Wood NDT 2011

14th Sept Sopron Hungary

Ultrasonic imaging of defects in standing trees

Loïc Brancheriau[1], Philippe Gallet[1], Philippe Lasaygues[2]

CIRAD

Production of tropical woods (Montpellier, France)

CNRS

Laboratory of mechanics and acoustics (Marseille, France)

Introduction and objective

- To design an automatic tomograph
- With ultrasonic sensors and controlled emission (frequency 50kHz-100kHz)
- To be used in transmission or diffraction (quantitative or qualitative imaging)
- With the possibility to modify the mesh of the scaned area

  - Presentation = preliminary test in transmission with maps of slowness and attenuation

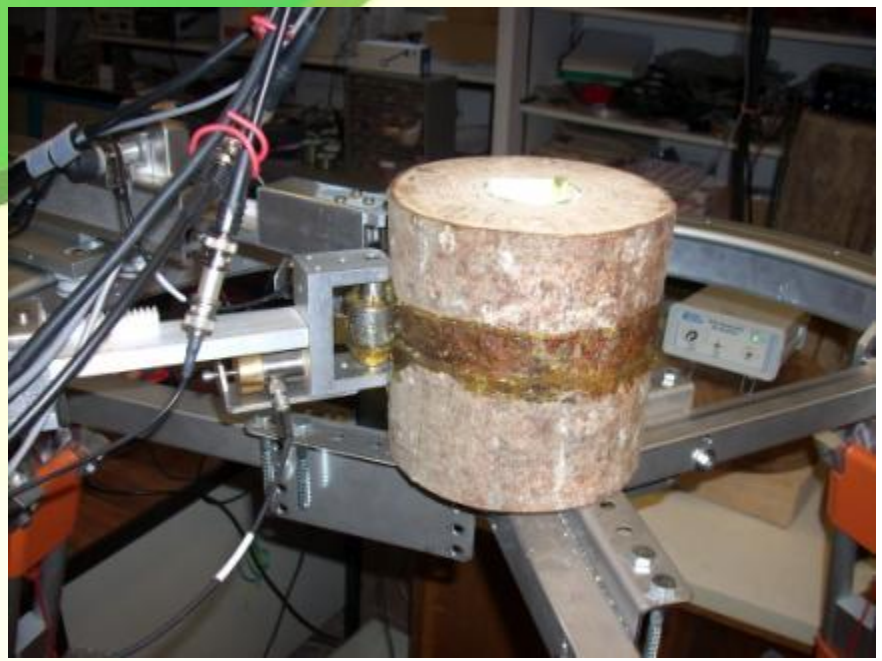
Wood sample

1 disk of poplar (without bark)

- Diameter: 33 cm
- Height: 10 cm
- Moisture content: 164 %
- Visible crack in the center (heart shake)

Tomographic apparatus

- 2 ultrasonic sensors
- Grease used as coupling medium
- For this experiment, angular step of 20°
  => 18 measurement points
  306 measurements ≈ 20 mn

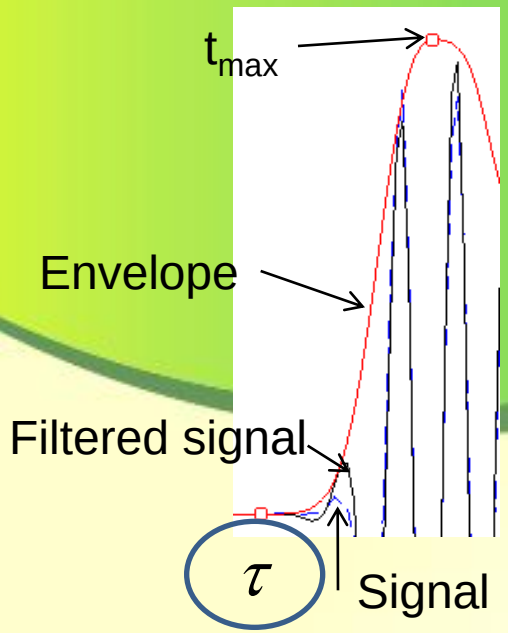


Ultrasonic settings

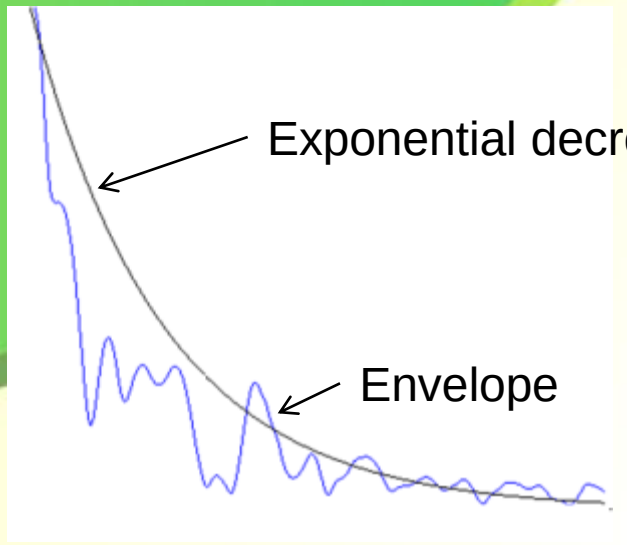
- **Transducer frequency** 80kHz
- **Emission**
  - pulse train of 10 square waves
  - 420 V
- **Signal acquisition**
  - ADC resolution: 16 bits
  - Sampling frequency: 500kHz
  - Acquisition points: 1024
  - Amplification: 66dB

Signal processing

- **Filtered by a Morlet wavelet of 80kHz (bandwidth 10kHz)**



Time of flight



$$\left|s_X(t)\right| \approx \beta_{Max}\mathrm{Exp}\left(-\frac{t-t_{Max}}{\tau_{AT}}\right)$$

Characteristic time

Ultrasonic parameters

- **Slowness (s/m)**

$$L = \frac{\tau}{d_{AB}}$$

- **Attenuation (dB/m)**

$$A_{dB} = 20\log_{10}\left(\frac{A_1}{A_0}\right) = \frac{-20}{\ln(10).\tau_{AT}.C} = \frac{-6{,}2.10^{-3}}{\tau_{AT}}$$

Speed set to a constant C = 1400 m/s

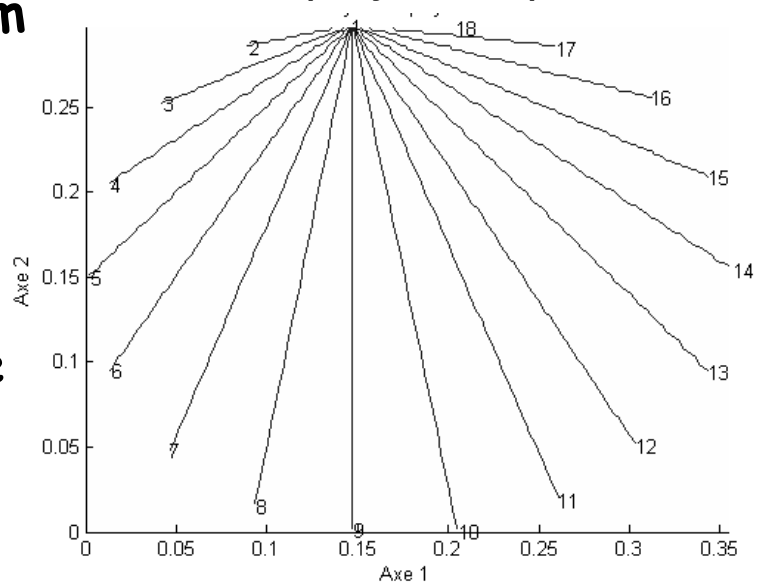
Imaging procedure

- **Main hypothesis: transverse isotropy**
  → Ultrasonic parameters summables along straight rays (Radon theory)

- **Filtered back projection algorithm (Shepp-Logan) with fan beam geometry**

- **Missing values of each back projection computed by cubic-spline interpolation**

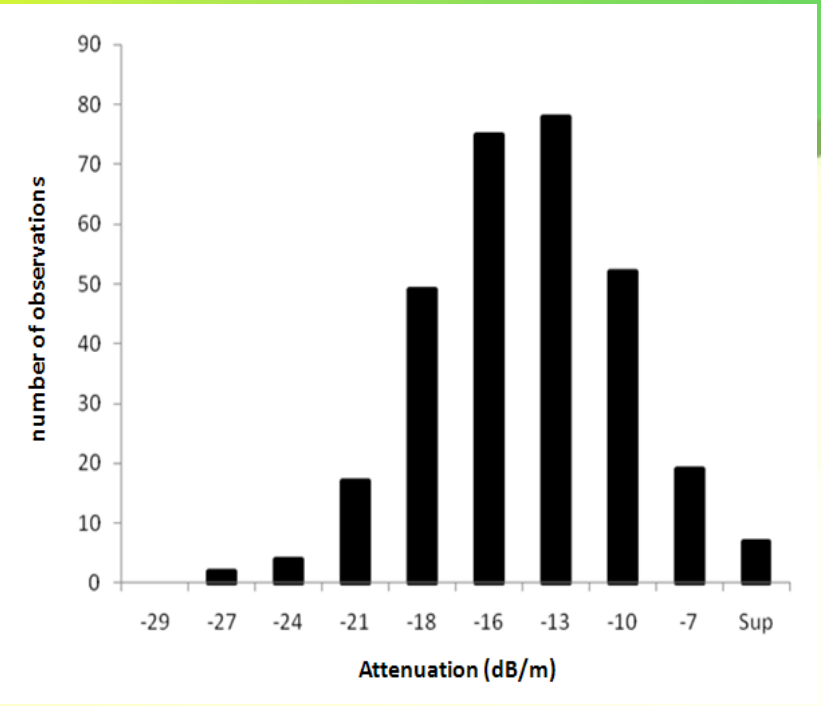
Back projection path



Results

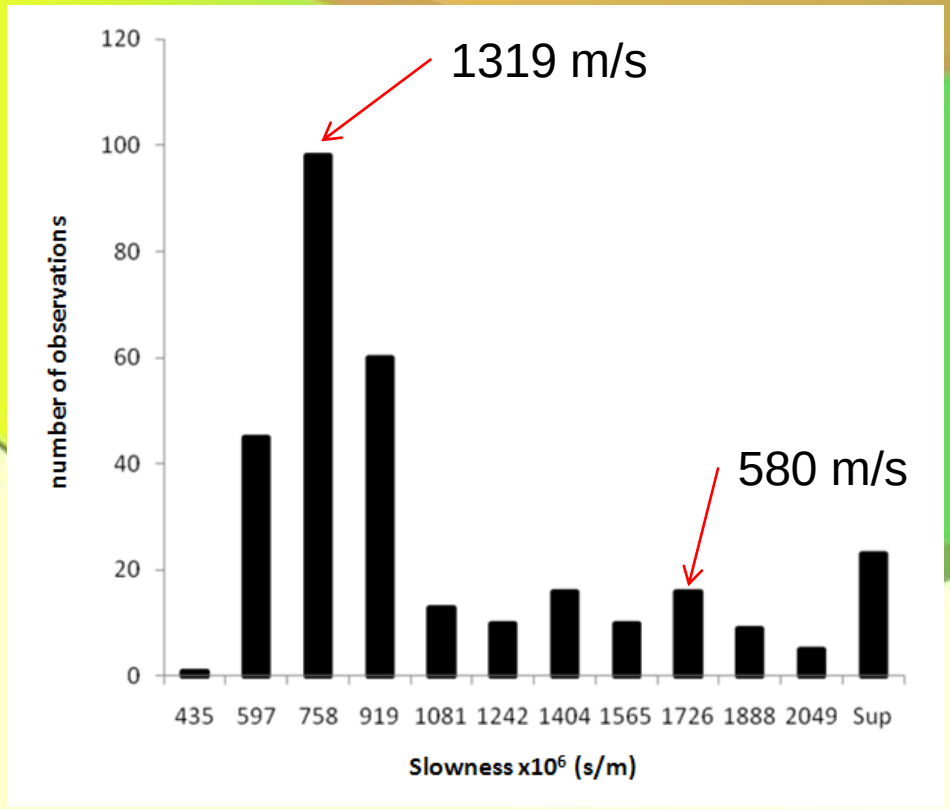
Descriptive statistics

- 306 ultrasonic measurements
- Mean transverse speed = 990 m/s
- Mean value of attenuation = -16 dB/m (without taking into account the amplification)



Quasi-normal distribution

Results

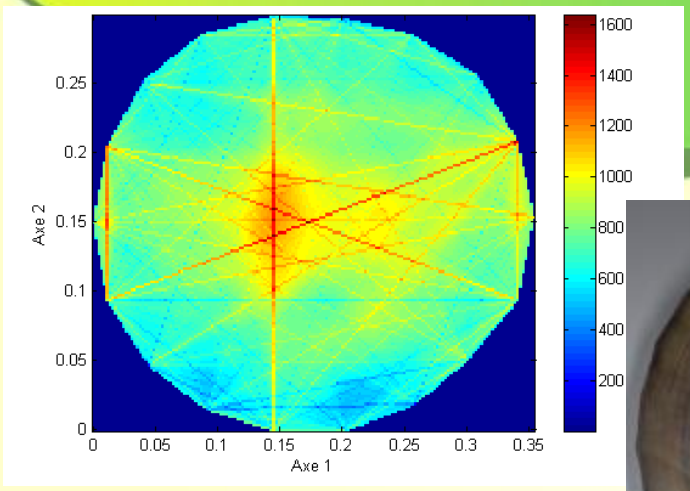


- Wide dissimetry towards the high values
- Uncertainty on the TOF determination + anisotropy
- Dominant received frequency 20kHz <> emission 80kHz

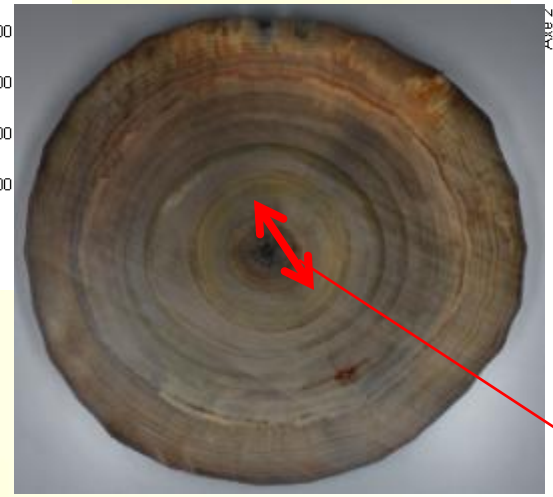
Results

Maps in the cross section

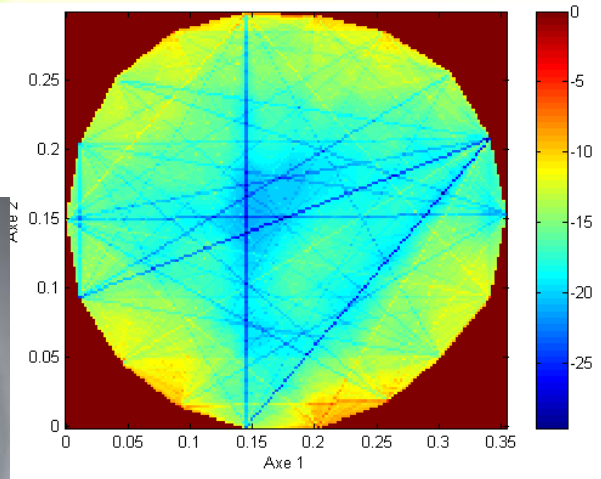
- Optimum number of pixels = 16x16
  Increased by interpolation = 160x160
- Slowness and attenuation $R^2 = 0.18$ (N = 306)
- But the same pattern was found ≈ heart shake
  Quantitative imaging <> Qualitative imaging



Slowness (x10^{-6})



Heart shake

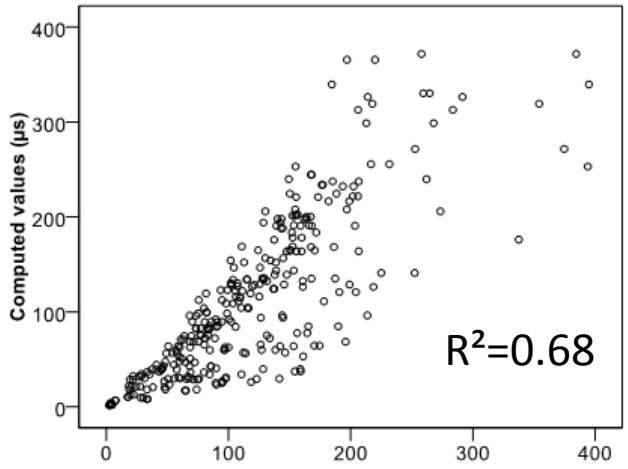


Attenuation (dB/m)

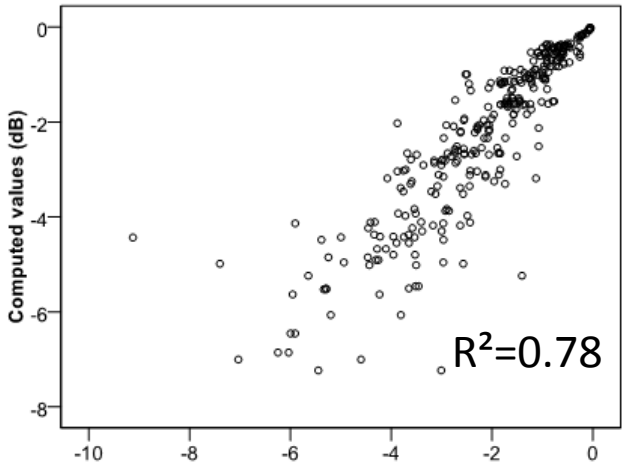
Results

« Quality » of the inversion procedure

- Relationship between ultrasonic measurements and computed values using the maps and the Radon hypothesis

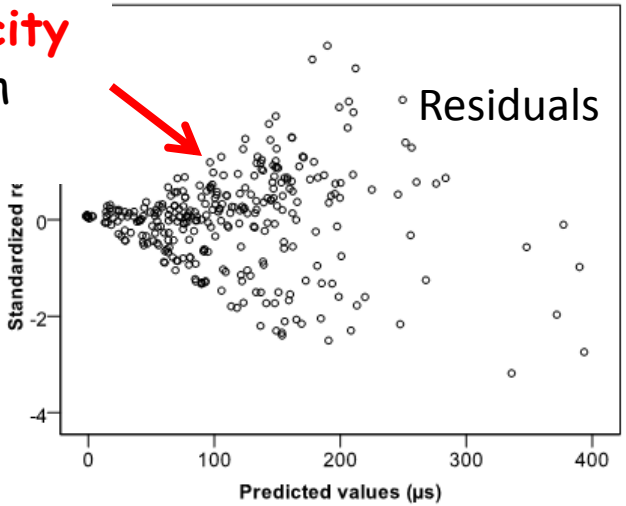


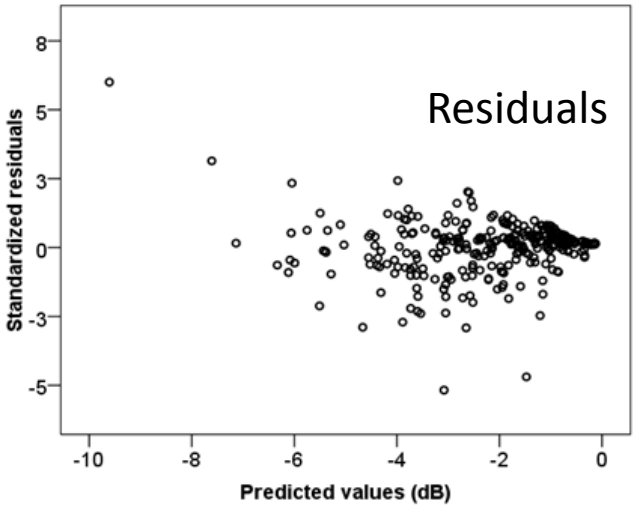
TOF (µs)



Attenuation (dB)

Heteroscedasticity
Error grows with the prop.time





Conclusions

- Maps ultrasonic slowness and attenuation in the cross section
- US parameters not correlated (different computation)
- But the same pattern was found ≈ heart shake
- Low spatial resolution => quantitative imaging + very low number of measurement (18 projections)
- Quality of the inversion procedure showed
  determination error grows with the TOF values
  (high values of slowness localised in the middle of the disk)
- This phenomenon was not observed for the attenuation values

Thank you