauw.
- Develop novel aspects of cross-wind scintillometry

Second Phase:

- Development of an operational system, based on the results of the first phase, which will then be fully tested at Schiphol airport.
- Embedment of WindVisions in IMPACT
- PhD thesis



End

