Distributed Temperature Sensing in the Atmosphere

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Atmospheric and Meteorological Instrumentation EGU2016-4832

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Outline

- **DTS principles**
- **Radiation**
- **RH**
- **Wind**

DTS Principles

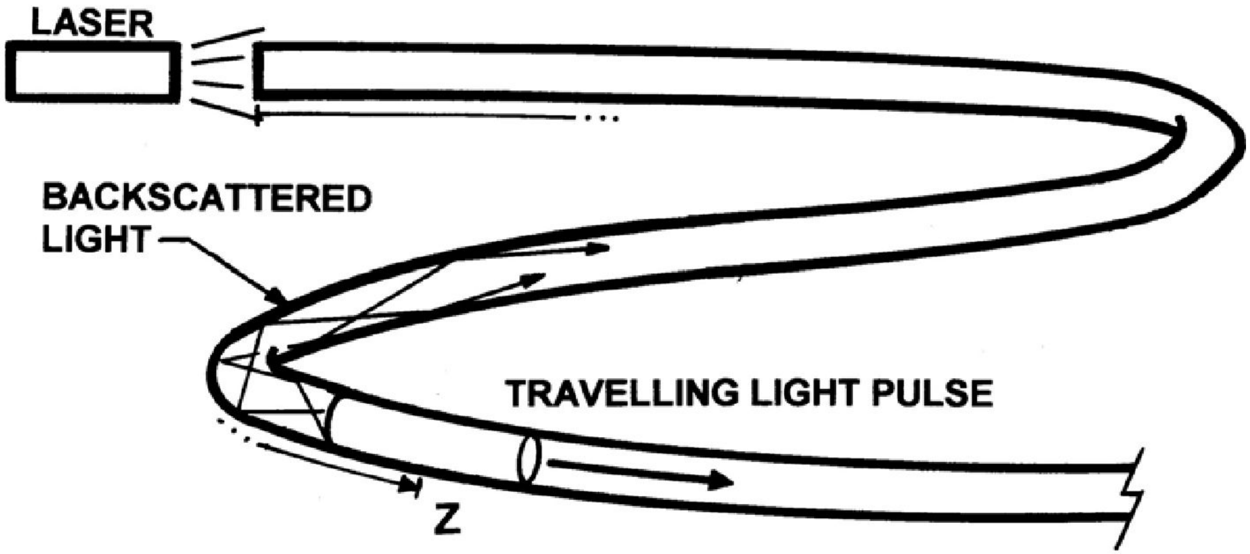
Distributed Temperature Sensing

- **Fiber optic cable**
- **Laser pulse (5 ns)**
- **Reflections**

Principles DTS

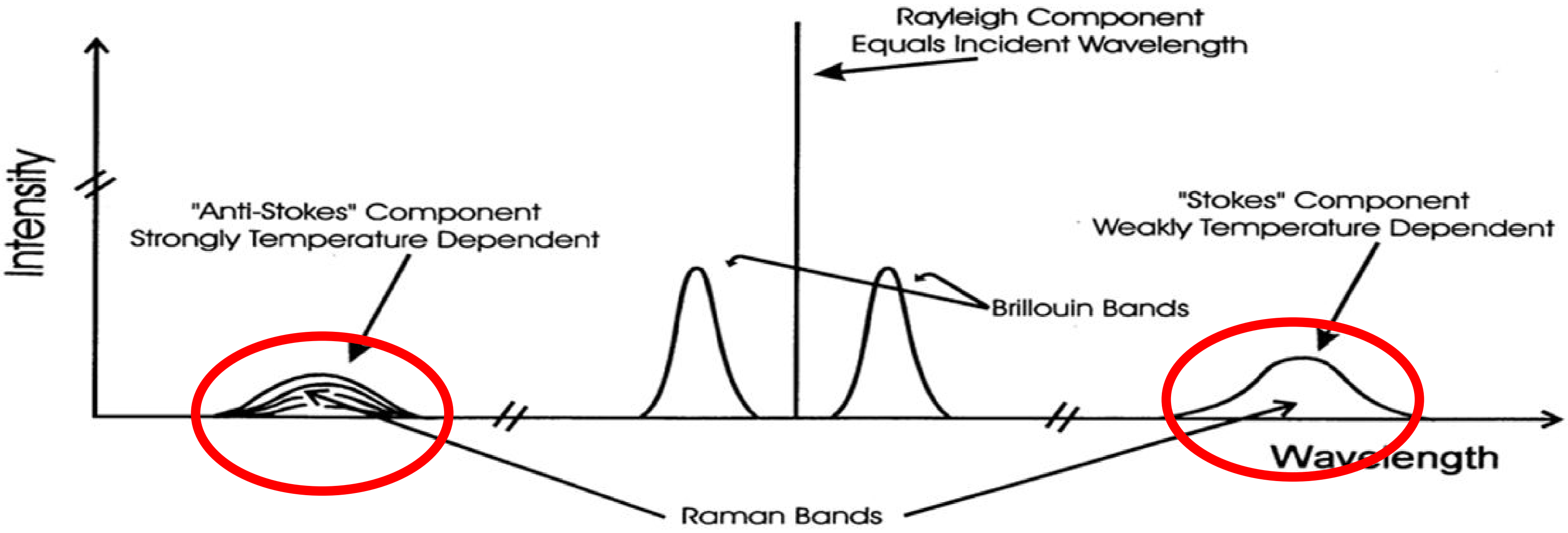
Time of flight

$$v = c/n = (3 \times 10^8)/1.5 = 2 \times 10^8 \text{ m/s}$$



DTS Principles

Raman spectrometry



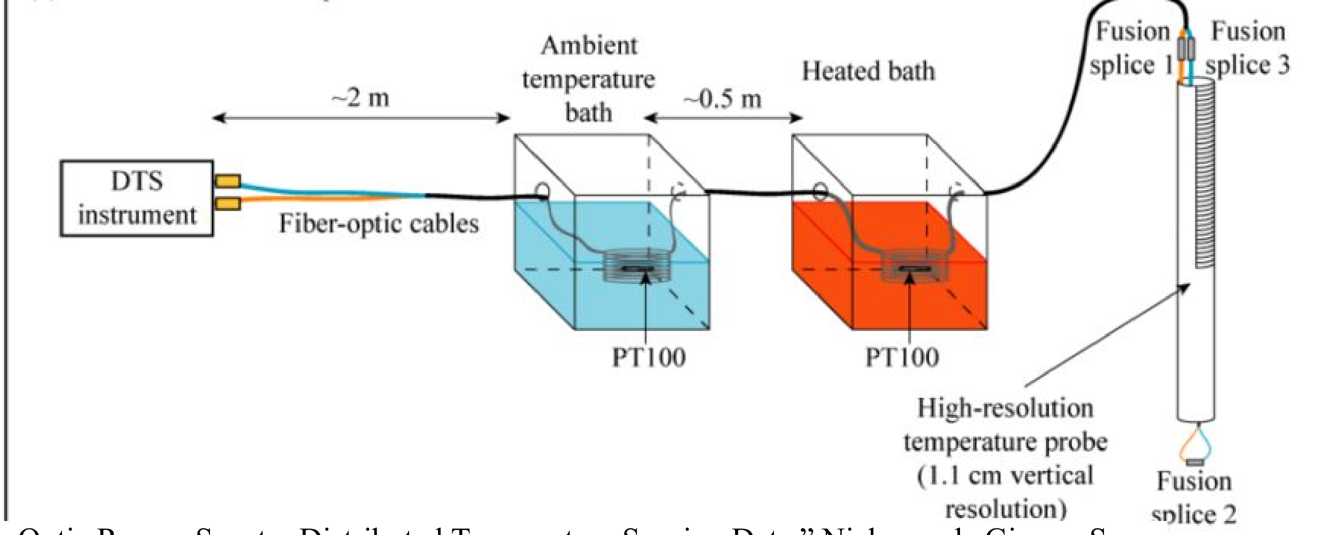
DTS Principles

Specifications

- **0.25 m spatial resolution**
- **Cable up to 5 km (50 km?)**
- **1 s temporal resolution**
- **0.01 K (10′ integration)**

Practicality 1

Calibrate!



(a) Schematic of the solar pond DTS installation

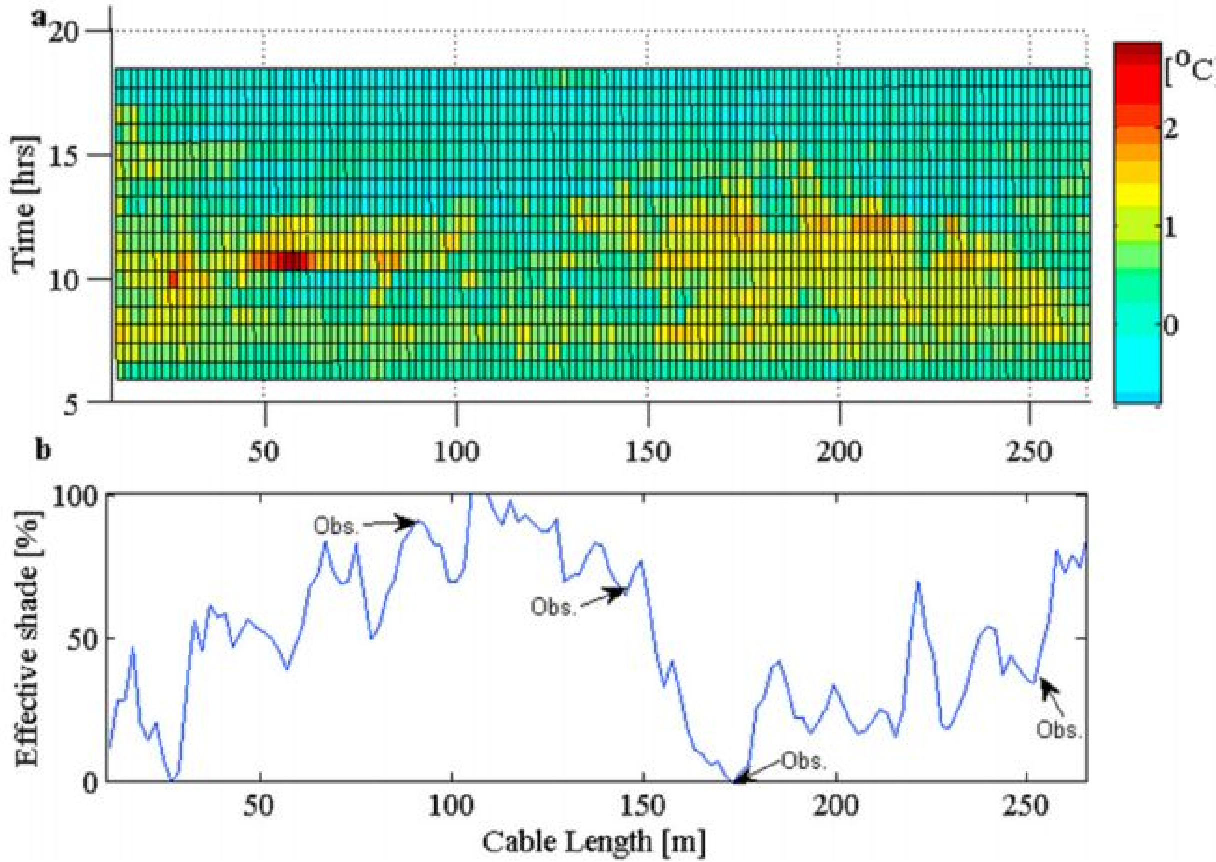
"Double-Ended Calibration of Fiber-Optic Raman Spectra Distributed Temperature Sensing Data." Nick van de Giesen, Susan Steele-Dunne, Jop Jansen, Olivier Hoes, Mark B. Hausner, Scott Tyler, John Selker. *Sensors*, 12(5):5471-5485; doi:10.3390/s120505471, 2012

"Calibrating single-ended fiber-optic Raman spectra distributed temperature sensing data." Mark B. Hausner, Francisco Suárez, Kenneth Glander, Nick van de Giesen, John S. Selker, Scott W. Tyler. *Sensors,* 11:10859-10879, doi:10.3390/s111110859, 2011

Air temperature

Radiation

Shading stream



Petrides, Huff, Arik, van de Giesen, Kennedy, Thomas, Selker: Shade estimation over streams using distributed temperature sensing, WRR 47 (W07601), 2011

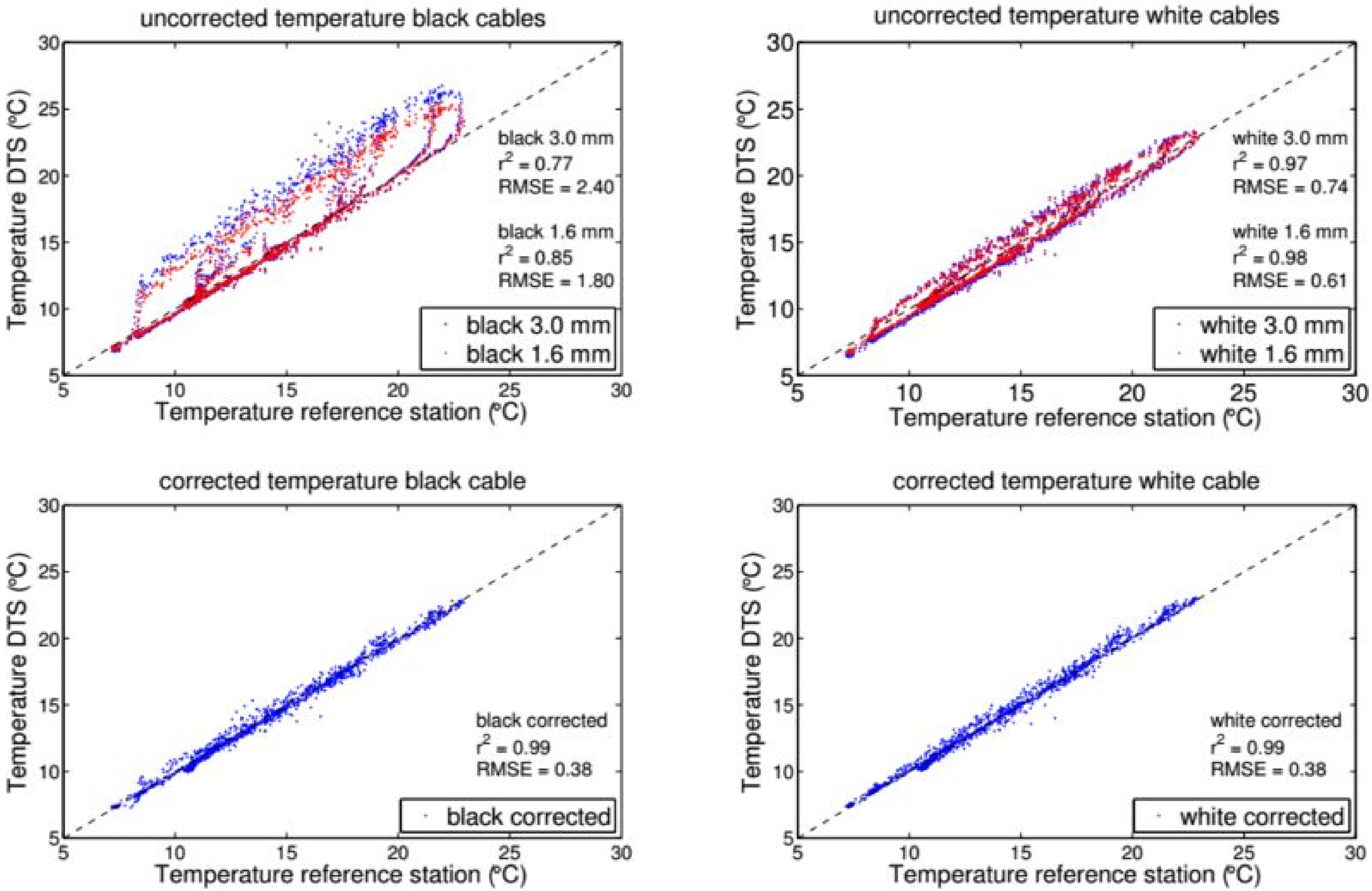
Air temperature

Radiation

Heating scales with √D

$$T_{\text{air}} = T_2 - \frac{T_1 - T_2}{\sqrt{\frac{d_1}{d_2}} - 1}$$

De Jong, Slingerland, van de Giesen: Fiber optic distributed temperature sensing for the determination of air temperature, Atmospheric Measurement Techniques, 8:335-339, 2015



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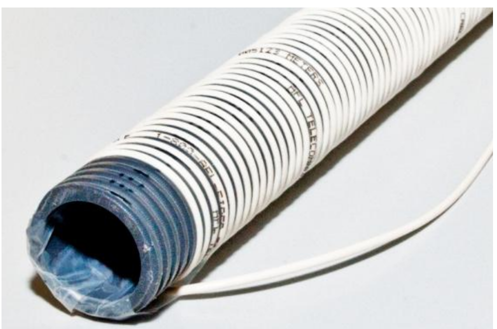
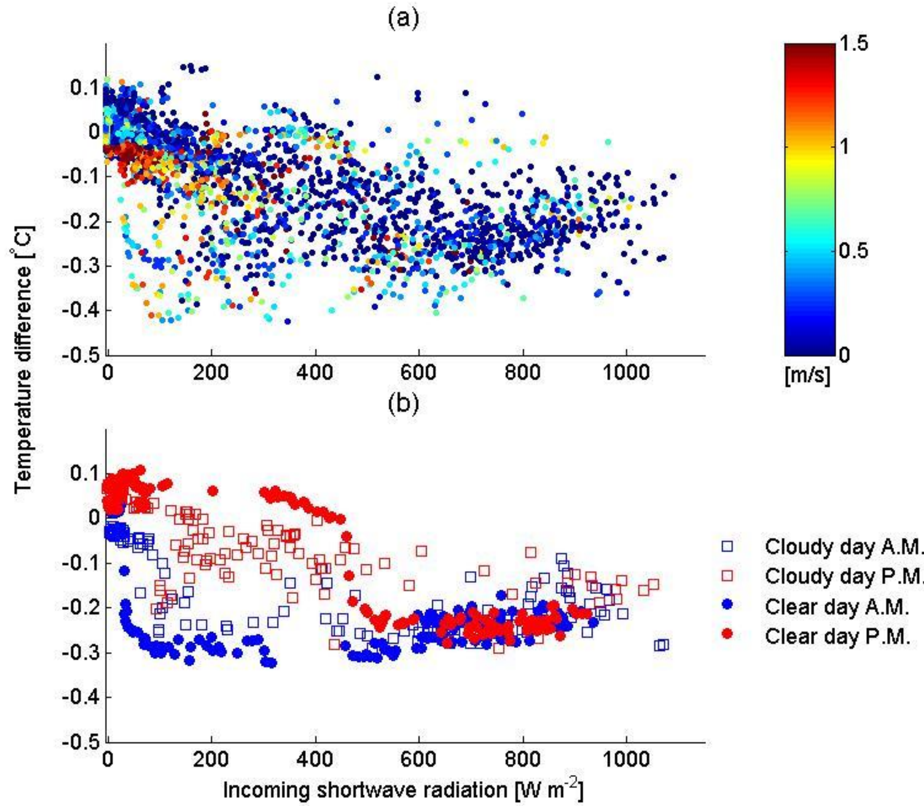
Practicality 2

Care about supports, suspension, etc.



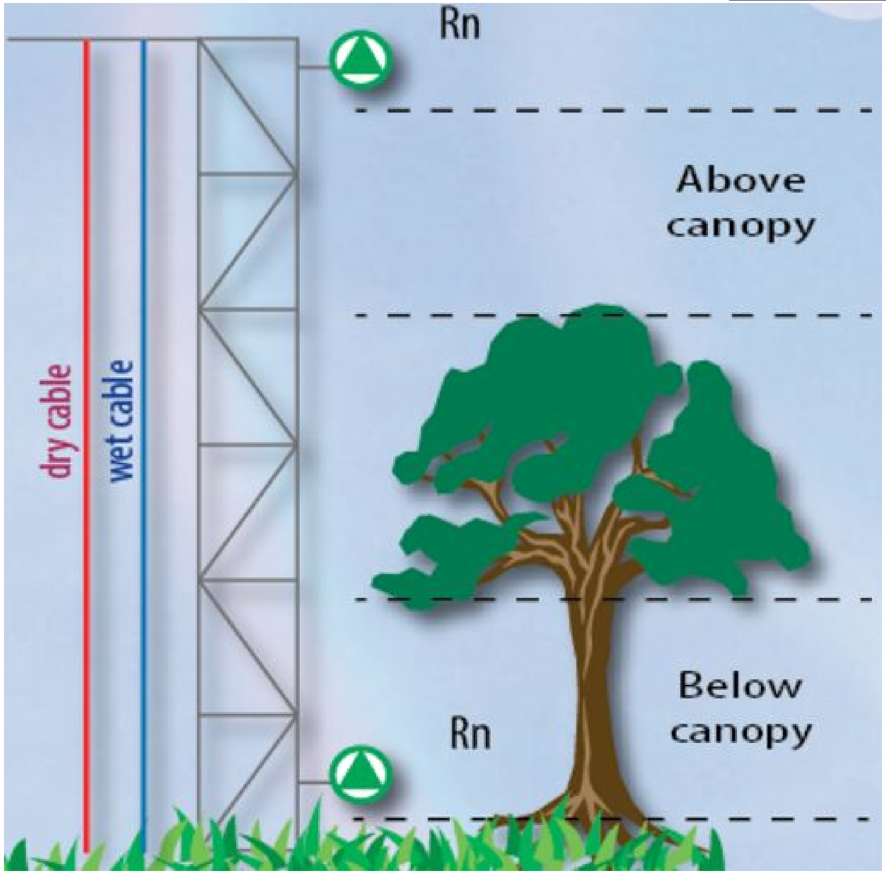


Hilgersom, van Emmerik, Solcerova, Berghuijs, Selker, van de Giesen, Practical considerations for enhanced-resolution coil-wrapped Distributed Temperature Sensing, Geoscientific Instrumentation, Methods and Data Systems Discussions, gi2016-1, 2016

Relative humidity

Bowen ratio

$$\left.\begin{aligned} R_n &= \rho\lambda E + H + Q \\ \beta &= \frac{H}{\rho\lambda E} = \gamma\frac{\Delta T}{\Delta e_a} \end{aligned}\right\} \rho\lambda E = \frac{R_n - Q}{1+\beta}$$



Euser, Luxemburg, Everson, Mengistu, Clulow, Bastiaanssen, A new method to measure Bowen ratios using high-resolution vertical dry and wet bulb temperature profilw, HESS 18:20121-2031, 2014

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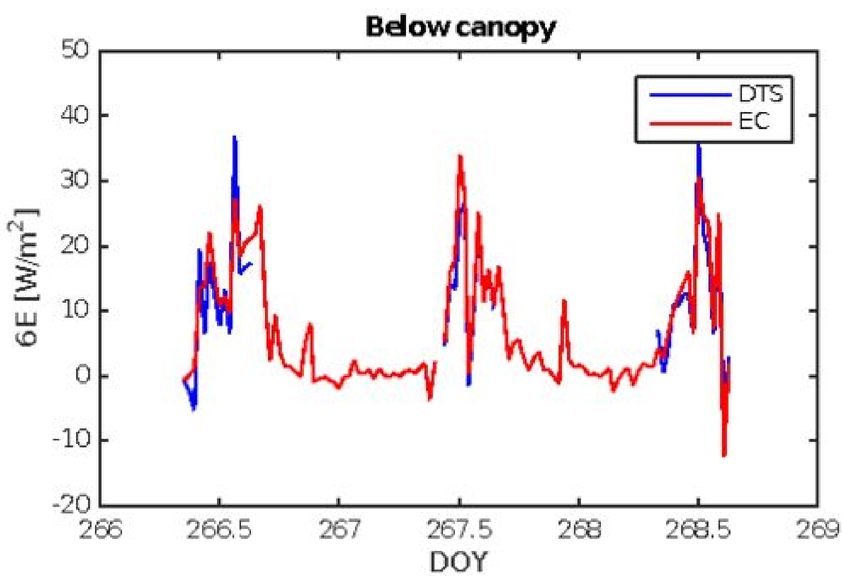
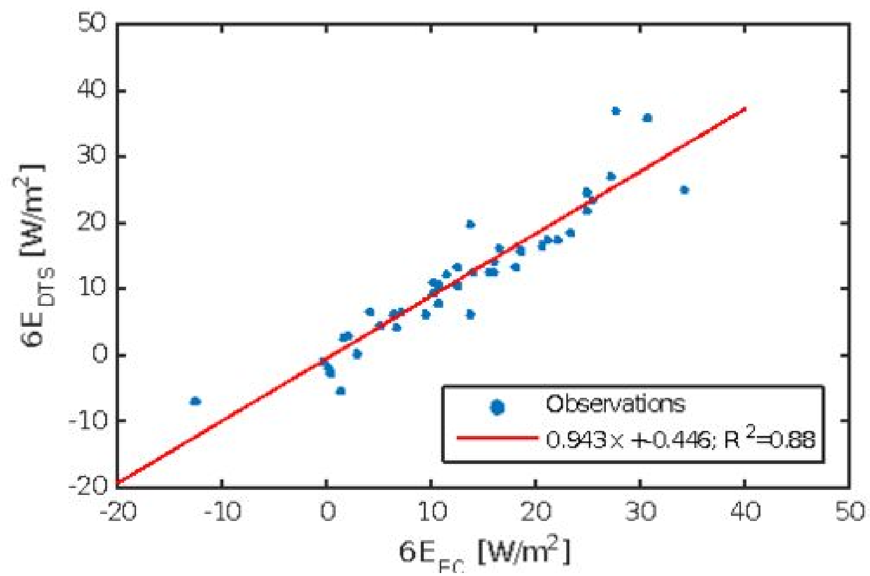
Relative humidity

Bowen ratio





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Relative humidity

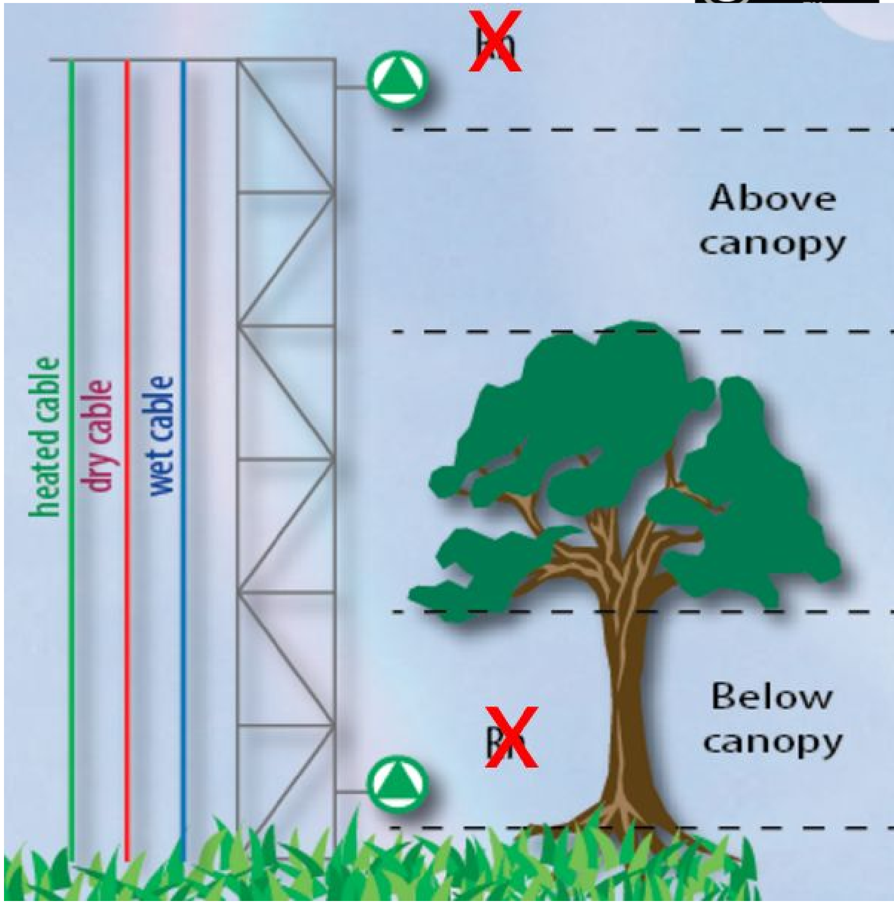
Bowen ratio

~~$R_n = \rho\lambda E + H + Q$~~

$$\beta = \frac{H}{\rho\lambda E} = \gamma \frac{\Delta T}{\Delta e_a}$$

$$H = u_* T_* c_p \rho_a$$

$$\rho\lambda E = \frac{u_* T_* c_p \rho_a}{\gamma \, \Delta T / \Delta e_a}$$



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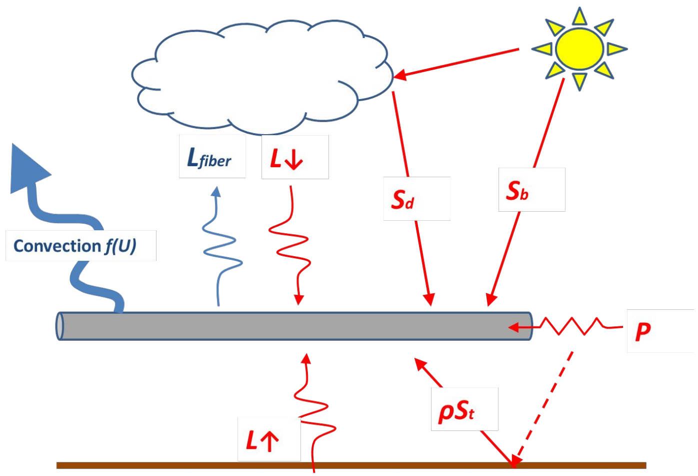
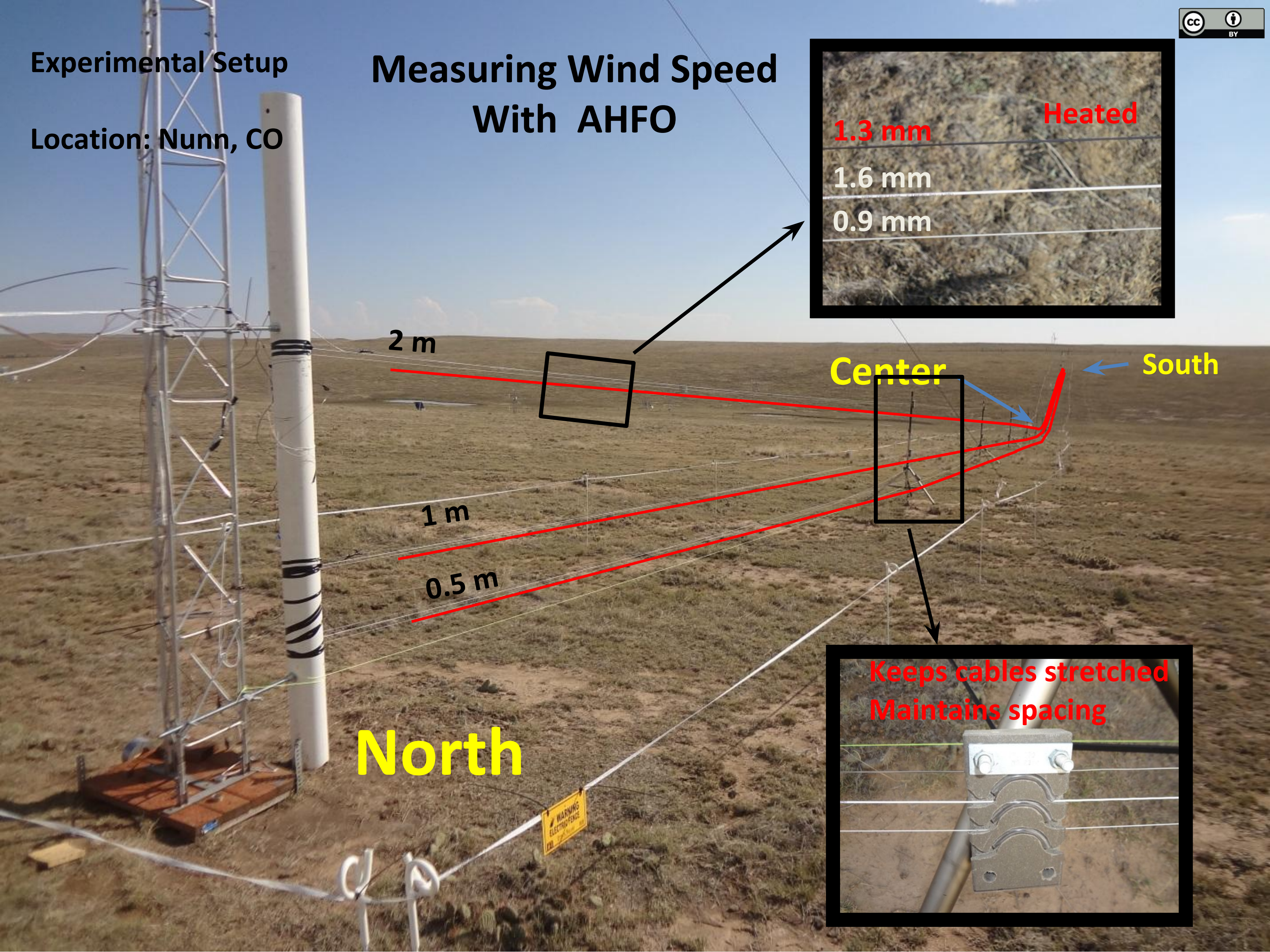
Hotwire anemometer

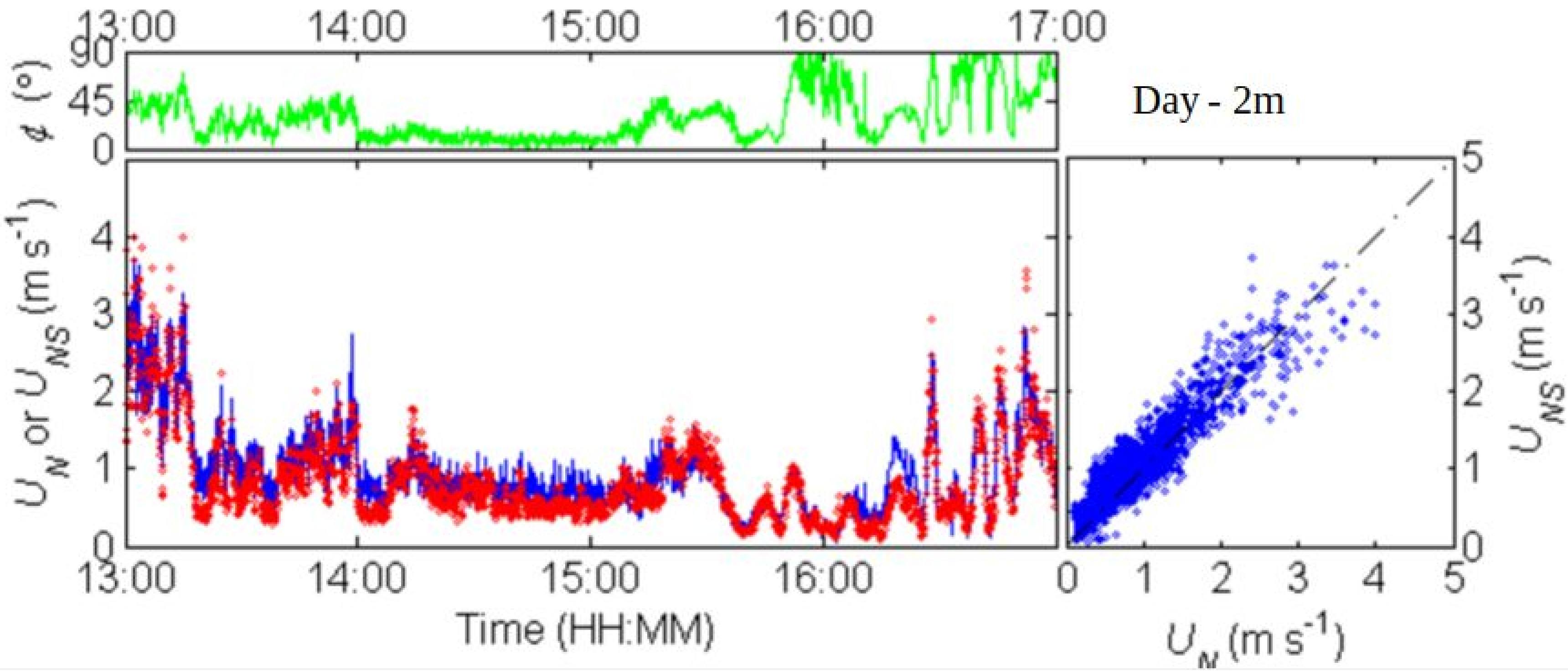
$$U_N = \left(\frac{0.5\, p\, \pi^{-1} r^{-1} + (\bar{S}_b + \bar{S}_d + \rho \bar{S}_t)(1-a) + (\bar{L}_\downarrow + \bar{L}_\uparrow)\varepsilon - \varepsilon\sigma T_s^4 + \frac{1}{2} c_p \rho r \frac{dT_s}{dt}}{-C(2r)^{m-1} Pr^n \left(\frac{Pr}{Pr_s}\right)^{\frac{1}{4}} K_A \upsilon^{-m} (T_s - T_f)} \right)^{\frac{1}{m}}$$



Sayde, C., C. K. Thomas, J. Wagner, and J. Selker, 2015. High-resolution wind speed measurements using actively heated fiber optics, Geophys. Res. Lett., 42, doi:10.1002/2015GL066729


Experimental Setup
Location: Nunn, CO
Measuring Wind Speed
With AHFO
Heated
1.3 mm
1.6 mm
0.9 mm
2 m
Center
South
1 m
0.5 m
North
Keeps cables stretched
Maintains spacing

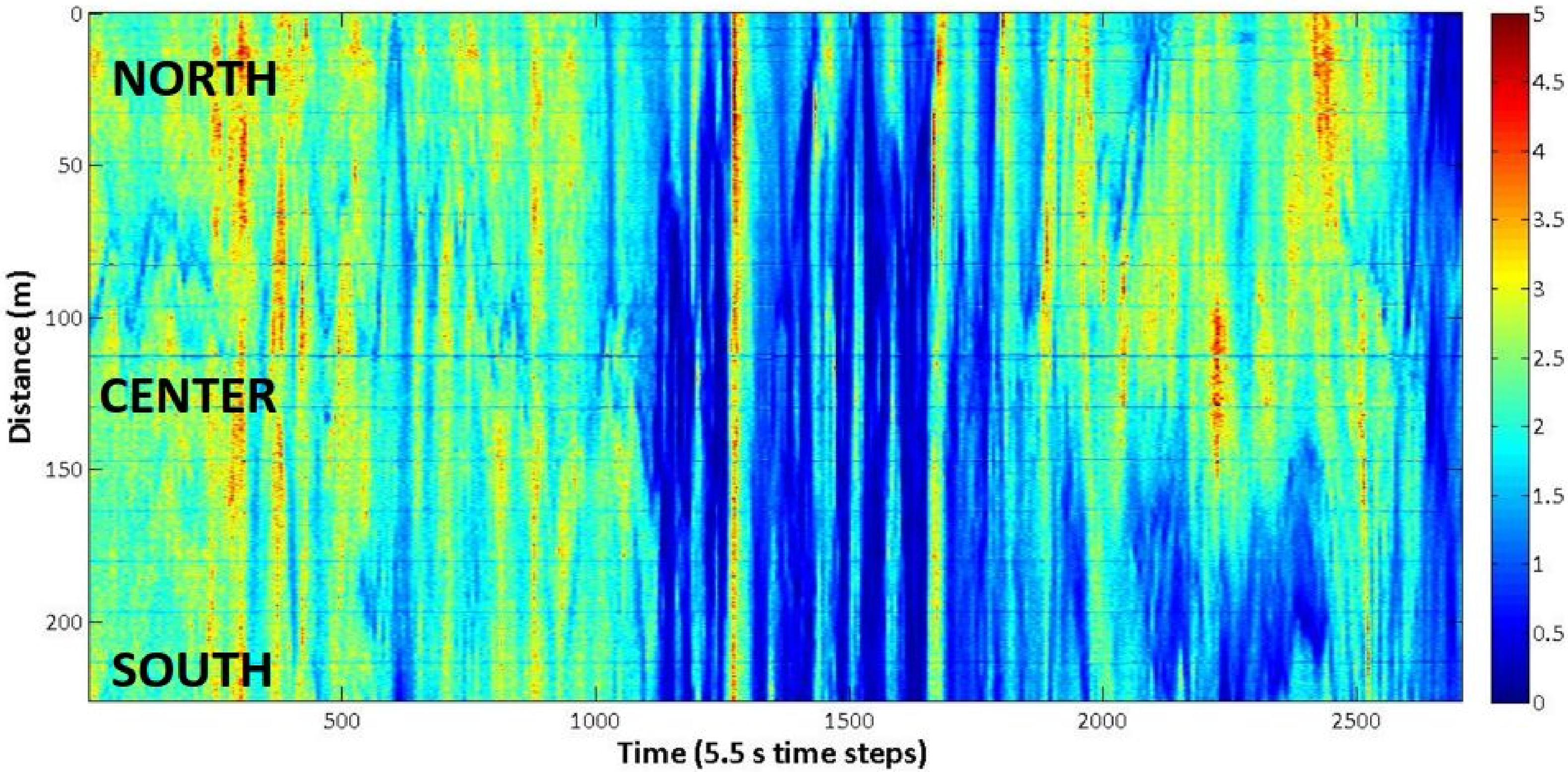
Hotwire anemometer



Sayde, C., C. K. Thomas, J. Wagner, and J. Selker, 2015. High-resolution wind speed measurements using actively heated fiber optics, Geophys. Res. Lett., 42, doi:10.1002/2015GL066729

Wind

Night



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Thanks!

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greetings from John, Chadi, Chris, Chad, Bart, Miriam, Wim, Koen, Tim, Anna, Wouter

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