X-ray imaging and computed tomography of conifers tree rings for climatology

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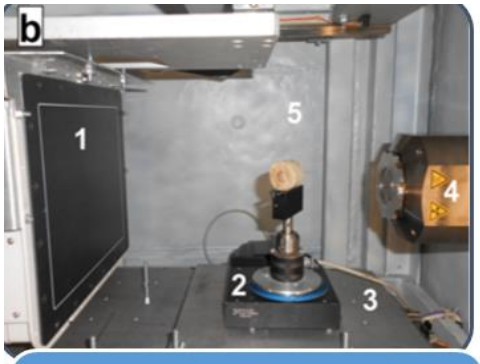
Background

- There is a correlation between solar activity and wood growth (Douglass,1929)
- Tree rings are an effective indicator of climatic changes (Fritts, 1971)
- Electro-optical and radiometric techniques are now used to measure the wood density (Polge, 1970; Schweingruber et al., 1978; Vaganov et al., 2006)

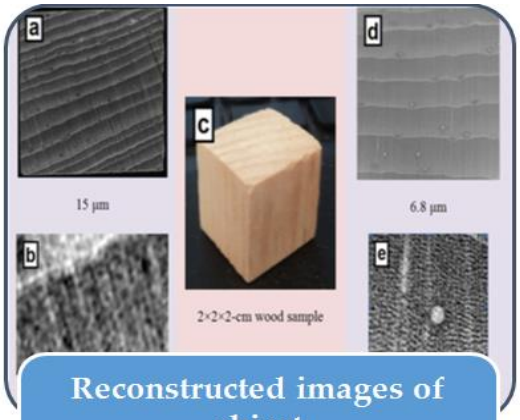
Objective and Approach

To study an applicability of the X-ray computed tomography (XCT) technique for assessment of the structure and density of tree rings in dendroclimatology and biometeorology problems



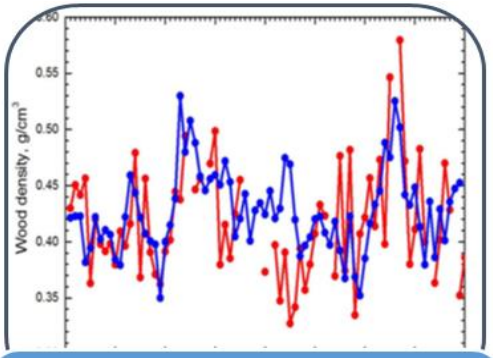
X-ray microtomography device

- 100 μm
- 5 μm



Reconstructed images of object

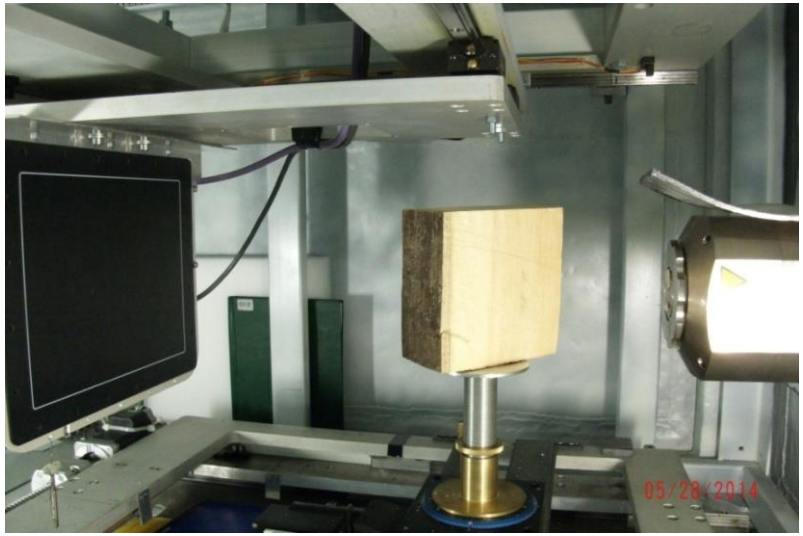
- 1024×1000 pix
- 1900×1516 pix



Images processing

- tree ring width
- tree ring density
- water in tree ring
- defects of structure

Advantages and Limitations



vs

X-ray microtomograph voxel

X-ray projection radiograph pixel

- **Better informativeness**
- **Better contrast sensitivity (<10 %)**
- **Better spatial resolution (5 to 100 μm)**
- **Complex mathematical programm**
- **High-priced components**

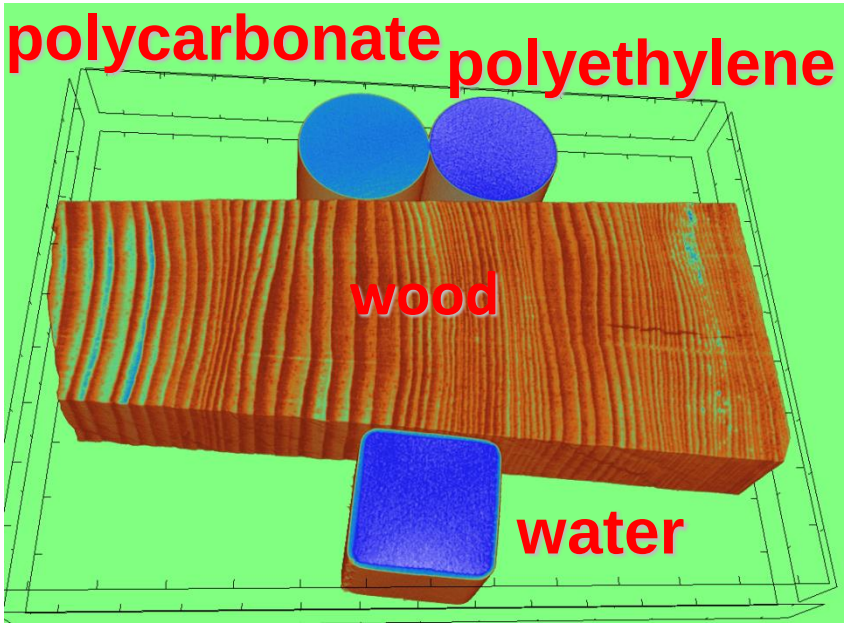
Method: Basis

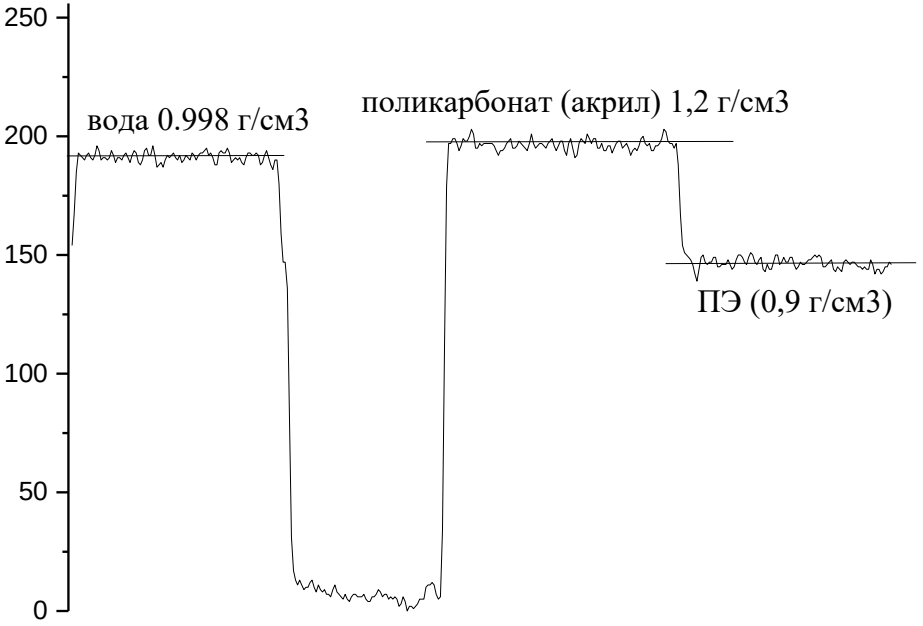
The XCT technique implies mathematical reconstruction of the inner three-dimensional structure of an object based on measurements of X-ray absorption under multiple irradiation of an object in different intersecting areas (Cormack, 1992; Hounsfield, 1992).

$$R = \frac{\mu - \mu_{water}}{\mu_{water} - \mu_{air}} \times 1000$$

The X-ray density *R* is a ratio of radiation attenuation in the air to that in distilled water equaled to 0–1000 HU at standard pressure and temperature.

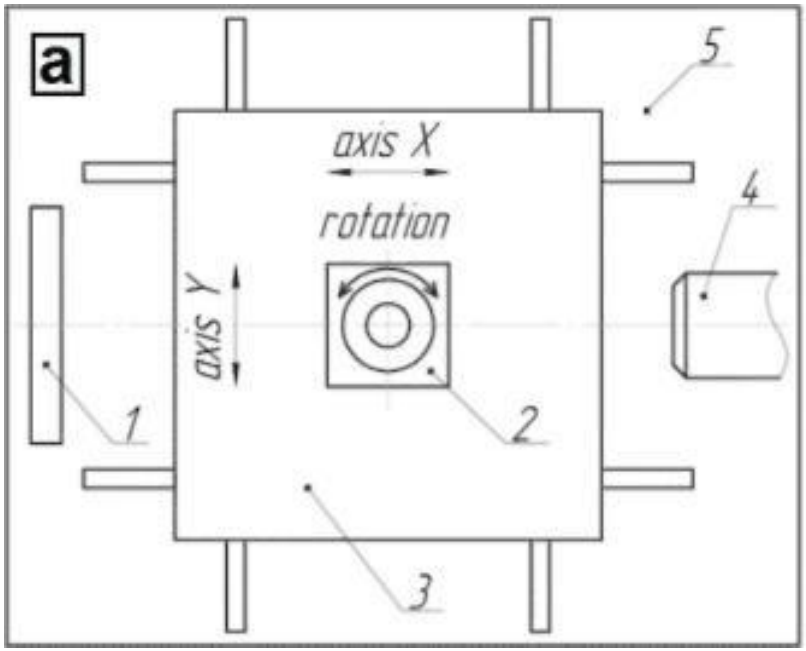
Method: Calibration

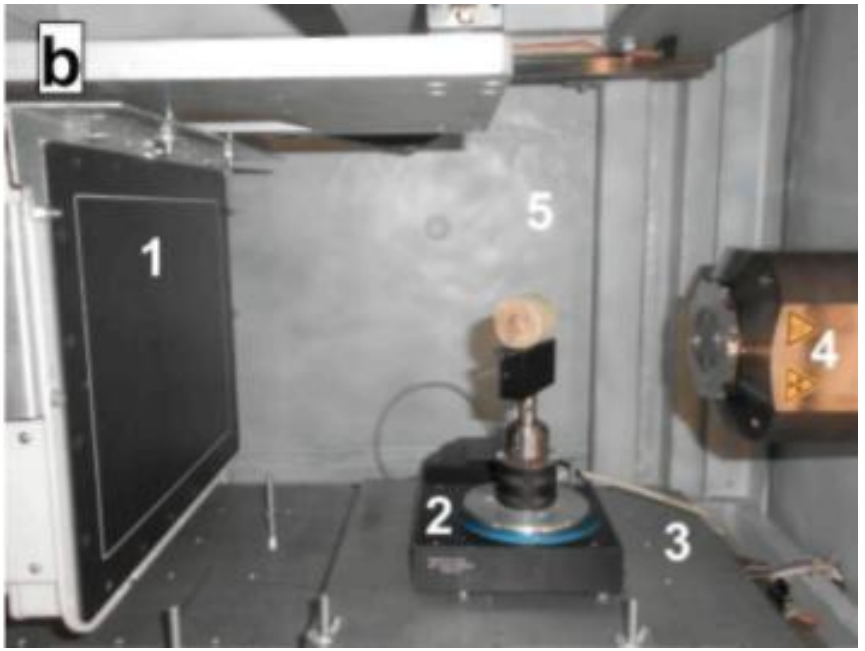




Average density of Siberian pine is 0.4 g/cm^3

Equipment

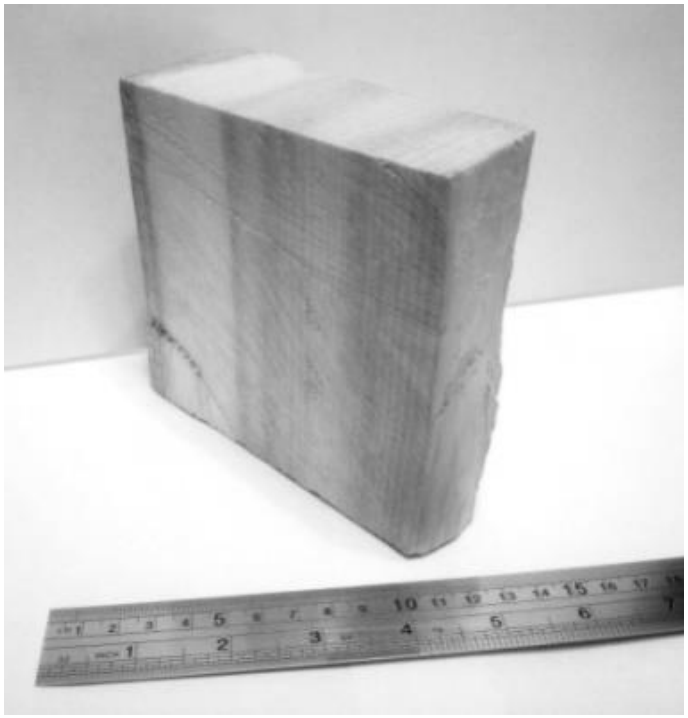




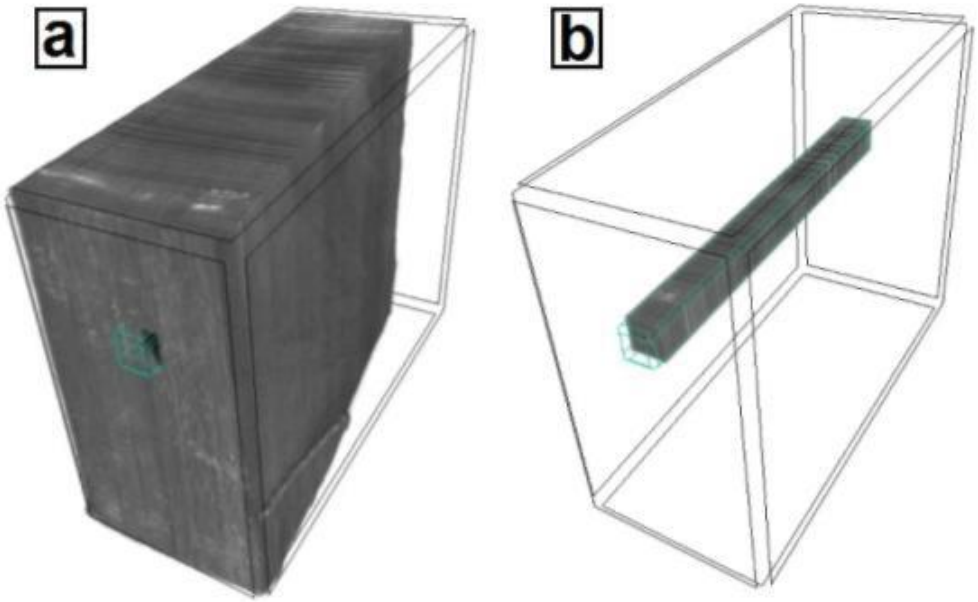
Scheme (a) and interior view (b) of the microtomograph Orel-MT: X-ray matrix detector (1); slewing table for examples (2); rail support (3); X-ray (tube) transmitter (4); protective housing (5)

(http://portal.tpu.ru/departments/laboratory/tti/eng/products/orel_tomo)

Material

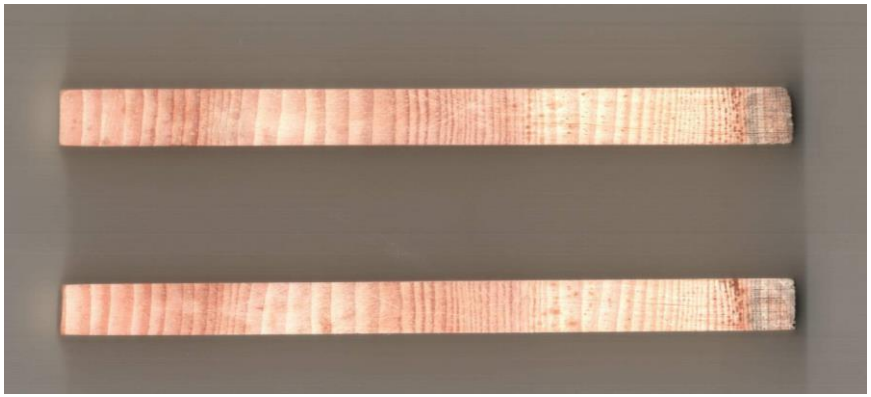


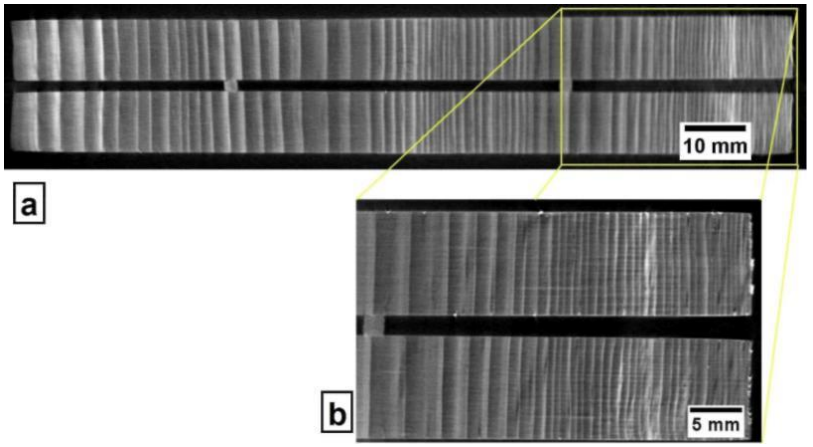
Wood sample of 130-year Siberian pine



X-ray tomogram of the whole wood sample (a) and virtual 3D core (b)

Comparison with Gravity (Weight) Technique





Two 12×1×1-cm wood samples of Siberian pine

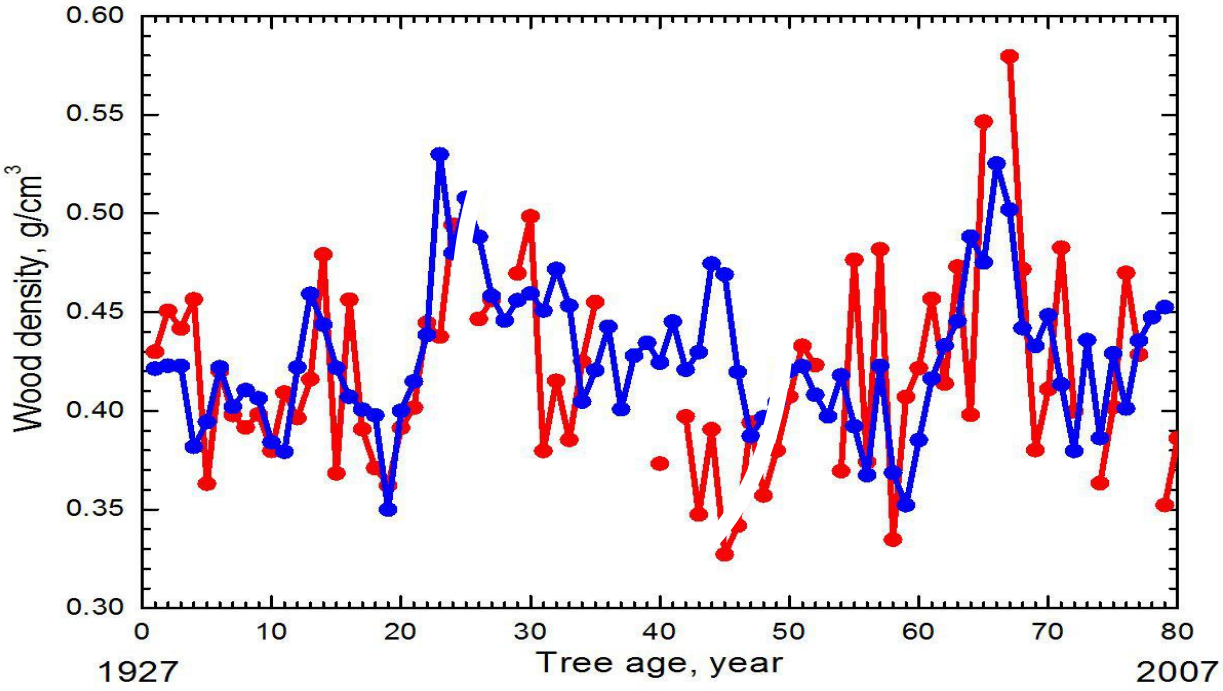
X-ray images of the whole samples scanned with 80-μm resolution (a) and their fragments scanned with 30-μm resolution (b)

Gravity (Weight) Technique: Instruments

Tree-ring measuring station Lintab-5
(http://www.rinntech.de)

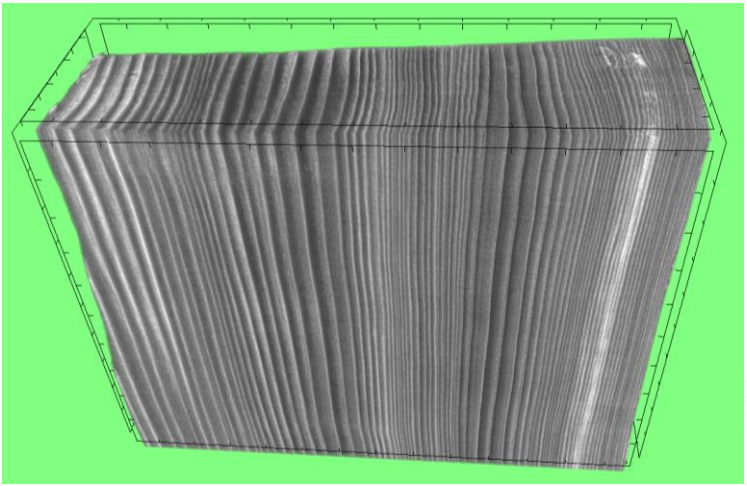
Electronic balance Kern ABS-220-4
(http://www.kern-sohn.com)

Results of Intercomparison

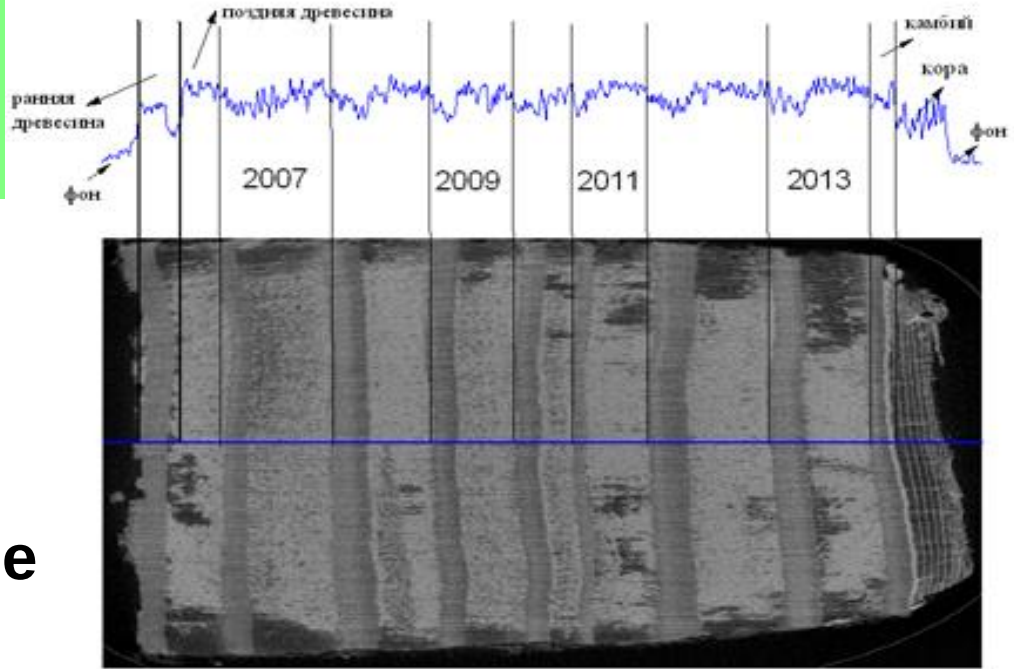


Tree ring density measured by weight and XCT techniques: R = 0.24 (p = 0.05), D_{avr} = 2 %, D_{max} = 28 %

Application of XCT: Width and Density of Tree Rings

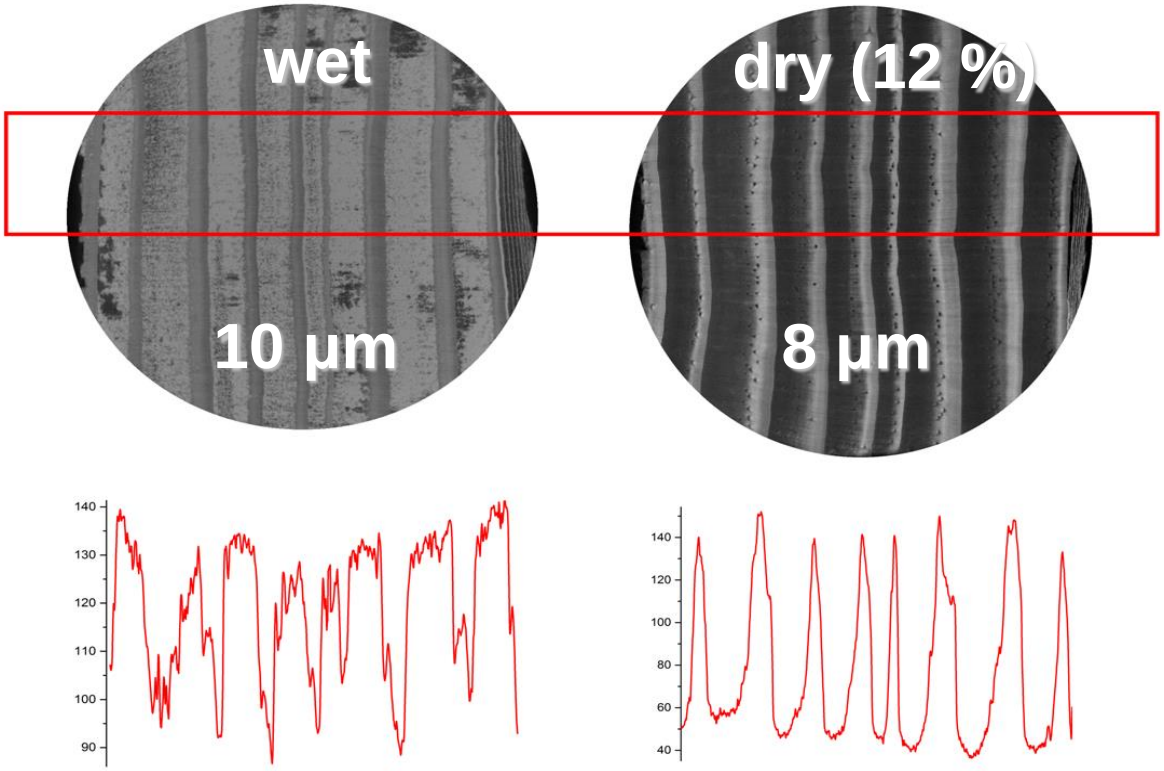


3D image of wood sample



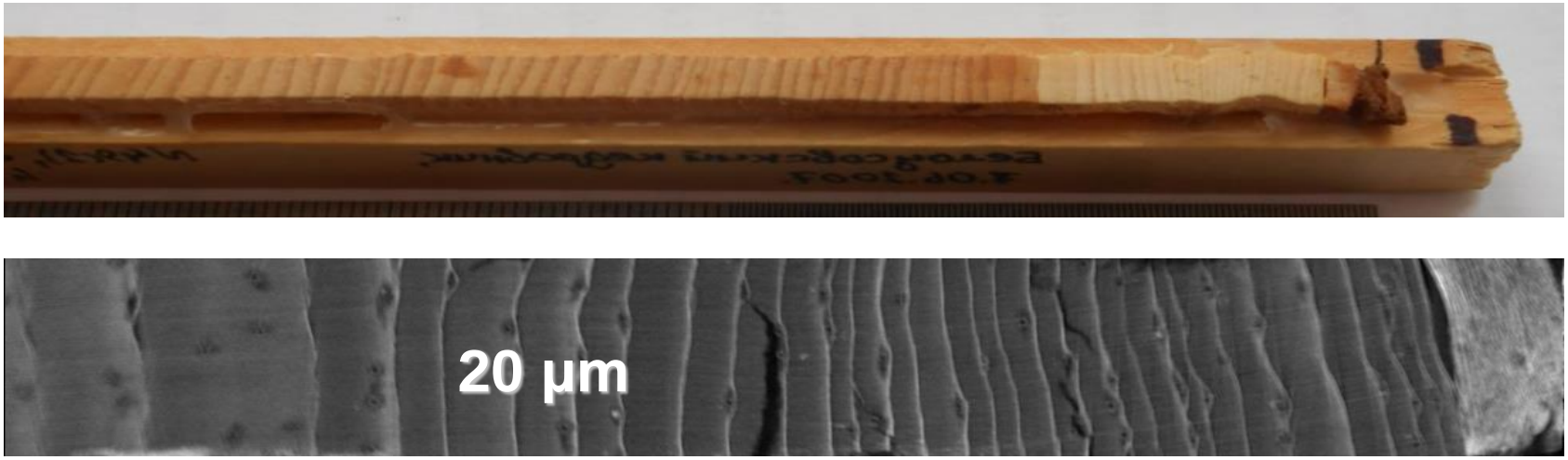
2D image of wood sample

Application of XCT: Fine Structure and Condition of Wood



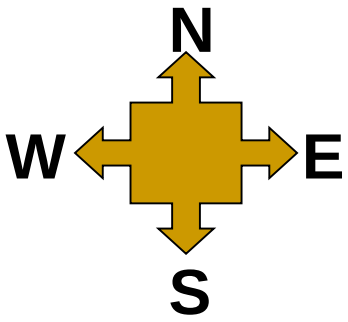
X-ray image and density of wet and dry wood

Application of XCT: Wood Structure and Tree Vitality

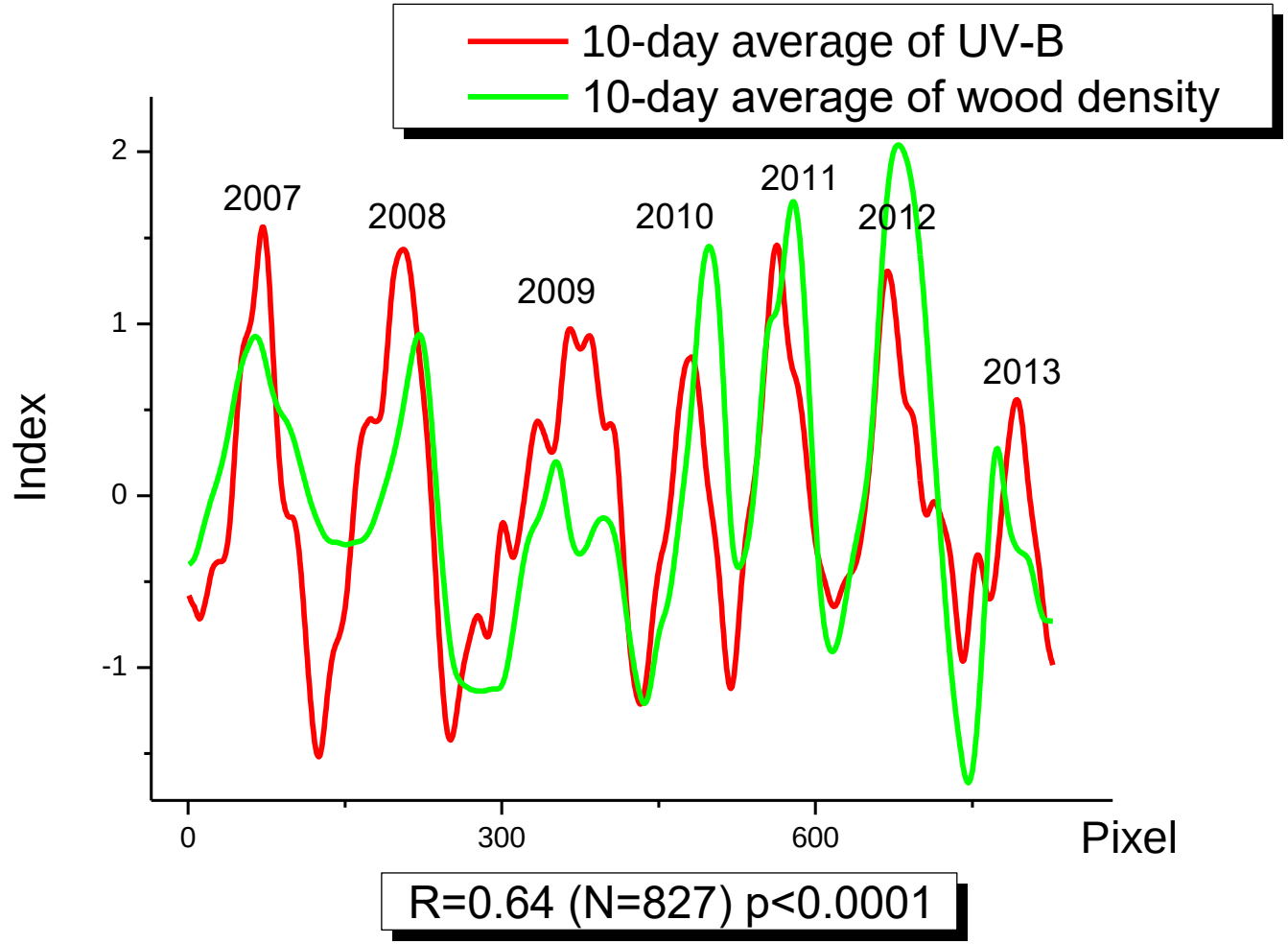


Siberian pine's core and its X-ray image showed the wood structure and tree vitality

Application of XCT: Tree Ring Density and UV Radiation (Object)



Application of XCT: Tree Ring Density and UV Radiation (Results)



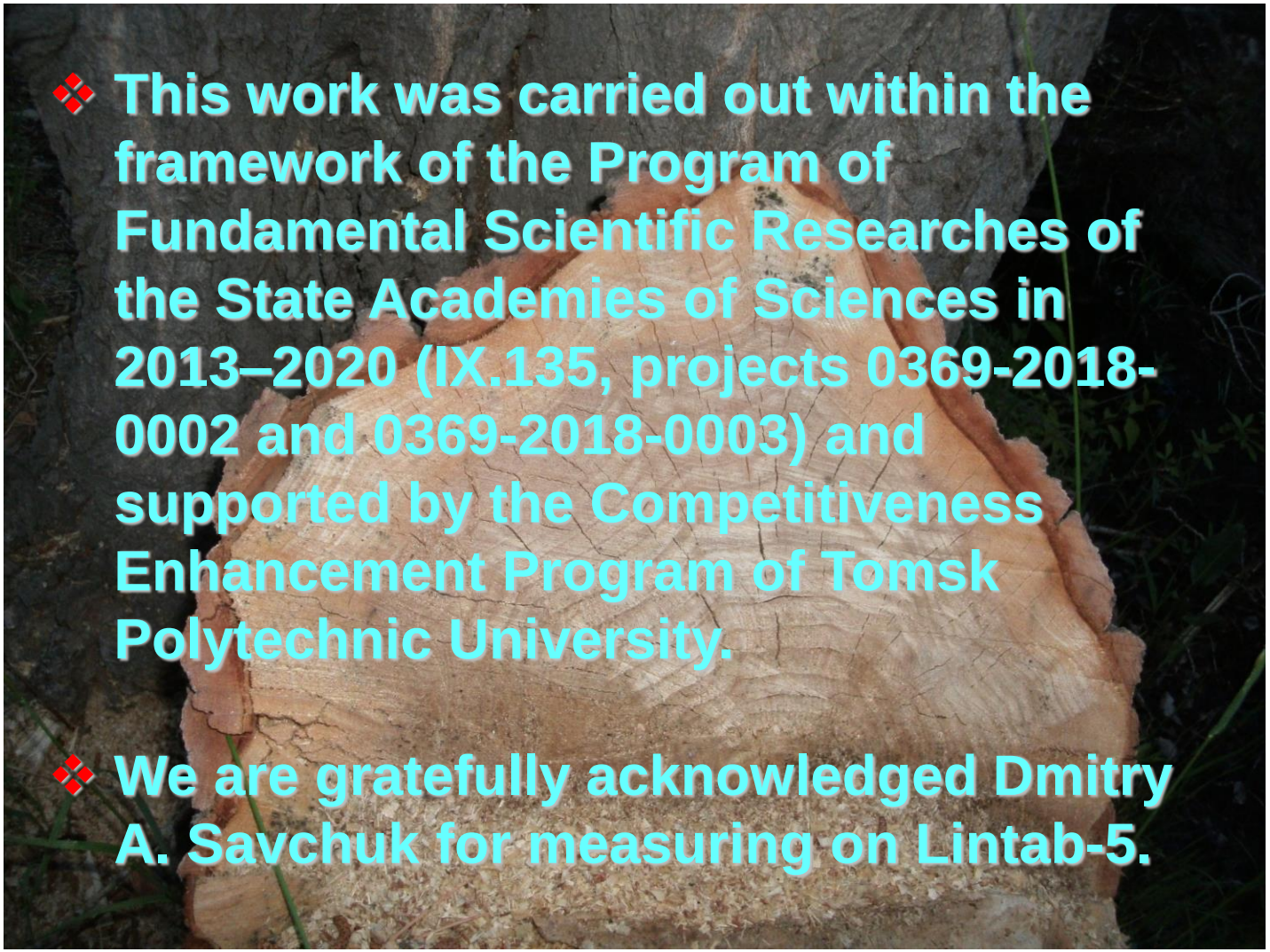
Summary

- **The high-resolution scanning X-ray tomograph can be applied in the dendroclimatology and biometeorology as a precision instrument for measurements of the width and density of tree rings without destruction of wood samples.**

- **The XCT technique allows to get data about a volume inner structure and texture of wood, incl. very small inclusions, defects and damages, very thin rings, and wood's components.**

- **The XCT technique allows to avoid subjective dendrology errors.**

Thanks for attention!



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