A New Type of Sap Flow Sensor*

Jinchen Liu[1], Silke Schweighoefer[2]
[1] ECOMATIK, Germany, www.ecomatik.de, liu@ecomatik.de
[2] UP GmbH, www.upgmbh.com s.schweighoefer@upgmbh.com
*Patent no. 102 22 640

Ecomatik
Umweltmess- und Datentechnik

Introduction

Due to its simplicity, reliability and affordability, the well-known Granier sap flow sensor is accepted by several scientists over the world (Granier, 1985). However, the technique has always some shortcomings, which include:

1. Granier technique determines arbitrarily the sap flow to a zero value every night. This contravenes the possibility of night-time transpiration and the fact of refilling process of tree body during the night (Liu et. al., 1995).
2. The technique ignores the effect of background temperature gradients of the sap-wood, which can cause considerable error in the results (Do, Rocheteau 2002).

In this paper we present a new sensor, called SF-L sensor, which is based on the Granier sensor, but elimitates its disadvantages largely.

Construction of the SF-L sensor

The SF-L sensor consists of an ordinary Granier sensor (S0-S1, S0 is heated) with two additional reference thermocouples (S2-S1, S3-S1) and a dendrometer.
The reference thermocouples record the temperature background gradient of the sapwood (ΔTR1 and ΔTR2). The dendrometer monitors the refilling state of the tree.
All the 3 thermocouples (S0-S1, S2-S1, S34-S1) have the same construction as designed by Granier (Granier, 1985), so that we can use the formula established by Granier (1985).

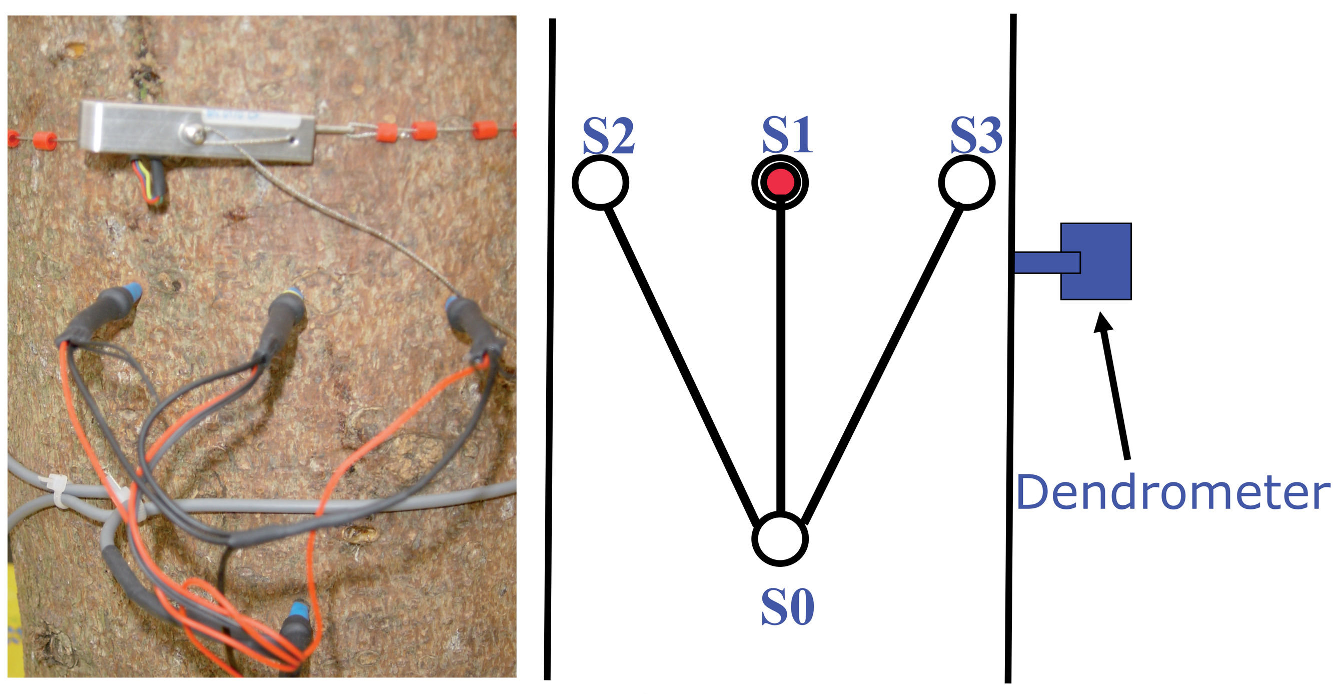

Fig.1 Construction of SF-L Sensor

The SF-L sensor provides four data series:
- ΔT: Temperature difference between S0-S1
- ΔT_{R1}: Background temperature gradient on the left side
- ΔT_{R2}: Background temperature gradient on the right side
- ΔD :Variation of tree diameter, indicating the refilling state of the tree

Data processing

In data processing, the temperature difference ΔT between S0 and S1 is corrected by the background temperature difference ΔT_{R1} and ΔT_{R1}.

$$\Delta TC = \Delta T - \frac{\Delta T_{R1} + \Delta T_{R2}}{2} \qquad (1)$$

The corrected ΔTC comes as initial data in the calculation formula of Granier (2) (Granier, 1985):

$$U = 0.714 \times \left(\frac{\Delta TC_{max} - \Delta TC}{\Delta TC} \right)^{1.231} \qquad (2)$$

ΔTC_{max} is the temperature difference between S0-S1 when sap flow is zero. In contrast to the Granier technique, zero sap flow does not occur every night. There must be two conditions met:

1. The tree is saturated and stops to absorb water. This can be recognized on stopping expansion of tree diameter, the dendrometer curve forms a plateau.
2. The air humidity is about 100% and the tree stops the transpiration.

Material

The SF-L sensor was installed at a tree in a 40-year-old spruce stand in Garmisch-Partenkirchen, Germany. The sensor was well insulated with Aluminium-coated polystyrene, and powered by a constant current source. The data were collected from 14th of June to 20th of August in 30 min. interval. In addition, climate parameters were measured in the canopy.

Results

The background temperature gradient

As shown in the fig 2, the tree trunk has a clear vertical temperature gradient. It varies between + / - 1.5 ° C. The course depends on the day-time. The maximum appears in the morning and the minimum at noon.

The point of zero sap flow

During the more than 2 months measurement period, the conditions for ΔTCmax as defined above occurred only once on the, it was 10:08 ° C in the night of July of 9th. During the measurement, this value is indeed approached several times, but never exceeded (fig. 3a).

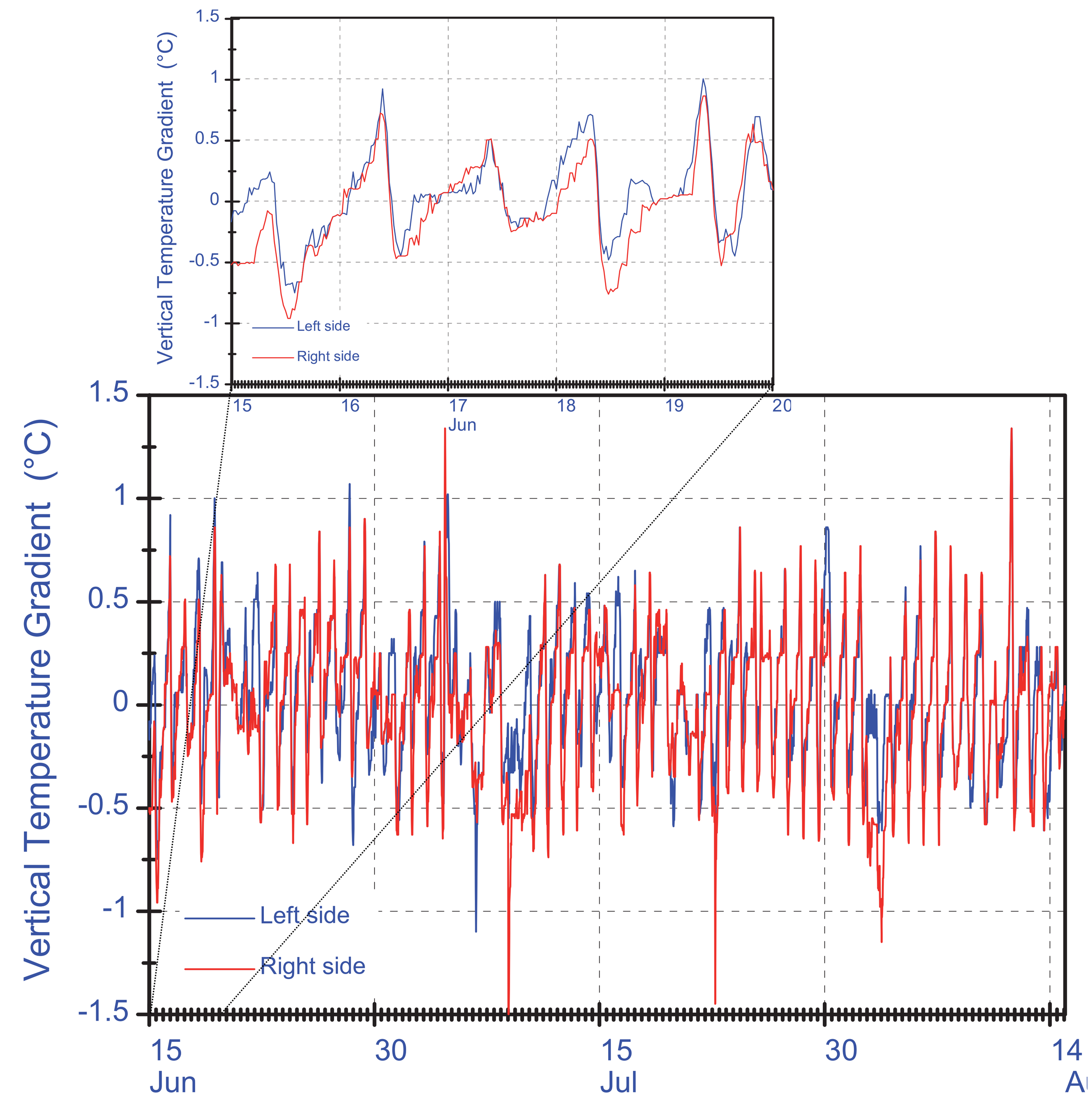

Fig. 2 Vertical temperature gradients of the tree

Comparison: Granier Sensor and SF-L Sensor

As shown in fig. 3b, the results of Granier sensor and SF-L sensor differ significantly. In the daytime, the sap flow of SF-L sensor is lower than that of Granier sensor. In contrast to Granier sensor, the SF-L sensor provides realistic values in the night. The minimum of daily sap flow varies between 0 and 67μl/(min*cm2). On average, the data of Granier sensor are at 75. μl/(min*cm2) and SF-L sensor at 75.22 μl/(min*cm2).

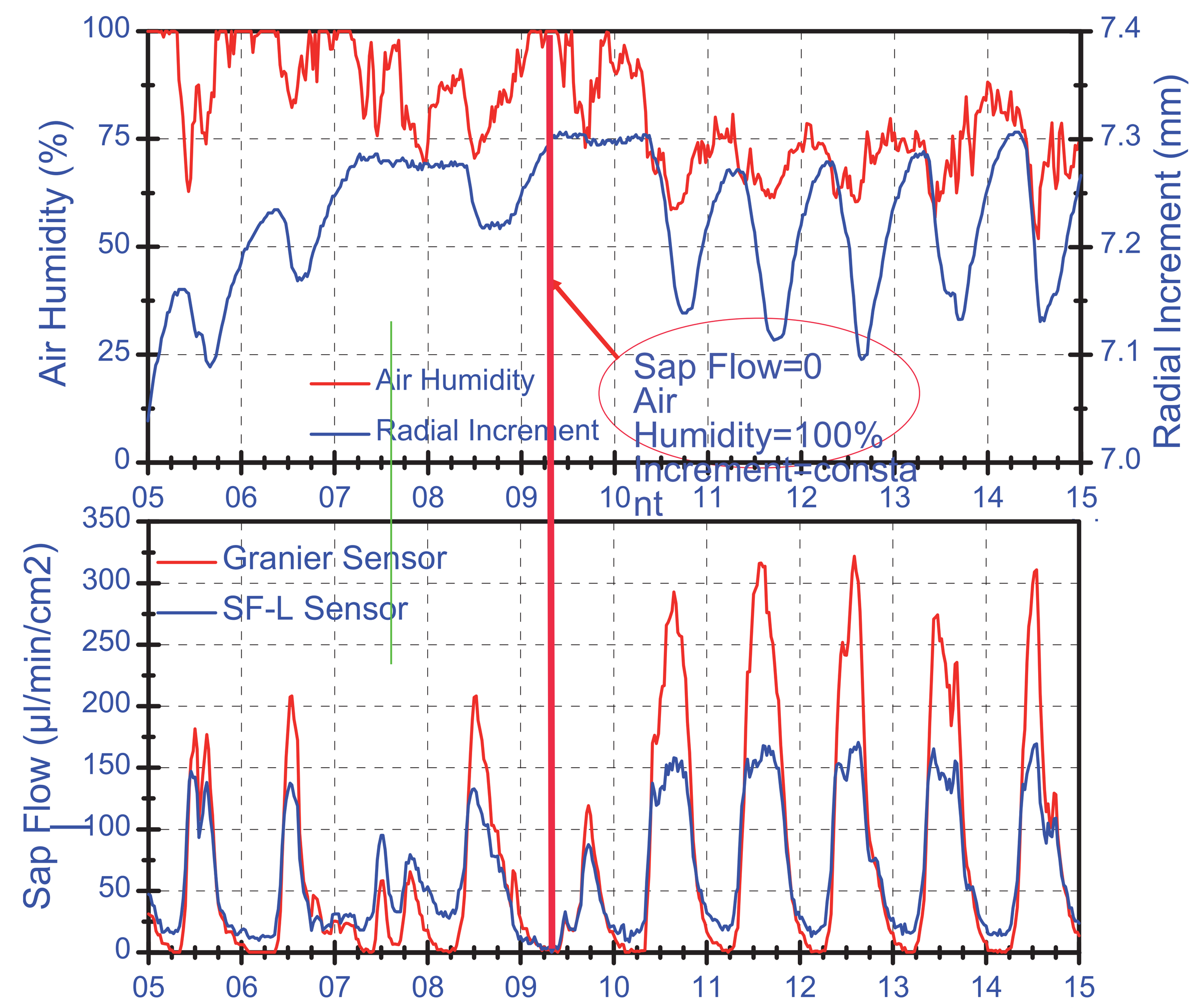

Fig.3a above: Air humidity and radial changes of a 40-year old spruce tree measured with an Ecomatik dendrometer type DR. In night of the 9th of July, the air humidity and the diameter variation meet the conditions for zero sap flow.
Fig.3b below: Comparison between sap flow measured with Granier sensor (red line) and with SF-L sensor (blue line). The Granier sensor shows zero sap flow every night while the SF-L detects zero value only on the night of 9th of July when air humidity reached 100% and the tree fully saturated with water.

Conclusion

Advantages

1. The SF-L sensor corrects the error due to the background temperature gradients of tree trunk, so that we can achieve higher accuracy than the ordinary Granier sensor.
2. In the definition of zero sap flow, the SF-L sensor takes into account the saturation state of the tree body and the conditions of transpiration. The new definition allows determination of the sap flow in the night.
3. The integrated dendrometer provides additional growth data.

Disadvantages

1. The SF-L sensor is only suitable for tree with a diameter larger than 10 cm.
2. A dendrometer is necessary.

Literature

Granier A (1985): Une nouvelle méthode pour la mesure du flux de sève brute dans le tronc des arbres, Ann. Sci. For., 1985, 42 (2), 193-200.
Liu J C, Firsching B M, Payer H D (1995): Untersuchungen zur Wirkung von Stoffeinträgen, Trockenheit, Ernährung und Ozon auf die Fichtenerkrankung am Wank in den Kalkalpen. GSF-Bericht 18/95, 236 S.
Do F and Rocheteau A (2002): Influence of natural temperature gradients on measurements of xylem sap flow with thermal dissipation probes. 2. Advantages and calibration of a non continuous heating system. Tree Physiology 22, 649-654..