Measuring and tracking night time inversions within a forest canopy

B. Schilperoort[1], A.M.J. Coenders-Gerrits[1], H.H.G. Savenije[1]

[1]Delft University of Technology, Water Management department

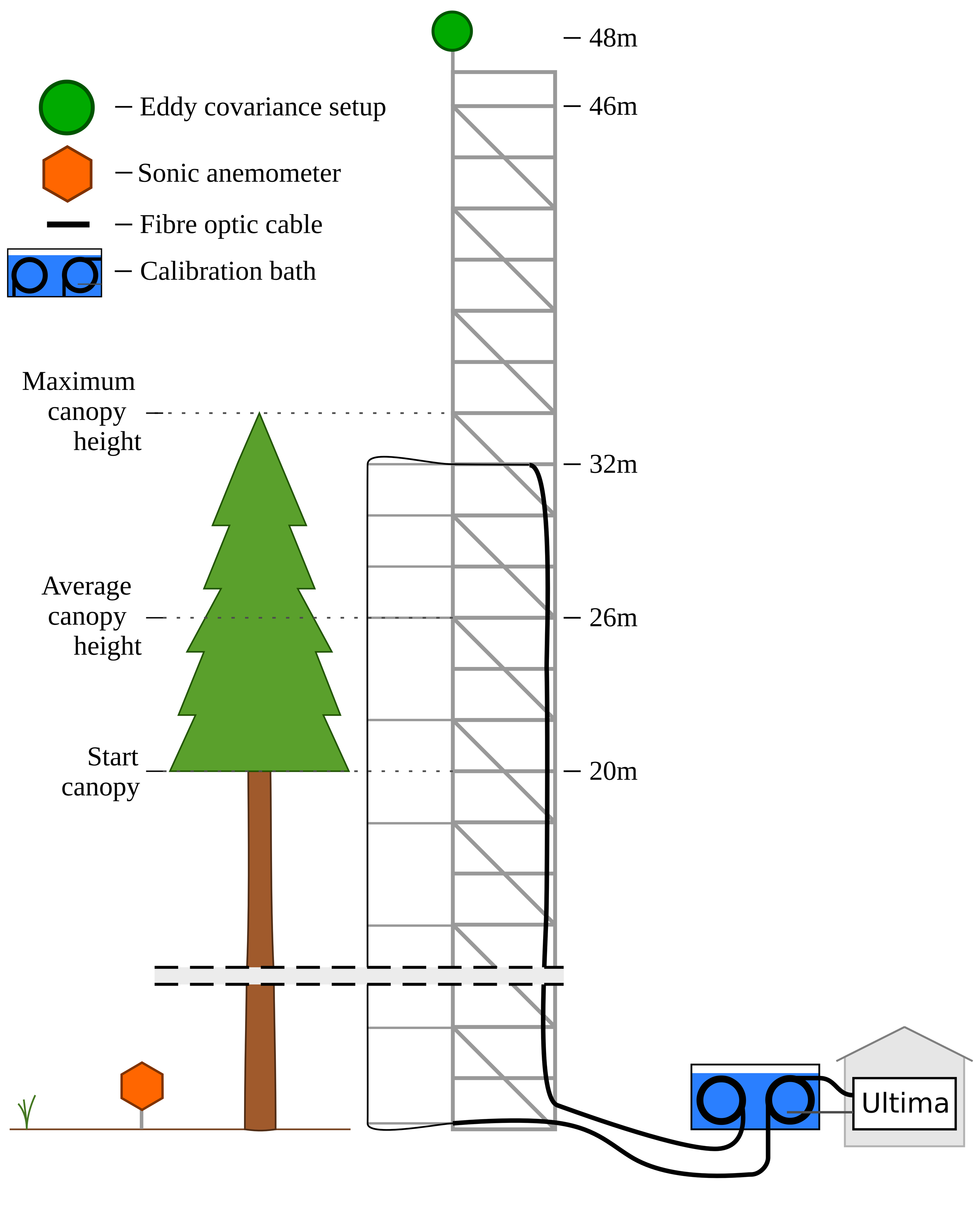
Introduction

One of the challenges of flux measurements above tall canopies, is that parts of the canopy can be decoupled from the atmosphere above. This can occur when the forest understory is colder than the air above, limiting exchange through convection.

While concurrent above and below canopy eddy covariance measurements help with addressing this issue, these are still disconnected point measurements and do not show what is happening along the entire vertical profile. For this, Distributed Temperature Sensing[1, 2] (DTS) can give additional insights, as it can perform continuous temperature measurements along a vertically deployed fiber optic cable.

Setup

Measurements were performed at the 'Speulderbos' site in the Netherlands, where a 48 m tall measurement tower is located in a stand of 34 m tall Douglas Fir trees. We measured a vertical temperature profile through the canopy using DTS. The measurement frequency was ~0.5 Hz, with a vertical resolution of 0.30 cm. Data was collected for two months.

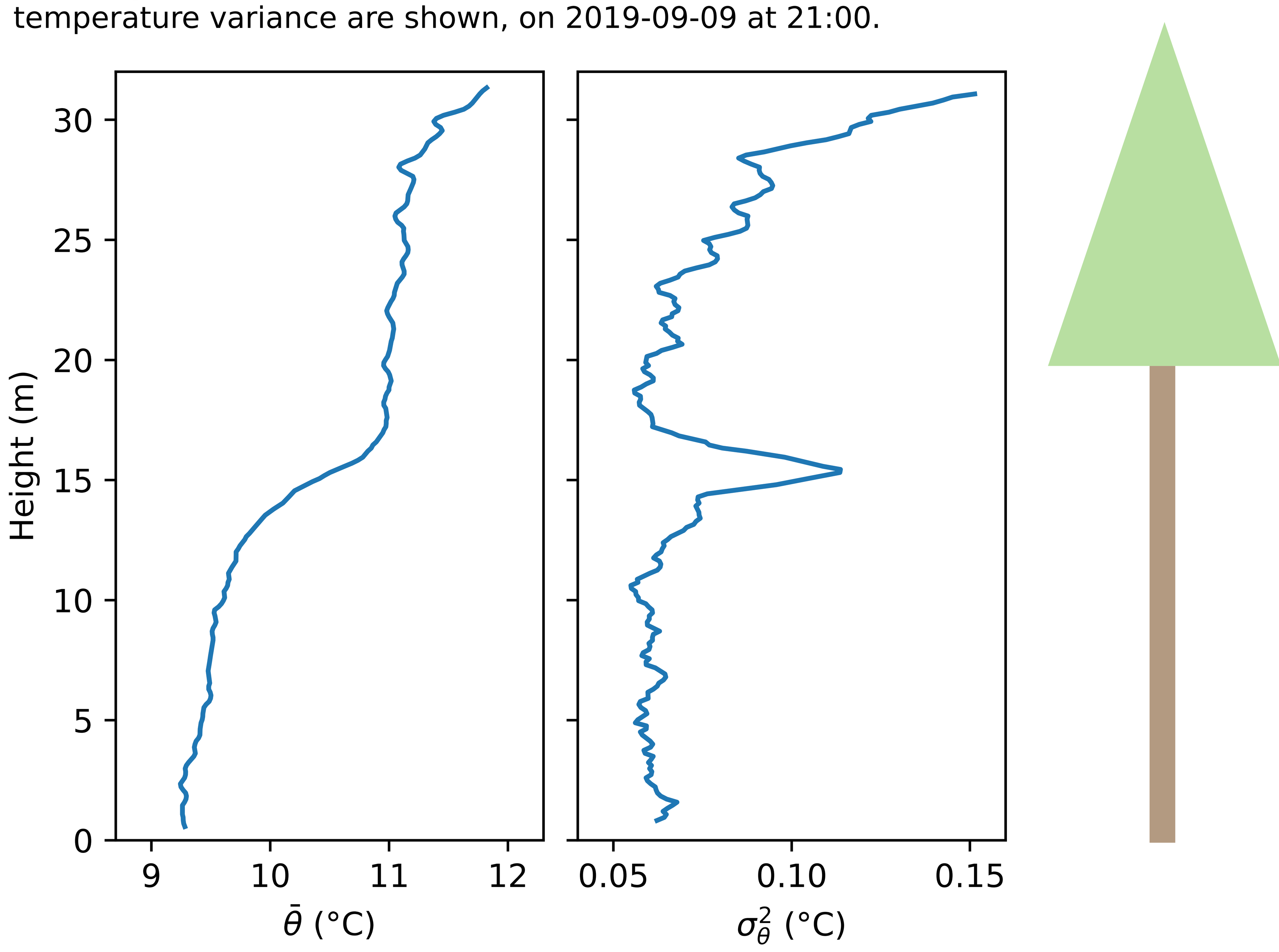


Inversion detection

To detect the presence of an inversion, we can make use of one of two methods; first is detecting a spike in the air temperature at a certain height, as at the height of the inversion the air temperature will vary strongly in time.

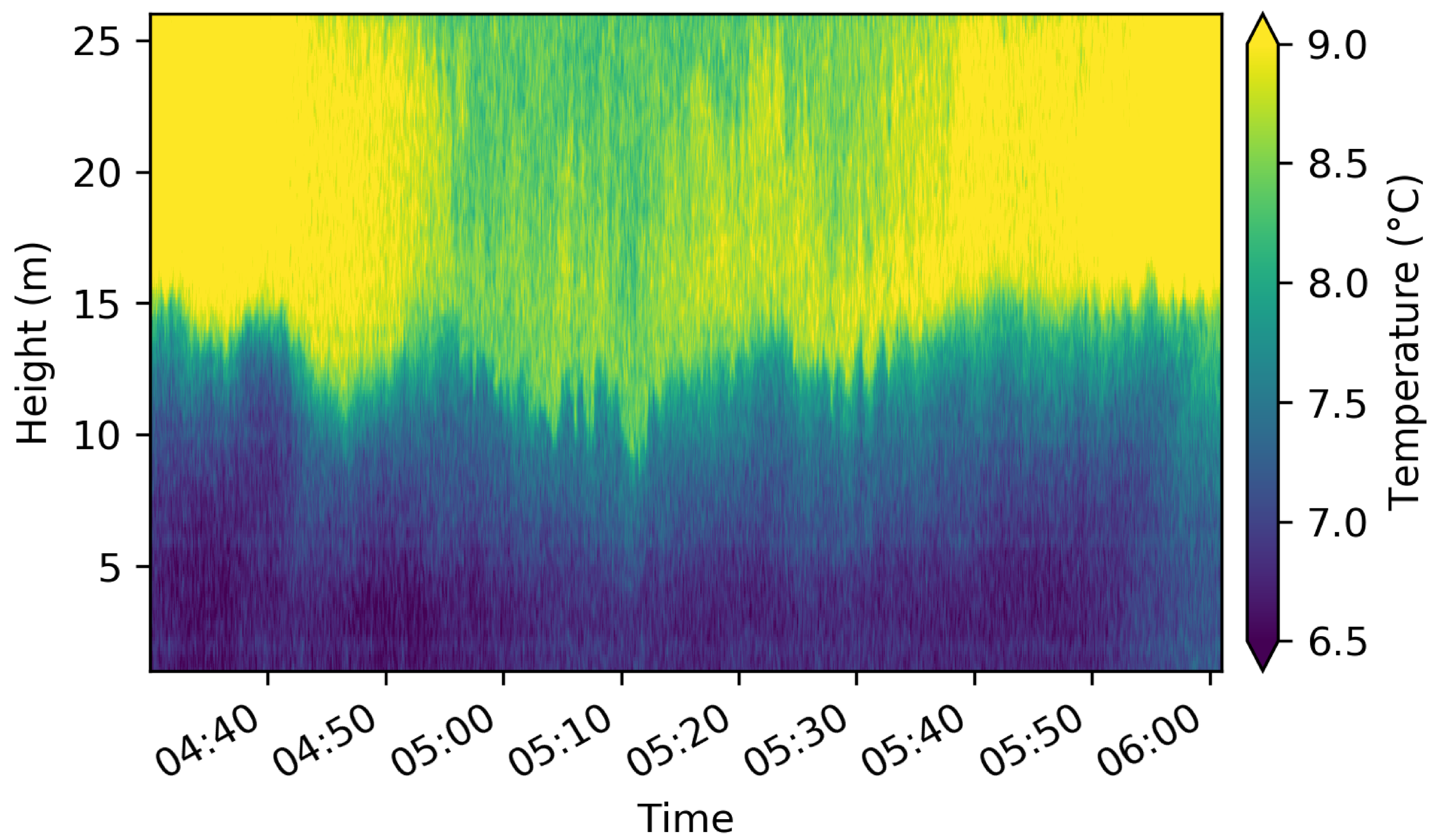
The second option is to use a block difference method, where a window is moved along the height, and the temperature difference over this window is calculated.

In the figure below the 5 minute mean potential temperature, and 5 minute temperature variance are shown, on 2019-09-09 at 21:00.



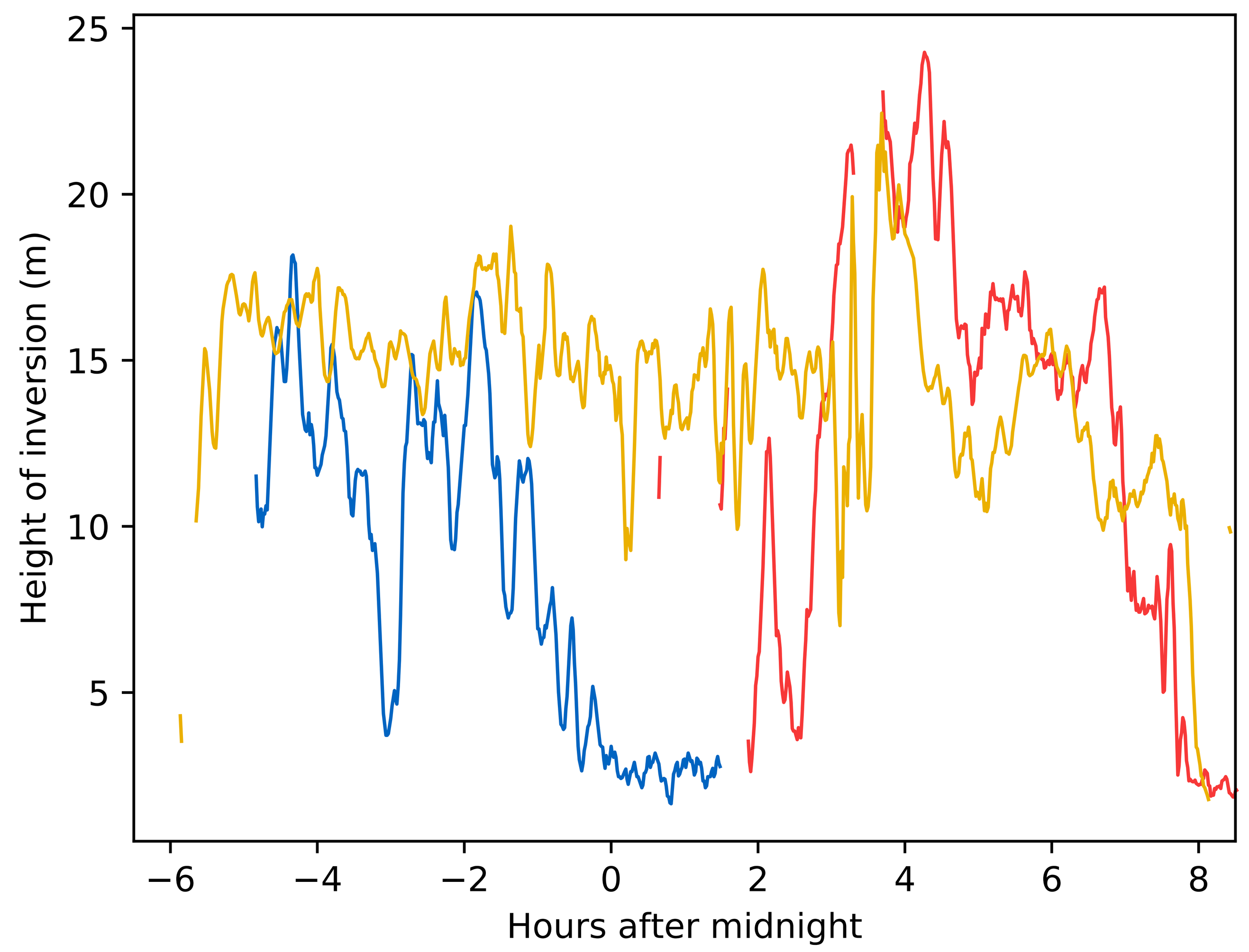
An inversion within the canopy

As a demonstration, measurements during a strong inversion are shown below. The air in the bottom 10 meters of the canopy is much colder than the air above (>1.5 °C). Oscillations in the inversion can be seen as well. Inversions like these are common at the Speulderbos site.

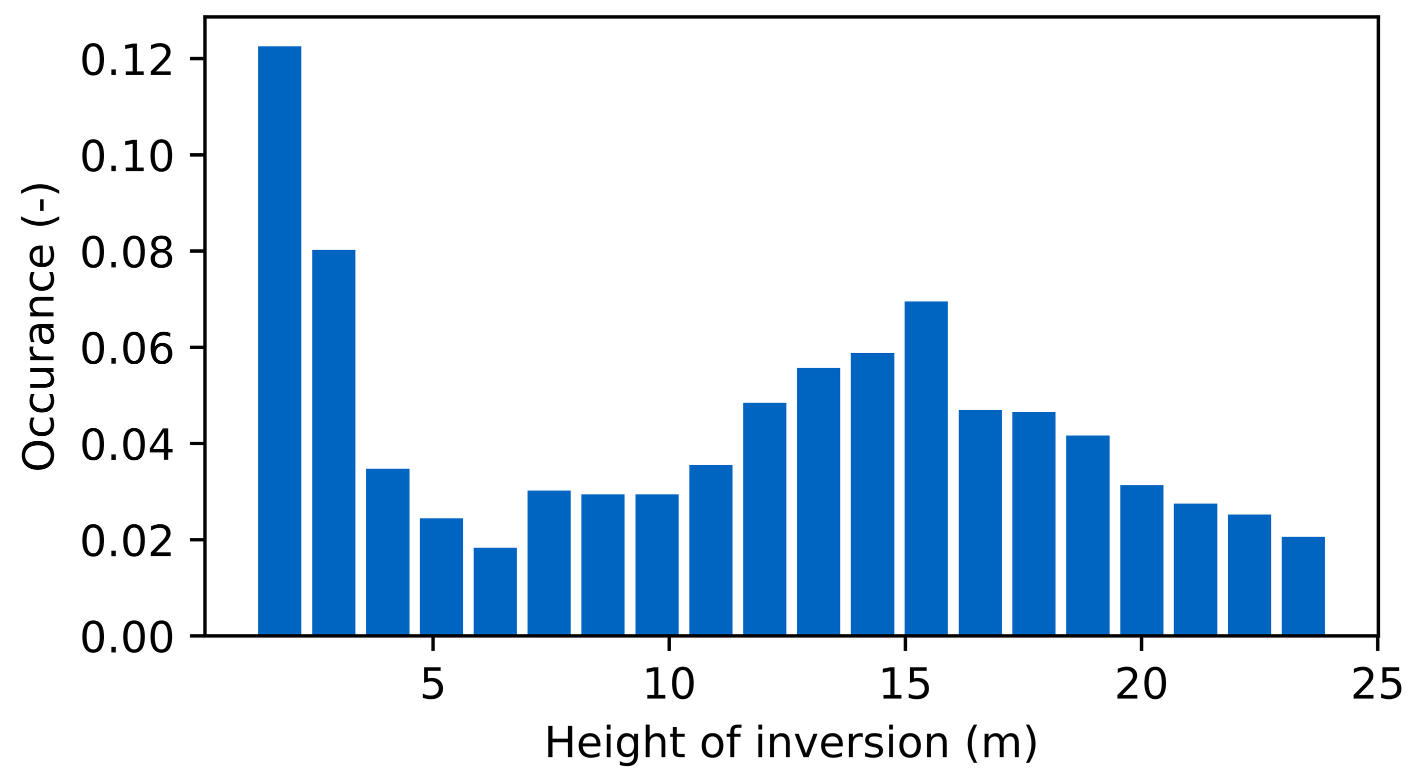


Inversion dynamics

In the figure below the detected inversion height during three different nights is shown, centered around midnight. The block difference method was used to determine the inversion height. Only the inversions with a strength greater than 0.10 K/m are shown. During some nights the inversion is present continuously, on other nights the inversion will form or fade due to changing wind speeds or changing longwave radiation.



The height of the inversion shows a bistable behavior (as can be seen in the figure below), either staying around 1 m above the ground, or at approximately 16 m, which is just below the dense branches of the canopy.



Histogram of inversion strength. Calculated from 30 days of data.

Conclusion & outlook

With this data we were able to detect the presence, height, and strength of inversions. The inversions appeared to occur mostly at night. By locating and tracking inversions within the canopy, decoupling events can be studied and explained in more detail. If vertical DTS profiles are available at a site, these can be used for filtering EC measurements as well.

While more research will be needed before a wide application at flux sites is possible, this study can serve as a 'proof-of-concept' and demonstrates how vertical DTS profiles can help understand problematic flux sites.

[1] Selker, J.S. et al.: Distributed fiber-optic temperature sensing for hydrologic systems, Water Resources Research, 42, 1 – 8, doi:10.1029/2006WR005326, 2006

[2] Schilperoort, B. et al: Using distributed temperature sensing for Bowen ratio evaporation measurements, Hydrol. Earth Sys. Sci., 22, 819–830, doi:10.5194/hess-22-819-2018, 2018.

Correspondence: b.schilperoort@tudelft.nl