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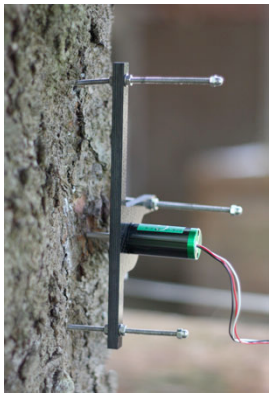
Point Dendrometer *ZN11-T-WP*

The **ZN11-T-WP** is the further developed version of the former ZB06. The frame is made out of one piece of carbon fibre (CFK) and is consequently combined with stainless steel elements (rods and nuts). The electronic displacement-sensor (linear motion potentiometer) is the same as for the ZB06.
Size of carbon fibre frame: 190 x 92 x 8 mm
Weight (without thread rods): < 100 g
Frame: T-shaped carbon fibre frame, 3 stainless steel thread rods, 6 screw nuts, 6 washers, and 3 cap nuts.
Displacement transducer: Weatherproof but not sealed potentiometer for measuring in a μm resolution. Hub of the moving rod is 2 cm.
Power supply: 5V DC.
Output: 0-5V DC, single ended measurement.




Voltage-Sensitivity: 1 mV = 4.0 μm
Temperature-Sensitivity: < -0.28 μm °C^{-1}

What is detected?
Diurnal stem radius fluctuations are mainly influenced by changes of the thickness of living tissues of the bark (mainly phloem cells). The thickness changes depend on the hydration status of the bark. While water is withdrawn from the bark through transpiration during the daytime, at night the tissue is replenished. As a result of this cycle, the diameter decreases during the day and increases at night. Over a period of weeks and months, this diurnal rhythm is altered by growth. New layers of xylem cells irreversibly increase the radius, particularly during wet periods in the growing season. An additional but smaller contribution comes from tensions within the wood and the growth and death of the phloem cells. In winter, ice formations in the wood induce strong decreases of the stem radius.

Advantages in comparison to other products
- No disturbances by deformations of the dead outermost layer of the bark, induced by temperature and air-humidity (a general argument in favour of point dendrometers and against band dendrometers).
- Materials and electronic parts insensitive to temperature allow for more accurate measurements.
- The spot of measurement is not influenced by the thread rods because it is neither in the vertical nor in the horizontal line of the anchor points.
- The application to different stem expositions allows a spatial resolution of stem radius fluctuations.
- Compatibility to most logging systems and easy to power with a stable 5V DC supply.
- Easy to mount.
- Minor disturbance of the tree stem.
- Weatherproof materials.
- Constructed, produced and tested by experts in tree physiology. Made in Switzerland.

Mounting principle
The electronic part of the dendrometer is mounted on a carbon fibre frame which is fixed to the stem by three stainless steel thread rods implanted into the inactive heartwood. A sensing rod is pressed slightly against the tree stem by a spring. The combination of weatherproof materials and a solid anchorage in the stem make it possible to precisely detect changes in the stem radius with a resolution of less than 1μm.

Mounting instruction
1. Hold the dendrometer against the stem and mark the three spots to drill. Use the outermost rod holes in the carbon frame whenever possible. Ensure that the sensing rod is pointing towards the centre of the stem.
2. Drill holes approximately 5-8 cm into the stem (drill diameter 4 mm). Ensure that the direction of the drill holes is kept horizontal.
3. Put the cap nuts on the thread rods and screw the thread rods into the drill holes previously prepared.
4. Clear the spot on the bark on which the sensor head is placed from rough, dead parts of bark. Use a knife, a chisel or sandpaper but never cut into the living part of the bark.
5. Remove the cap nuts and mount a screw nut followed by a washer on each thread rod.
6. Mount the dendrometer on the thread rods and adjust the distance to the stem with the screw nuts.
7. Fix the dendrometer with a second washer and a screw nut.
8. Connect the **brown** wire to a stabilised +5V DC power supply, the **yellow** wire to GND, and the **white** wire to the data logger.

Maintenance
Put a droplet of WD-40 on the moveable sensor rod twice a year.

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Point Dendrometer *ZN12-T-2WP*

The **ZN12-T-2WP** is a T-shaped dendrometer with two sensors to be mounted on tree stems >7 cm in diameter. The two sensors allow measuring stem radius changes over bark and on the xylem in parallel. The frame is made out of one piece of carbon fibre (CFK) and is consequently combined with stainless steel elements (rods and nuts). The two electronic displacement-sensors (linear motion potentiometer) are of the same type as for the ZN11-T-WP and the former ZB06.

Size of carbon fibre frame: 190 x 92 x 8 mm
Weight (with thread rods): 180 g
Frame: T-shaped carbon fibre frame, 3 stainless steel thread rods, 6 screw nuts, 6 washers, and 3 cap nuts.
Displacement transducer: Two weather-proof but not sealed potentiometer for measuring in a μm resolution. The hub of the moving rod is 2 cm.

Power supply: 5V DC.
Output: 0-5V DC, single ended measurement.
Voltage-Sensitivity: 1 mV = 4.0 μm
Temperature-Sensitivity: < -0.28 μm $°C^{-1}$

What is detected?
Diurnal stem radius fluctuations are mainly influenced by changes of the thickness of living tissues of the bark (mainly phloem cells). However, also the xylem undergoes size changes. The radial size changes depend on water tensions inside the stem and have an influence on the hydration status of the bark. While water is withdrawn from the bark through transpiration during the daytime, at night the tissue is replenished. As a result of this cycle, the diameter decreases during the day and increases at night. Over a period of weeks and months, this diurnal rhythm is altered by growth. New layers of xylem cells irreversibly increase the radius, particularly during wet periods in the growing season. In winter, ice formations in the wood induce strong decreases of the stem radius.

Advantages in comparison to other products
- No disturbances by deformations of the dead outermost layer of the bark, induced by temperature and air-humidity (a general argument in favour of point dendrometers and against band dendrometers).
- Materials and electronic parts insensitive to temperature allow for more accurate measurements.
- The spot of measurement is not influenced by the thread rods because it is neither in the vertical nor in the horizontal line of the anchor points.
- The application to different stem expositions allows a spatial resolution of stem radius fluctuations.
- Compatibility to most logging systems and easy to power with a stable 5V DC supply.
- Easy to mount.
- Minor disturbance of the tree stem.
- Weatherproof materials.
- Constructed, produced and tested by experts in tree physiology. Made in Switzerland.

Mounting principle
The two electronic parts of the dendrometer are mounted on a carbon fibre frame which is fixed to the stem by three stainless steel thread rods implanted into the inactive heartwood. Two sensing rods are pressed slightly against the tree stem by a spring. The combination of weatherproof materials and a solid anchorage in the stem make it possible to precisely detect changes in the stem radius with a resolution of less than 1μm with an accurate logging system.

Mounting instruction
1. Hold the dendrometer against the stem and mark the three spots to drill. Use the outermost rod holes in the carbon frame whenever possible. Ensure that the sensing rod is pointing towards the centre of the stem.
2. Drill holes approximately 5-8 cm into the stem (drill diameter 4 mm). Ensure that the direction of the drill holes is kept horizontal.
3. Put the cap nuts on the thread rods and screw the thread rods into the drill holes previously prepared.
4. Clear the spot on the stem from rough, dead parts of bark on which the first sensor head is placed. Use a knife, a chisel or sandpaper but never cut into the living part of the bark.
5. Cut with a knife a window of about 1x1 cm in size into the bark. Remove bark and cambium tissue and place the second sensor head on the xylem.
6. Remove the cap nuts and mount a screw nut followed by a washer on each thread rod.
7. Mount the dendrometer on the thread rods and adjust the distance to the stem with the screw nuts.
8. Fix the dendrometer with a second washer and a screw nut.
9. Connect the **red** wire to a stabilised +5V DC power supply, the **black** wire to GND, and the **white** wire to the data logger.

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Point Dendrometer *ZN11-T-IP*

The **ZN11-T-IP** consists of a sealed electronic displacement transducer on a carbon fibre (CFK) frame. The design of the sensor closely follows the one of the ZN11-T-WP. Mounting elements are of stainless steel (rods and nuts). The sensor is designed to be applied under very wet conditions.
Size of carbon fibre frame: 190 x 92 x 8 mm
Weight (without thread rods): < 200 g
Frame: T-shaped carbon fibre frame, 3 stainless steel thread rods, 6 screw nuts, 6 washers, and 3 cap nuts.
Displacement transducer: Sealed potentiometer (IP54) for measuring in a μm resolution. Hub of the moving rod is 2 cm. Weather-proof plug on sensor.
Power supply: 5V DC.
Output: 0-5V DC, single ended measurement.
Voltage-Sensitivity: 1 mV = 4.0 μm

What is detected?
Diurnal stem radius fluctuations are mainly influenced by changes of the thickness of living tissues of the bark (mainly phloem cells). The thickness changes depend on the hydration status of the bark. While water is withdrawn from the bark through transpiration during the daytime, at night the tissue is replenished. As a result of this cycle, the diameter decreases during the day and increases at night. Over a period of weeks and months, this diurnal rhythm is altered by growth. New layers of xylem cells irreversibly increase the radius, particularly during wet periods in the growing season. An additional but smaller contribution comes from tensions within the wood and the growth and death of the phloem cells. In winter, ice formations in the wood induce strong decreases of the stem radius.

Advantages in comparison to other products
- No disturbances by deformations of the dead outermost layer of the bark, induced by temperature and air-humidity (a general argument in favour of point dendrometers and against band dendrometers).
- Materials and electronic parts insensitive to temperature allow for more accurate measurements.
- The spot of measurement is not influenced by the thread rods because it is neither in the vertical nor in the horizontal line of the anchor points.
- The application to different stem expositions allows a spatial resolution of stem radius fluctuations.
- Compatibility to most logging systems and easy to power with a stable 5V DC supply.
- Easy to mount.
- Minor disturbance of the tree stem.
- Very robust and weather-proof materials, sealed electronic displacement transducer, weather-roof plug.
- Constructed, produced and tested by experts in tree physiology. Made in Switzerland.

Mounting principle
The electronic part of the dendrometer is mounted on a carbon fibre frame which is fixed to the stem by three stainless steel thread rods implanted into the inactive heartwood. A sensing rod is pressed slightly against the tree stem by a spring. The combination of weatherproof materials and a solid anchorage in the stem make it possible to precisely detect changes in the stem radius with a resolution of less than 1μm.

Mounting instruction
1. Hold the dendrometer against the stem and mark the three spots to drill. Use the outermost rod holes in the carbon frame whenever possible. Ensure that the sensing rod is pointing towards the centre of the stem.
2. Drill holes approximately 5-8 cm into the stem (drill diameter 4 mm). Ensure that the direction of the drill holes is kept horizontal.
3. Put the cap nuts on the thread rods and screw the thread rods into the drill holes previously prepared.
4. Clear the spot on the bark on which the sensor head is placed from rough, dead parts of bark. Use a knife, a chisel or sandpaper but never cut into the living part of the bark.
5. Remove the cap nuts and mount a screw nut followed by a washer on each thread rod.
6. Mount the dendrometer on the thread rods and adjust the distance to the stem with the screw nuts.
7. Fix the dendrometer with a second washer and a screw nut.
8. Connect the **red** wire to a stabilised +5V DC power supply, the **black** wire to GND, and the **white** wire to the data logger.

Maintenance
Put a droplet of WD-40 on the moveable sensor rod twice a year.

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Point Dendrometer *ZN12-T-2IP*

The **ZN12-T-2IP** consists of two sealed electronic displacement transducers on a carbon fibre (CFK) frame. Mounting elements are of stainless steel (rods and nuts). The dendrometer is designed to be applied under very wet conditions and enables to measure stem radius changes over bark and on xylem in parallel.
Size of carbon fibre frame: 190 x 92 x 8 mm
Weight (without thread rods): < 200 g
Frame: T-shaped carbon fibre frame, 3 stainless steel thread rods, 6 screw nuts, 6 washers, and 3 cap nuts.
Displacement transducer: Two sealed potentiometer (IP54) for measuring in a μm resolution. Hub of the moving rod is 2 cm. Weather-proof plug on sensor.
Power supply: 5V DC.
Output: 0-5V DC, single ended measurement.
Voltage-Sensitivity: 1 mV = 4.0 μm

What is detected?
Diurnal stem radius fluctuations are mainly influenced by changes of the thickness of living tissues of the bark (mainly phloem cells). The thickness changes depend on the hydration status of the bark. While water is withdrawn from the bark through transpiration during the daytime, at night the tissue is replenished. As a result of this cycle, the diameter decreases during the day and increases at night. Over a period of weeks and months, this diurnal rhythm is altered by growth. New layers of xylem cells irreversibly increase the radius, particularly during wet periods in the growing season. An additional but smaller contribution comes from tensions within the wood and the growth and death of the phloem cells. In winter, ice formations in the wood induce strong decreases of the stem radius.

Advantages in comparison to other products
- No disturbances by deformations of the dead outermost layer of the bark, induced by temperature and air-humidity (a general argument in favour of point dendrometers and against band dendrometers).
- Materials and electronic parts insensitive to temperature allow for more accurate measurements.
- The spot of measurement is not influenced by the thread rods because it is neither in the vertical nor in the horizontal line of the anchor points.
- The application to different stem expositions allows a spatial resolution of stem radius fluctuations.
- Compatibility to most logging systems and easy to power with a stable 5V DC supply.
- Easy to mount.
- Minor disturbance of the tree stem.
- Very robust and weather-proof materials, sealed electronic displacement transducer, weather-proof plug.
- Constructed, produced and tested by experts in tree physiology. Swiss Made.

Mounting principle
The electronic parts of the dendrometer are mounted on a carbon fibre frame which is fixed to the stem by three stainless steel thread rods implanted into the inactive heartwood. A sensing rod is pressed slightly against the tree stem by a spring. The combination of weatherproof materials and a solid anchorage in the stem make it possible to precisely detect changes in the stem radius with a resolution of less than 1μm.

Mounting instruction
1. Hold the dendrometer against the stem and mark the three spots to drill. Use the outermost rod holes in the carbon frame whenever possible. Ensure that the sensing rod is pointing towards the centre of the stem.
2. Drill holes approximately 5-8 cm into the stem (drill diameter 4 mm). Ensure that the direction of the drill holes is kept horizontal.
3. Put the cap nuts on the thread rods and screw the thread rods into the drill holes previously prepared.
4. Clear the spot on the bark on which the sensor head is placed from rough, dead parts of bark. Use a knife, a chisel or sandpaper but never cut into the living part of the bark.
5. Remove the cap nuts and mount a screw nut followed by a washer on each thread rod.
6. Mount the dendrometer on the thread rods and adjust the distance to the stem with the screw nuts.
7. Fix the dendrometer with a second washer and a screw nut.
8. After mounting the dendrometer, press the sensing rod back into its housing and let it slip back onto the tree surface. This procedure makes sure that the sensing rod gets not jammed.
9. Connect the **brown** wire to a stabilised +5V DC power supply, the **yellow** wire to GND, and the **white** wire to the data logger.

Maintenance
Put a droplet of WD-40 on the moveable sensor rod twice a year.

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Point Dendrometer *ZN11-O$_x$-WP*

The **ZN11-O-WP** is a point dendrometer with a ring-shaped frame offered in different sizes to optimally fit small stems. On request, the frame can be equipped with up to three sensors.
Diameter frames: 100 mm (**ZN11-O$_{100}$**), 80 mm (**ZN11-O$_{80}$**), 60 mm (**ZN11-O$_{60}$**).
Weight: 120-160 g
Components: Ring-shaped carbon fibre frame (CFK), 3 stainless steel screws, 1 electronic displacement sensor (linear motion potentiometer).
Power supply: 5V DC (stabilised).
Output: 0-5V DC, single ended measurement.

Voltage-Sensitivity: 1 mV = 4.0 μm
Temperature-Sensitivity: < 0.5 μm °C^{-1}

What is detected?
Diurnal stem radius fluctuations are mainly influenced by changes of the thickness of living tissues of the bark (mainly phloem cells). The thickness changes depend on the hydration status of the bark. While water is withdrawn from the bark through transpiration during the daytime, at night the tissue is replenished. As a result of this cycle, the diameter decreases during the day and increases at night. Over a period of weeks and months, this diurnal rhythm is altered by growth. New layers of xylem cells irreversibly increase the radius, particularly during wet periods in the growing season. An additional but smaller contribution comes from tensions within the wood and the growth and death of the phloem cells. In winter, ice formations in the wood induce strong decreases of the stem radius.

Advantages in comparison to other products
- No disturbances by deformations of the dead outermost layer of the bark, induced by temperature and air-humidity (a general argument in favour of point dendrometers and against band dendrometers).
- Minimal sensitivity to temperature and other weather impacts due to the circular construction of the frame and the weatherproof electronic displacement-sensor allow for more accurate measurements.
- The spot of measurement is not influenced by the mounting screws.
- Compatibility to most logging systems and easy to power with a stable 5V DC supply.
- Easy to mount. The only tool needed is a screw driver.
- Minor disturbance of the tree stem.
- Weatherproof materials.
- Constructed, produced and tested by experts in tree physiology. Made in Switzerland.

Mounting principle
The electronic part of the ZN11-O$_x$-WP is mounted on a circular carbon fibre frame (CFK) which is fixed to the stem by three screws. A sensing rod is pressed slightly against the tree stem by a spring. The combination of weatherproof materials and a solid three-point anchorage on the stem surface make it possible to precisely detect changes in the stem radius with a resolution of less than 1μm.

Mounting instruction
1. Dismantle the two screws on one side of the frame.
2. Enclose the stem, branch or root section with the frame and torque the two screws of the frame.
3. Clear the spot on the bark on which the sensor head is placed from rough, dead parts of bark. Use a knife, a chisel or sandpaper but never cut into the living part of the bark.
4. Adjust the distance between the potentiometer and the stem. Place the sensing rod on the bark. Ensure that the sensing rod is pointing towards the centre of the stem.
5. Place the three screws tightly on the bark surface (no drill wholes necessary). Make sure the frame is not moving anymore after fixing the screws.
6. Connect the **red** wire to a stabilised +5V DC power supply, the **black** wire to GND, and the **white** wire to the data logger.

Maintenance
Put a droplet of WD-40 on the moveable sensor rod twice a year.

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Point Dendrometer *ZN12-O$_x$-2WP*

The **ZN12-O-2WP** is a point dendrometer with a ring-shaped frame offered in different sizes to optimally fit small stems. The frame is equipped with two displacement transducers allowing to measure stem radius changes over bark and on xylem in parallel.
Diameter frames: 100 mm (**ZN12-O$_{100}$**), 80 mm (**ZN12-O$_{80}$**), 60 mm (**ZN12-O$_{60}$**).
Weight: <150 g
Components: Ring-shaped carbon fibre frame (CFK), 3 stainless steel screws, 2 electronic displacement sensor (linear motion potentiometer).
Power supply: 5V DC (stabilised).
Output: 0-5V DC, single ended measurement.
Voltage-Sensitivity: 1 mV = 4.0 μm
Temperature-Sensitivity: < 0.5 μm °C^{-1}

What is detected?
Diurnal stem radius fluctuations are mainly influenced by changes of the thickness of living tissues of the bark (mainly phloem cells). The thickness changes depend on the hydration status of the bark. While water is withdrawn from the bark through transpiration during the daytime, at night the tissue is replenished. As a result of this cycle, the diameter decreases during the day and increases at night. Over a period of weeks and months, this diurnal rhythm is altered by growth. New layers of xylem cells irreversibly increase the radius, particularly during wet periods in the growing season. An additional but smaller contribution comes from tensions within the wood and the growth and death of the phloem cells. In winter, ice formations in the wood induce strong decreases of the stem radius.

Advantages in comparison to other products
- No disturbances by deformations of the dead outermost layer of the bark, induced by temperature and air-humidity (a general argument in favour of point dendrometers and against band dendrometers).
- Minimal sensitivity to temperature and other weather impacts due to the circular construction of the frame and the weatherproof electronic displacement-sensor allow for more accurate measurements.
- The spot of measurement is not influenced by the mounting screws.
- Compatibility to most logging systems and easy to power with a stable 5V DC supply.
- Easy to mount. The only tool needed is a screw driver.
- Minor disturbance of the tree stem.
- Weatherproof materials.
- Constructed, produced and tested by experts in tree physiology. Made in Switzerland.

Mounting principle
The electronic parts of the ZN12-O$_x$-2WP are mounted on a circular carbon fibre frame (CFK) which is fixed to the stem by three screws. two sensing rods are pressed slightly against the tree stem by a spring. The combination of weatherproof materials and a solid three-point anchorage on the stem surface make it possible to precisely detect changes in the stem radius with a resolution of less than 1μm.

Mounting instruction
1. Dismantle the two screws on one side of the frame.
2. Enclose the stem, branch or root section with the frame and torque the two screws of the frame.
3. Clear the spot on the bark on which the sensor head is placed from rough, dead parts of bark. Use a knife, a chisel or sandpaper.
4. Adjust the distance between the potentiometer and the stem. Place the sensing rod on the bark. Ensure that the sensing rod is pointing towards the centre of the stem.
5. Place the three screws tightly on the bark surface (no drill wholes necessary). Make sure the frame is not moving anymore after fixing the screws.
6. Connect the **brown** wire to a stabilised +5V DC power supply, the **yellow** wire to GND, and the **white** wire to the data logger.

Maintenance
Put a droplet of WD-40 on the moveable sensor rod twice a year.

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References *stem radius fluctuations* …

… with natkon-dendrometers

Mencuccini M, Salmon Y, Mitchell P, Holtta T, Choat B, Meir P, O'Grady A, Tissue D, Zweifel R, Sevanto S, Pfautsch S. 2017. **An empirical method that separates irreversible stem radial growth from bark water content changes in trees: theory and case studies.** Plant Cell and Environment 40(2): 290-303.

Zweifel R, Haeni M, Buchmann N, Eugster W. 2016. **Are trees able to grow in periods of stem shrinkage?** New Phytologist DOI: 10.1111/nph.13995: 11 (link to New Phytologist).

Brinkmann N, Eugster W, Zweifel R, Buchmann N, Kahmen A. 2016. **Temperate tree species show identical response in tree water deficit but different sensitivities in sap flow to summer soil drying.** Tree Physiology 36(12): 1508-1519.

Zweifel R. 2015. **Radial stem variations – a source of tree physiological information not fully expoited yet.** Plant, Cell and Environment doi: 10.1111/pce.12613: 2 (PDF 235KB).

Dawes M.A., Zweifel R., Dawes N., Rixen Ch., and Hagedorn F. 2014. **CO2 enrichment alters diurnal stem radius fluctuations of 36-yr-old Larix decidua growing at the alpine tree line.** New Phytologist. DOI: 10.1111/nph.12742 (PDF 1.3MB)

Zweifel R., Drew DM, Schweingruber FH, Downes GM. 2014. **Xylem as the main origin of stem radius changes in Eucalyptus.** Functional Plant Biology. http://dx.doi.org/10.1071/FP13240 (PDF 1.7MB)

Verlinden MS, Broeckx LS, Zona D, Berhongaray G, De Groote T, Serrano MC, Janssens IA, Ceulemans R. 2013. **Net ecosystem production and carbon balance of an SRC poplar plantation during its first rotation.** Biomass & Bioenergy 56: 412-422. (PDF 960kB)

Etzold S., Zweifel R., Ruehr N.K., Eugster W., and Buchmann N. 2013. **Long-term stem CO2 concentration measurements in Norway spruce in relation to biotic and abiotic factors.** New Phytologist. 197, 1173-1184. (PDF 1MB)

Carrasco, L.O., Bucci, S.J., Scholz, F.G., Campanello, P., Madanes, N., Cristiano, P.M., Hao, G.-.Y., Wheeler, J.K., Holbrook, N.M. and Goldstein, G. 2013. **Water storage discharge and refilling in the main stems of canopy tree species investigated using frequency domain reflectometry and electronic point dendrometers.** Acta Hort. (ISHS) 991:17-24 (link to journal)

De Schepper V, van Dusschoten D, Copini P, Jahnke S, Steppe K. 2012. **MRI links stem water content to stem diameter variations in transpiring trees.** Journal of Experimental Botany 63(7): 2645-2653. (PDF 920kB)

Ehrenberger W, Rüger S, Fitzke R, Vollenweider P, Günthardt-Goerg M, Kuster T, Zimmermann U, Arend M. 2012. **Concomitant dendrometer and leaf patch pressure probe measurements reveal the effect of microclimate and soil moisture on diurnal stem water and leaf turgor variations in young oak trees.** Functional Plant Biology. 39: 297-305. (PDF 870kB)

Leuzinger S, Bader MKF. 2012. **Experimental vs. modeled water use in mature Norway spruce (Picea abies) exposed to elevated CO2.** Frontiers in Plant Science 3, Article 229, 1-11. (PDF 1.9MB)

Etzold S., Ruehr N.K., Zweifel R., Dobbertin M., Zingg A., Pluess P., Häsler R., Eugster W., Buchmann N. 2011. **The carbon balance of two contrasting mountain forest ecosystems in Switzerland: Similar annual trends, but seasonal differences.** Ecosystems, 14 (8): 1289-1309. (PDF 740KB)

Zweifel R., Eugster W., Etzold S., Dobbertin M., Buchmann N. and Häsler R. 2010. **Link between continuous stem radius changes and net ecosystem productivity of a subalpine Norway spruce forest in the Swiss Alps.** New Phytologist, 187: 819-830. (PDF 510KB)

De Schepper V, Steppe K. 2010. **Development and verification of a water and sugar transport model using measured stem diameter variations.** Journal of Experimental Botany. 61(8): 2083-2099. (PDF 1MB)

Zweifel R., Rigling, A. & Dobbertin, M. 2009. **Species-specific stomatal response of trees to drought – a link to vegetation dynamics?** Journal of Vegetation Science, 20, 442-454. (PDF 776KB)

Zweifel R., Steppe K. and Sterck FJ. 2007. **Stomatal regulation by microclimate and tree water relations: interpreting ecophysiological field data with a hydraulic plant model.** Journal of Experimental Botany, 58, 2113-2131. (PDF 1437KB)

Zweifel, R., L. Zimmermann, F. Zeugin and D.M. Newbery. 2006. **Intra-annual radial growth and water relations of trees – implications towards a growth mechanism.** Journal of Experimental Botany 57(6):1445-1459. (PDF 810KB)

Zweifel, R., L. Zimmermann and D.M. Newbery. 2005. **Modeling tree water deficit from microclimate: an approach to quantifying drought stress.** Tree Physiology 25:147-156. (PDF 810KB)

Zweifel, R., H. Item, R. Häsler. 2001. **Link between diurnal stem radius changes and tree water relations.** Tree Physiology 21:869-877. (PDF 950KB)

Zweifel, R., R. Häsler. 2001. **Dynamics of water storage in mature subalpine Picea abies: temporal and spatial patterns of change in stem radius.** Tree Physiology 21:561-569. (PDF 1MB)

Zweifel, R., H. Item, R. Häsler. 2000. **Stem radius changes and their relation to stored water in stems of young Norway spruce trees.** Trees 15: 50-57. (PDF 2.6MB)

Zweifel, R., R. Häsler. 2000. **Frost-induced reversible shrinkage of bark of mature, subalpine conifers.** Agric. For. Meteorol. 102: 213-222. (PDF 1.6MB)