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First Results of two Optical and Millimeter-wave Scintillometer systems during LITFASS2009

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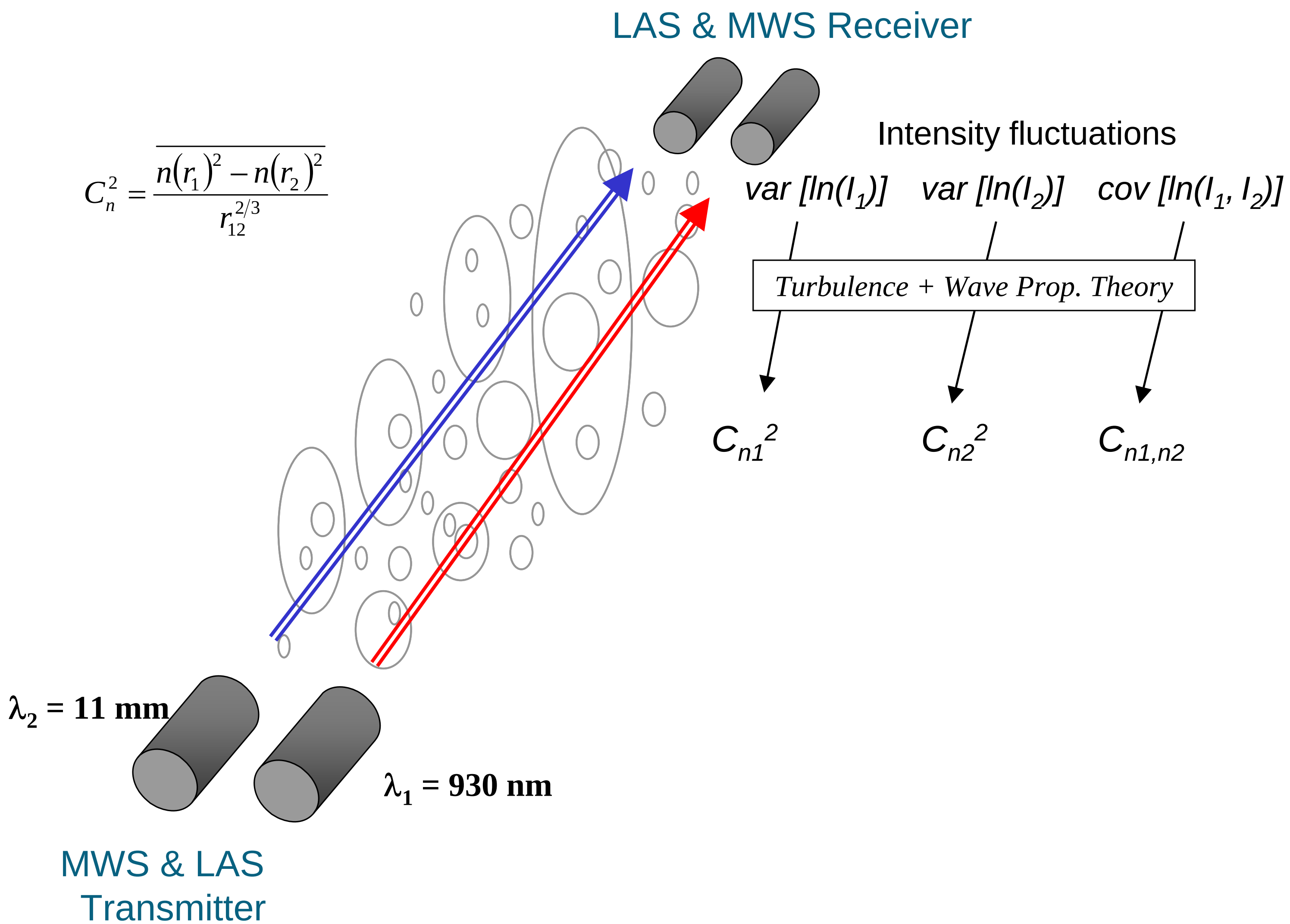
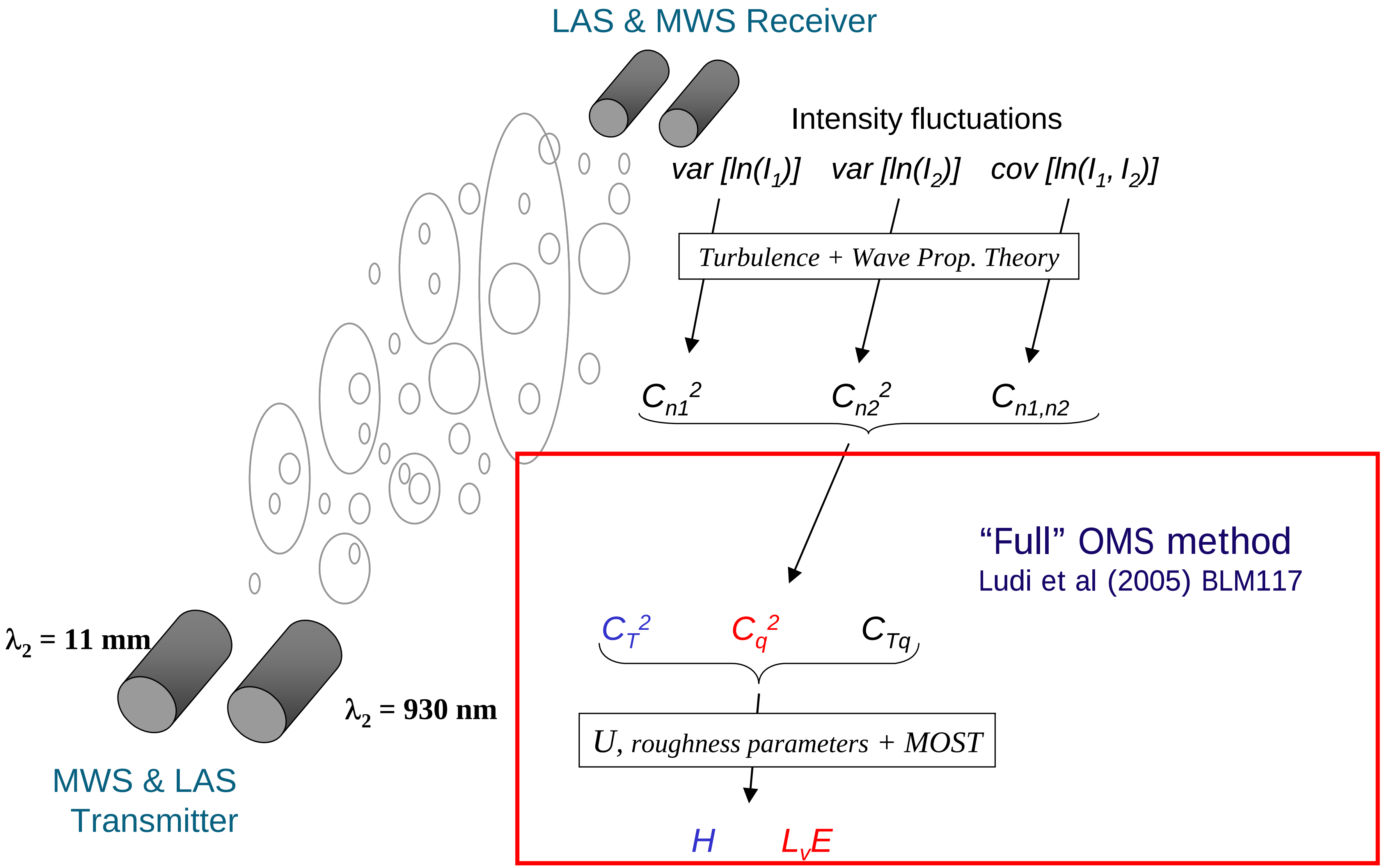
Outline Talk:

- Describe an Optical-Millimetre wave Scintillometer (OMS) System that measures $H + L_v E$ directly at km-scale.
- First results of LITFASS2009 experiment – Cross-wind.

OMS System Description



OMS System Description

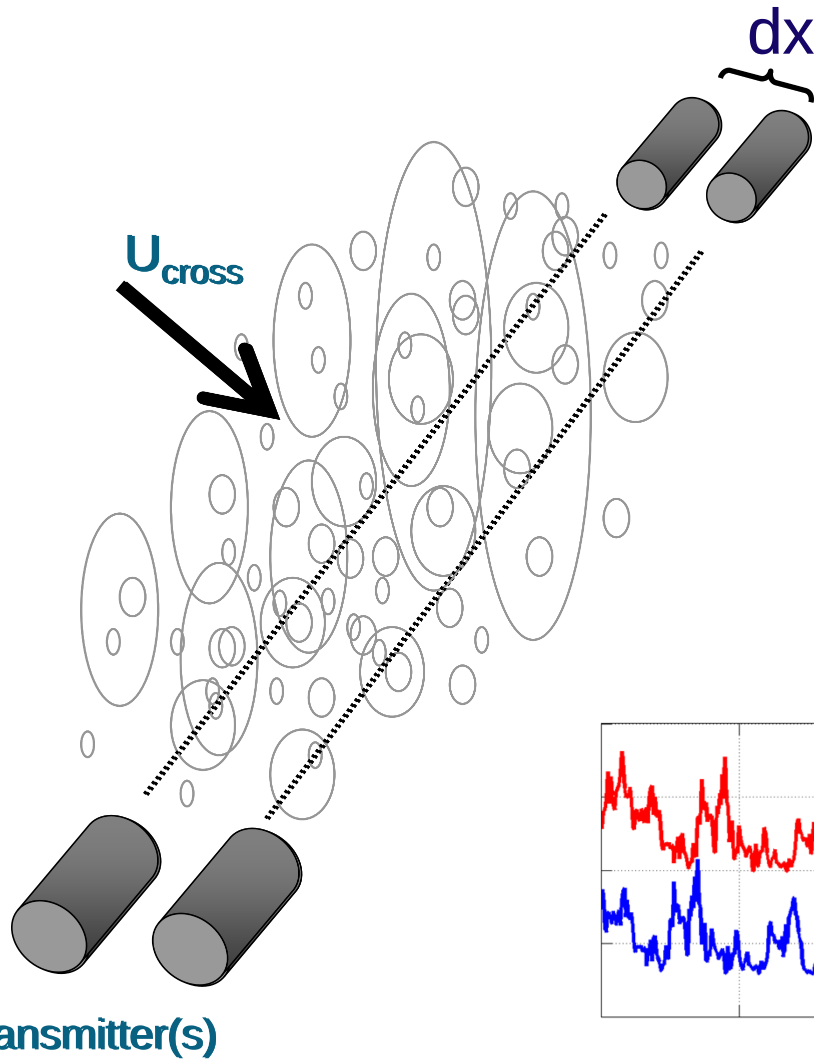


LITFASS2009 Experiment – DWD Meteorological Observatory Lindenberg

- **CEH94 MW** … iver frequency
- **MOL94 MW** … eiver frequency
- **Wageningen LAS** – λ=940nm,D=0.15m – concave mirror to focus beam onto detector
- Path length=4700m – Raw data@500Hz

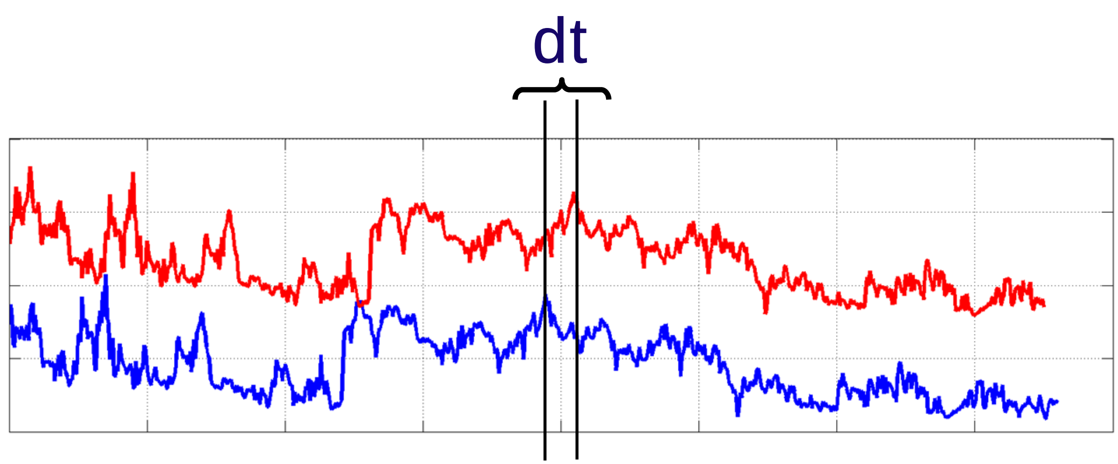
…and now for something ~~completely~~ different: CROSS-WIND

Cross-wind – Dual Aperture Approach



Scintec BLS-series

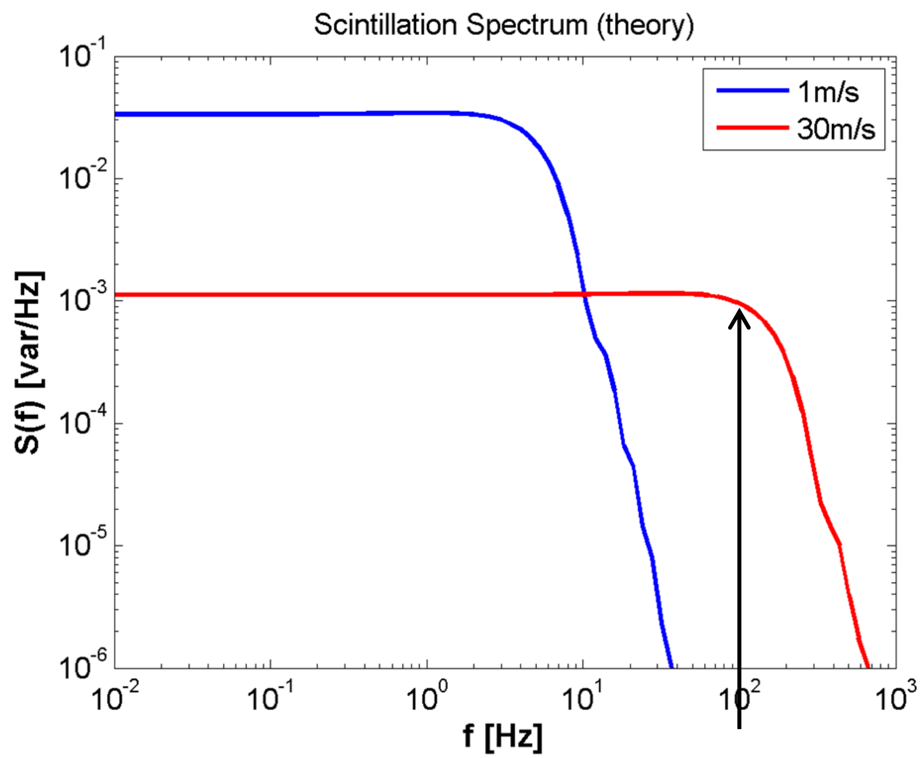
$$U_{cross}=dx/dt$$

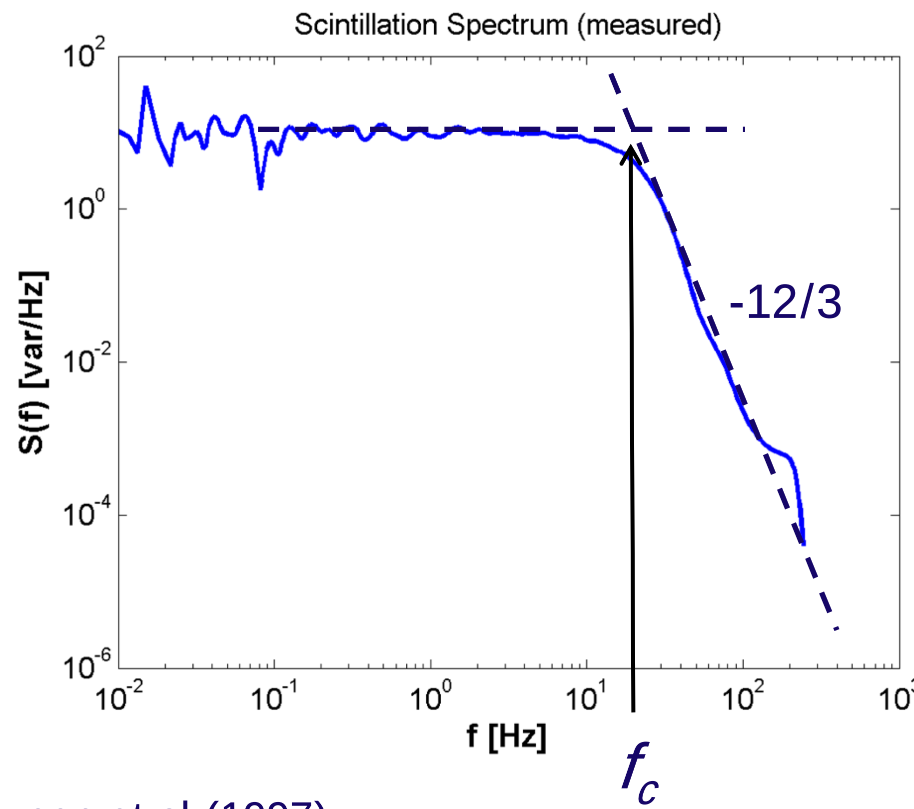


Cross-wind – Single Aperture Approach1 – Corner-Frequency

Scintillometer Spectrum: $S(f)=4\pi^2K^2\int_0^L\int_{2\pi f/v}^{\infty} k\phi_n \sin^2\left(\frac{k^2x(L-x)}{2KL}\right)\left[(kv)^2-(2\pi f)^2\right]^{-1/2}dkdx$

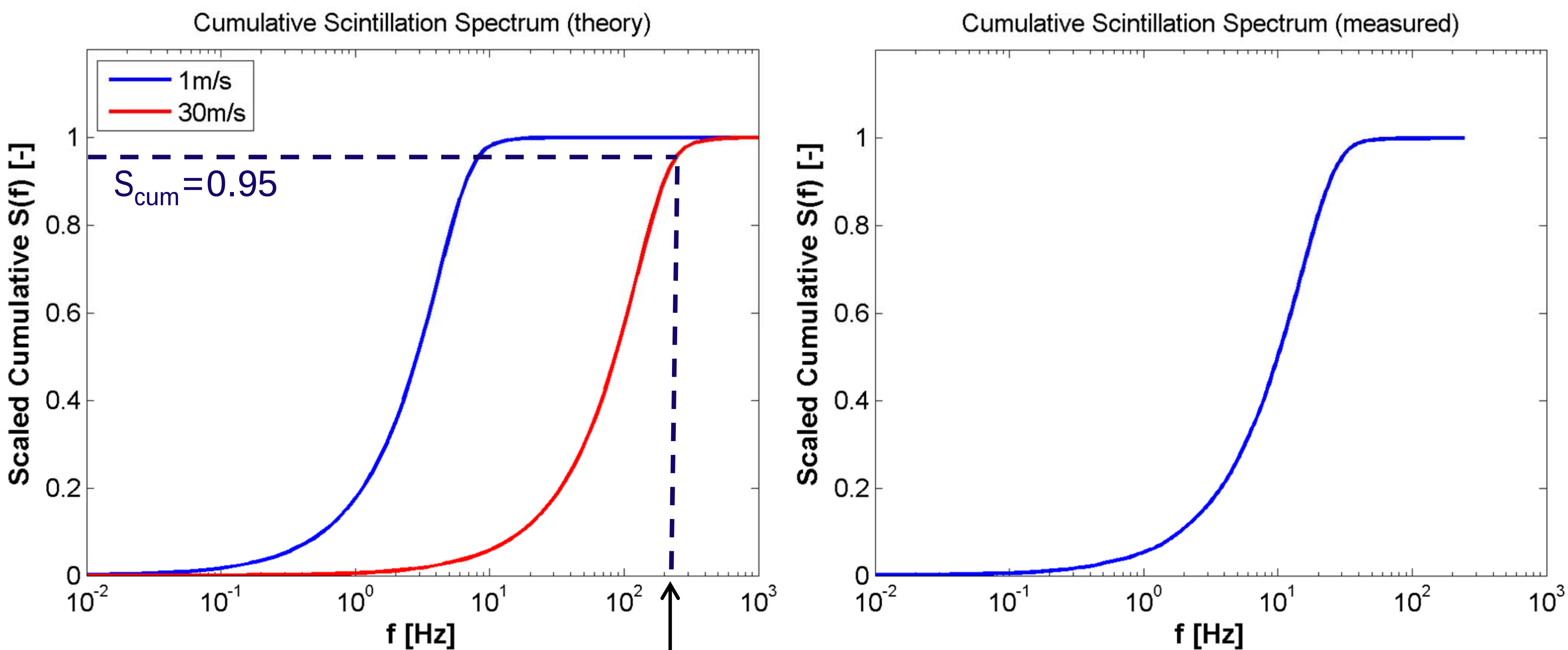
Clifford (1971)





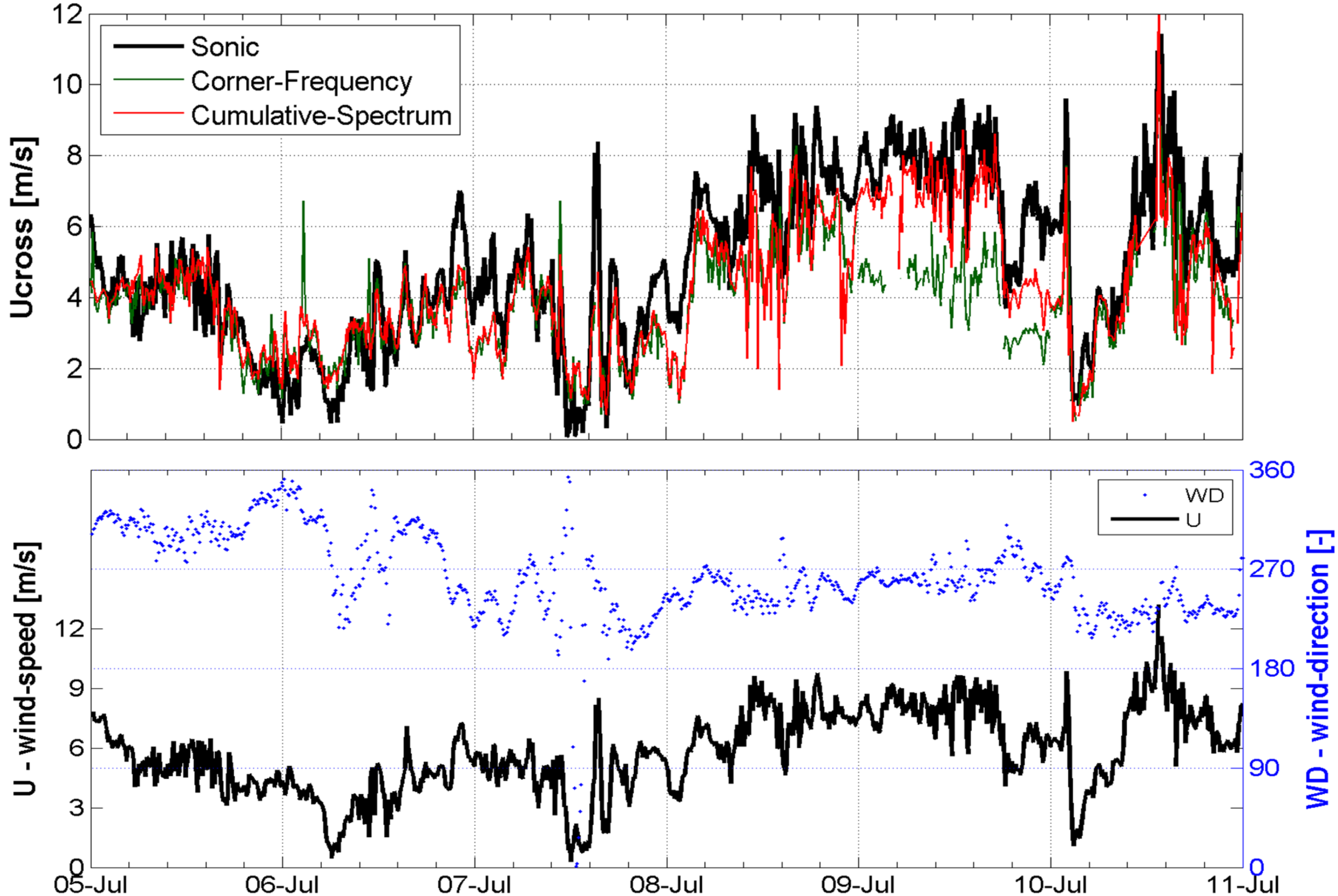
$$f_c=\frac{v}{1.25D}$$ Nieveen et al (1997)

Cross-wind – Single Aperture Approach2 – Cumulative-Spectrum

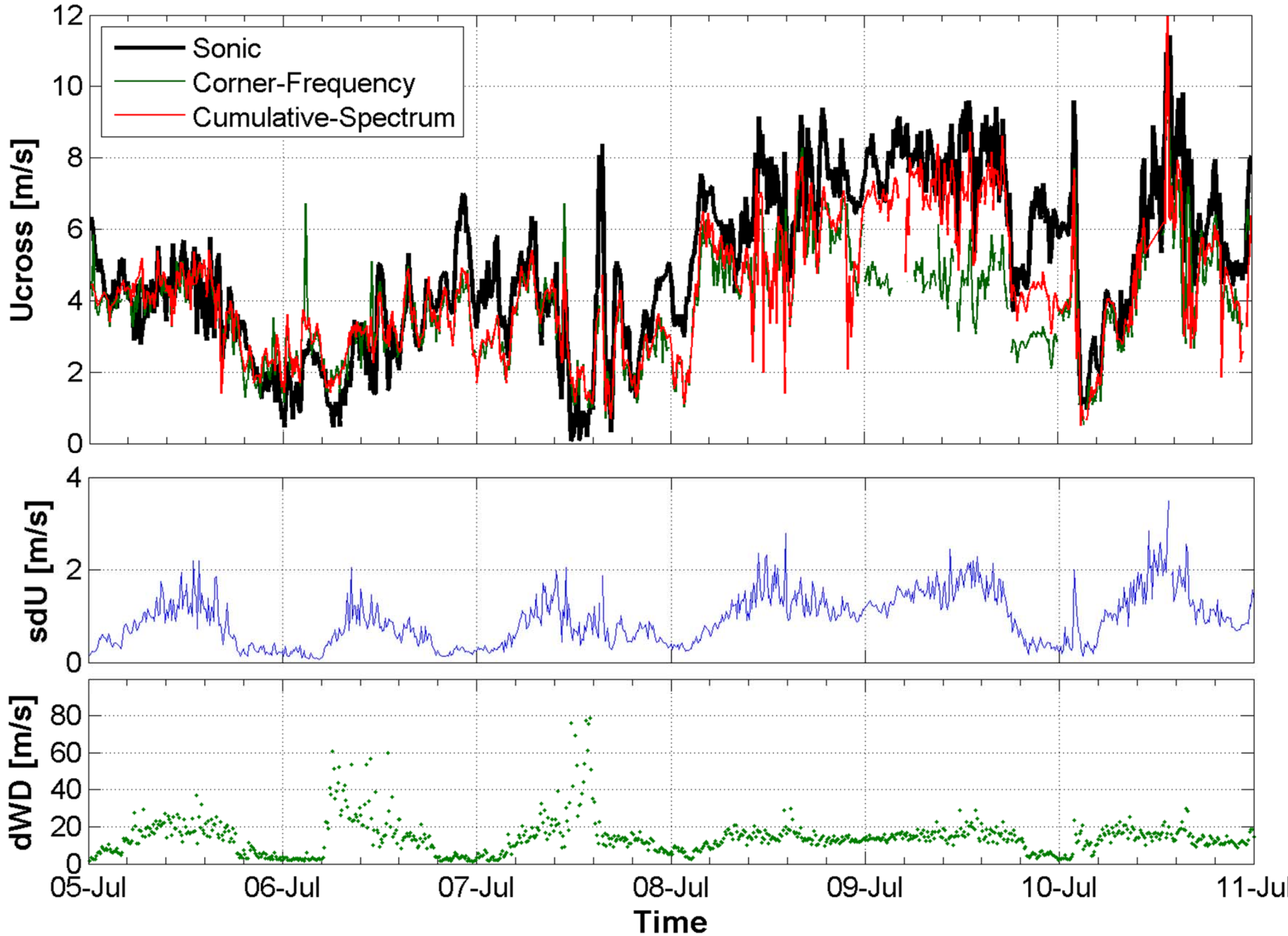


$$f_{95} = \frac{v}{0.844D}$$ "New"

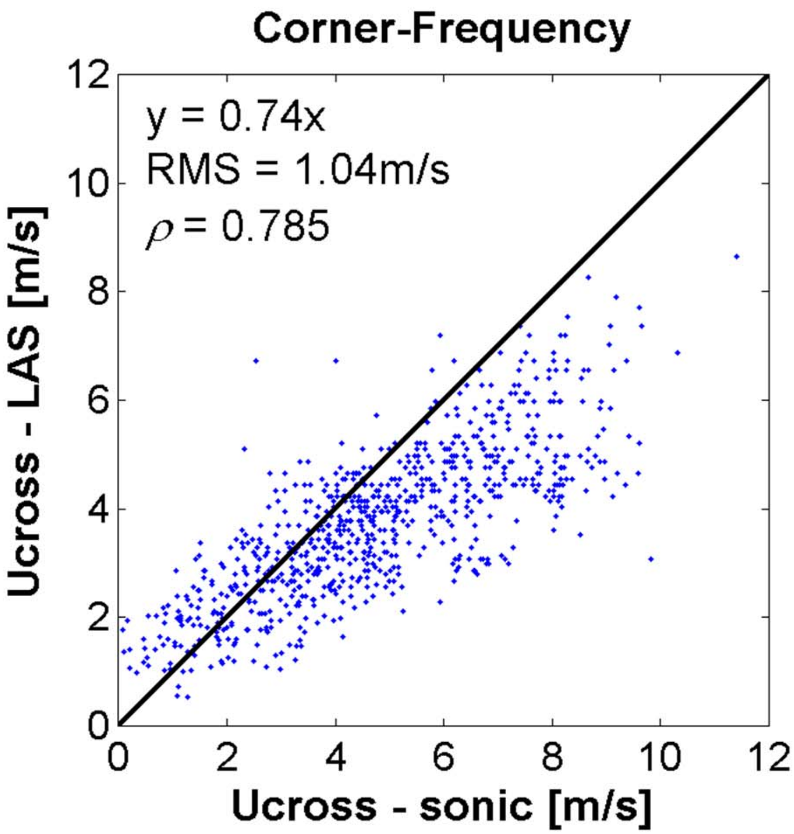
Cross-wind – Results

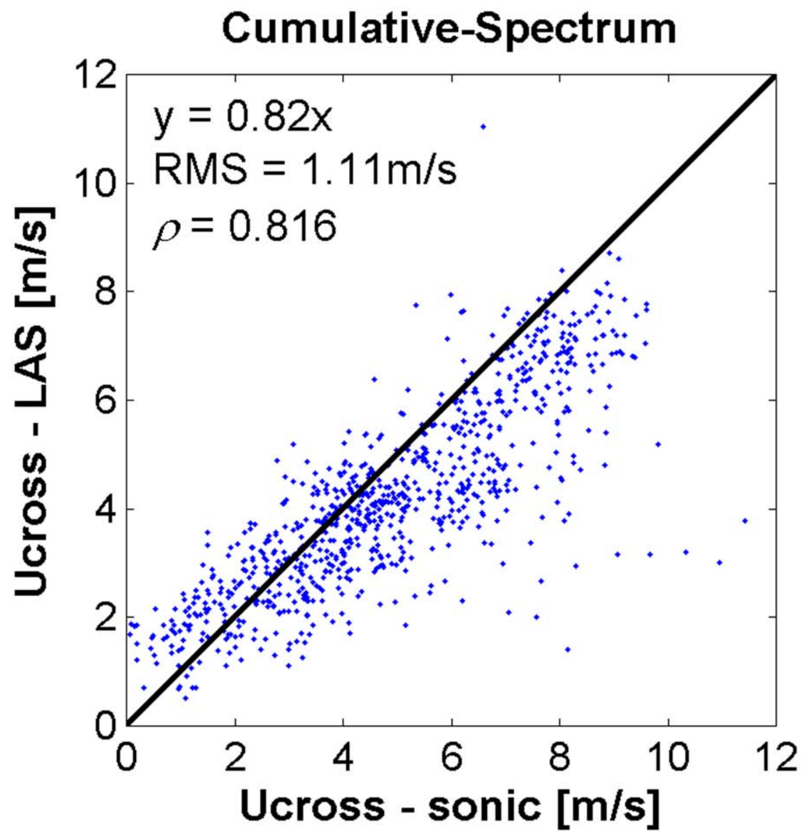


Cross-wind – Results

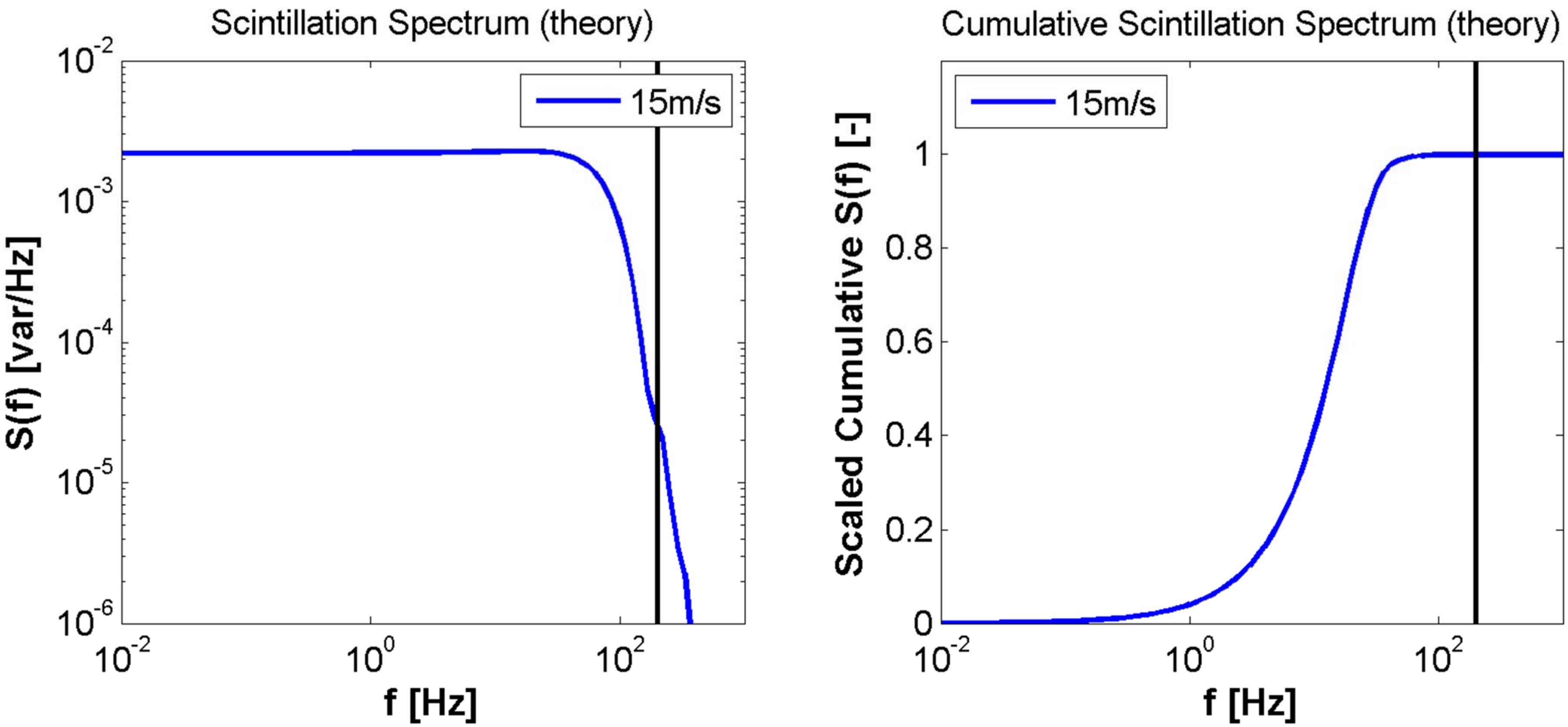


Cross-wind – Results





Cross-wind – Results



Nyquist frequency @ 250Hz

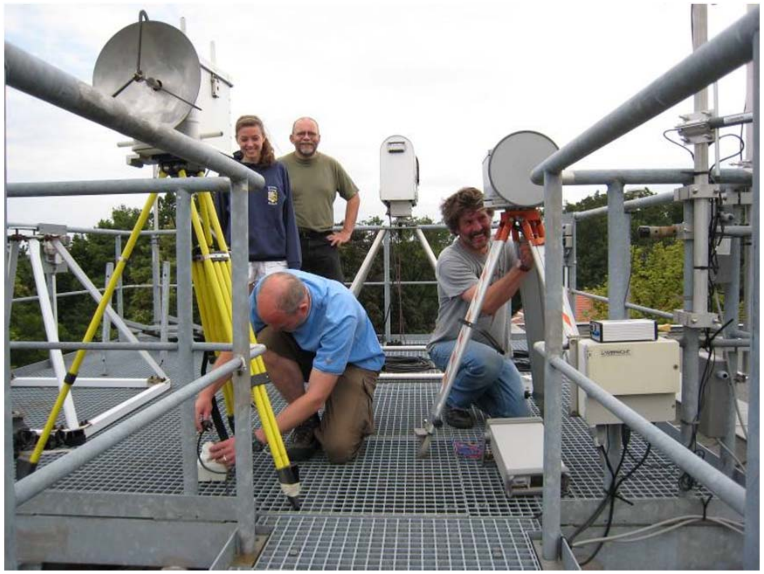
OMS systems:

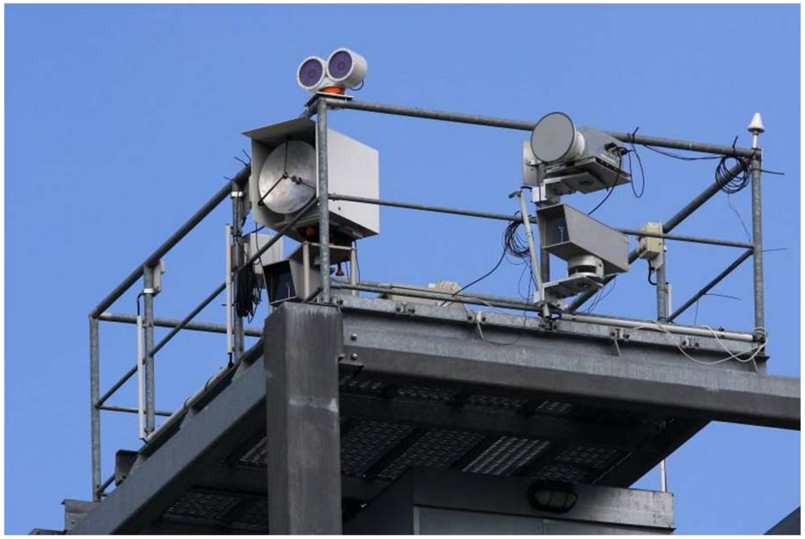
- still to be analyzed ...

Single Aperture Cross-Wind:

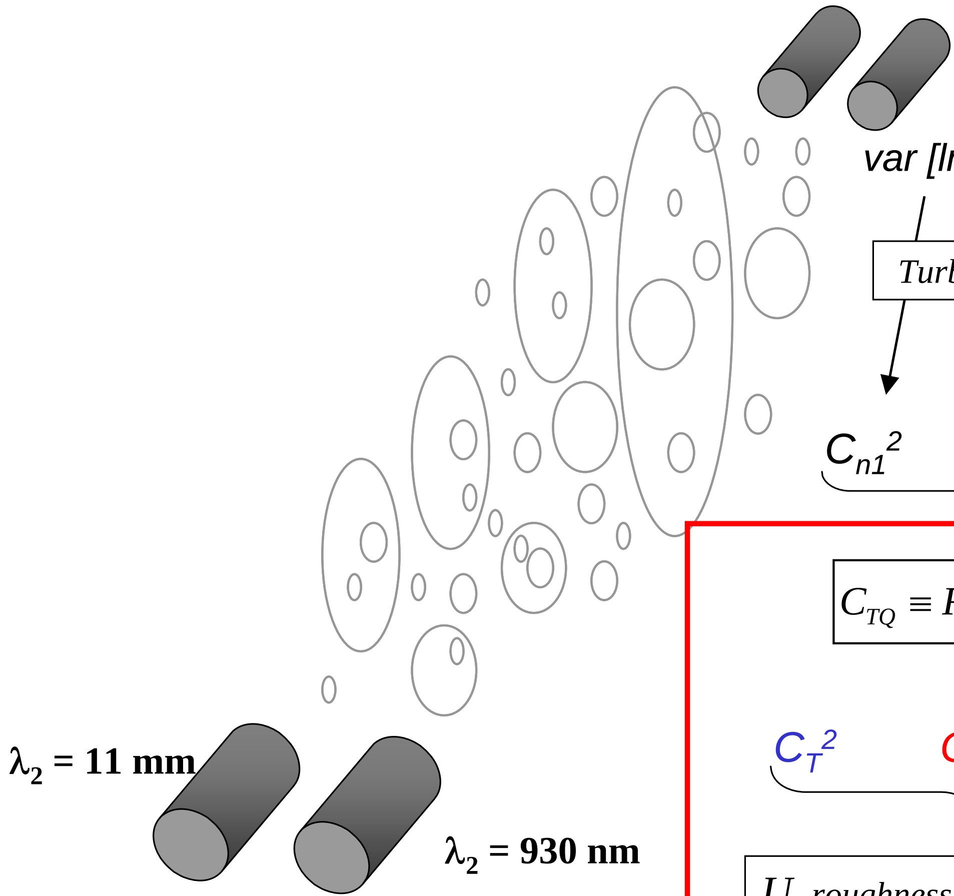
- New approaches are “promising”
- Methods work reasonably well under low wind speed conditions
- Higher sampling rate to improve performance under high wind-speed conditions
- Improve on non-stationary conditions by using local spectra from wavelets

Thank you





LAS & MWS Receiver



MWS & LAS Transmitter

Intensity fluctuations

var [ln(I_1)] *var [ln(I_2)]* *cov [ln(I_1, I_2)]*

↓

Turbulence + Wave Prop. Theory

↓

C_{n1}^2 C_{n2}^2 $C_{n1,n2}$

↓

$$C_{TQ} \equiv R_{TQ}\sqrt{C_T^2 C_Q^2}$$

↓

C_T^2 C_q^2 C_{Tq}

↓

U, roughness parameters + MOST

↓

H L_vE

Additional data: R_{Tq}

Meijnininger et al (2006) BLM121

OMS system – Structure parameter of refractive index

Refractive index of air: $n'(\lambda) = A_T(\lambda)\frac{T'}{\overline{T}} + A_Q(\lambda)\frac{Q'}{\overline{Q}} + A_P(\lambda)\frac{P'}{\overline{P}}$ (last term crossed out)

$$A_T(\lambda) \equiv \overline{T}\frac{\partial n(\lambda)}{\partial \overline{T}}$$

$$A_Q(\lambda) \equiv \overline{Q}\frac{\partial n(\lambda)}{\partial \overline{Q}}$$

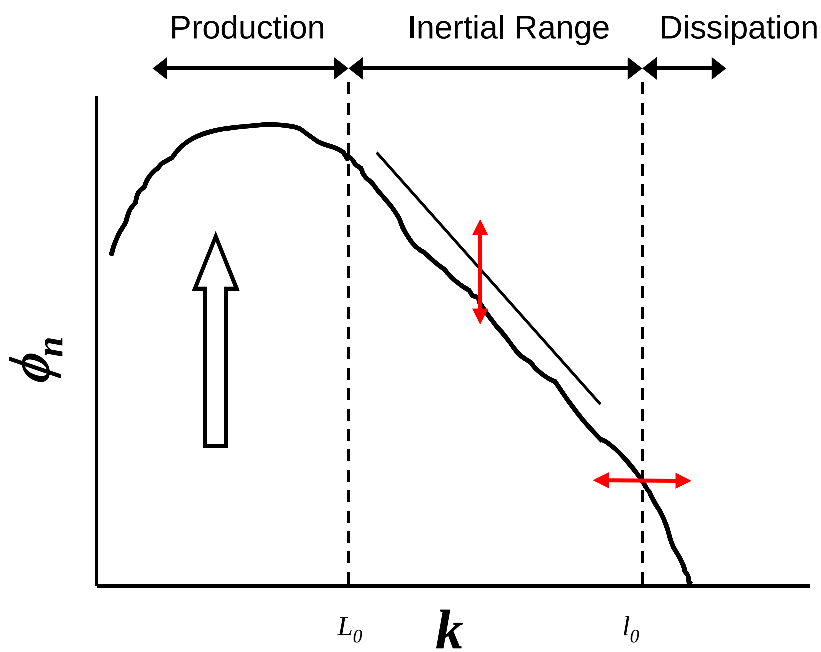
$$C_{n\_\lambda}^2 = \frac{A_{T\_\lambda}^2}{\overline{T}^2}C_T^2 + \frac{2A_{T\_\lambda}A_{Q\_\lambda}}{\overline{T}\,\overline{Q}}C_{TQ} + \frac{A_{Q\_\lambda}^2}{\overline{Q}^2}C_Q^2$$

		C_n^2	$\frac{A_T^2}{\overline{T}^2}C_T^2$	$2\frac{A_T A_Q}{\overline{T}\,\overline{Q}}C_{TQ}$	$\frac{A_Q^2}{\overline{Q}^2}C_Q^2$
LAS:	λ = 930 nm	1.22×10^{-14}	1.09×10^{-14}	1.19×10^{-15}	3.89×10^{-17}
MWS:	λ = 11 mm	8.7×10^{-13}	1.7×10^{-14}	-2.49×10^{-13}	1.10×10^{-12}
			H		***L_vE***

Scintillometer Equation:

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

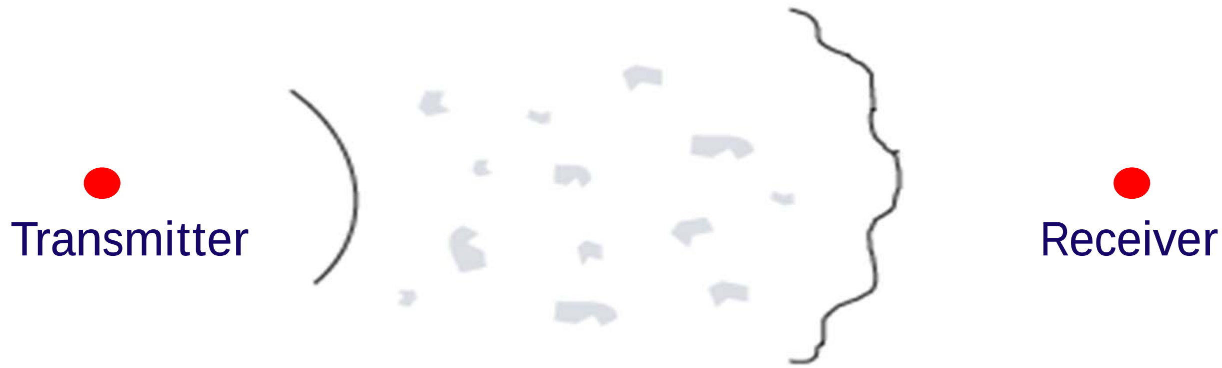
n-spectrum

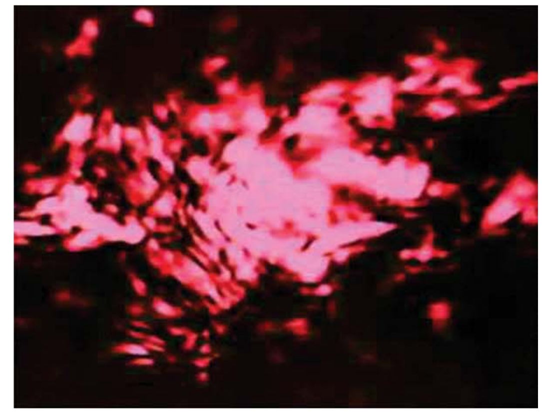


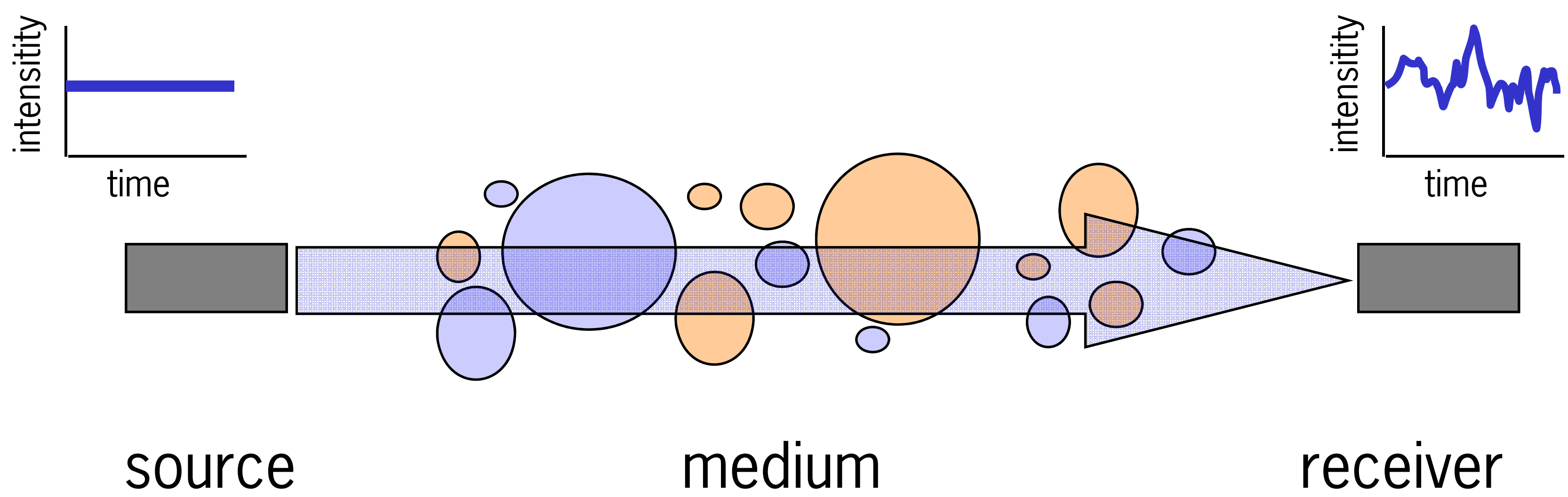
Inertial Range – Kolmogorov
Dissipation Range - Hill

- Scintillometer sensitive to one eddy scale: largest of *D* or *F*= $(\lambda L)^{1/2}$
- If in Inertial range → $\phi_n = 0.033\underline{C_n^2}\, k^{-11/3}$
- If in Dissipation range → $\phi_n = 0.033\underline{C_n^2}\, k^{-11/3} f_A(k\underline{l_0})$

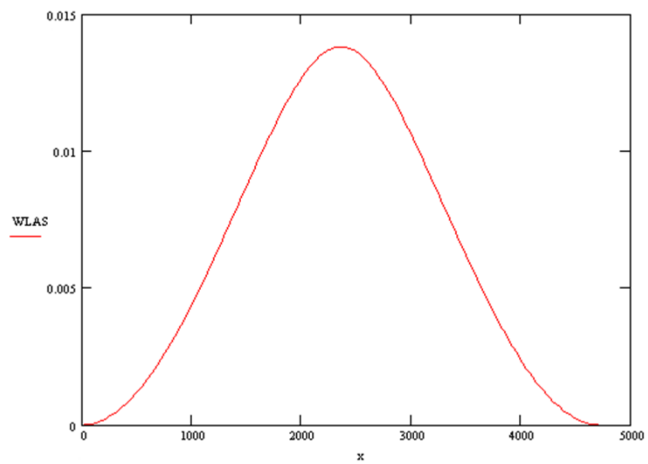
Scintillation – Diffraction Process

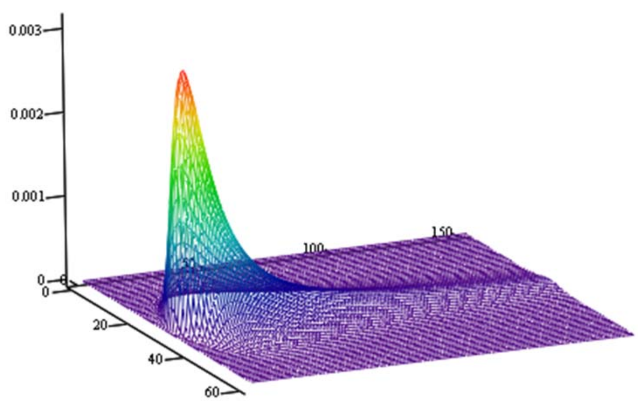


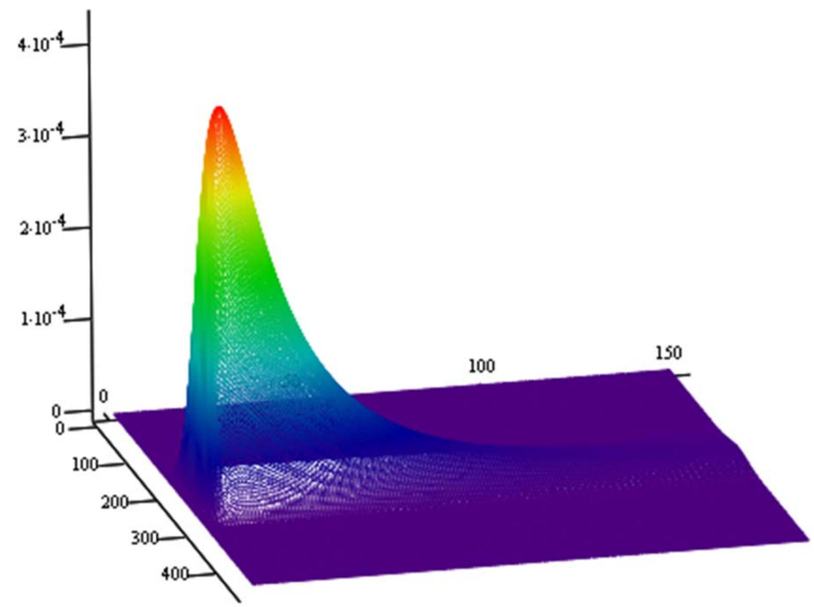




Scintillometer footprint







For different atmospheric conditions and wind directions