Analyse thermographique des sources de chaleur accompagnant la fatigue à grand nombre de cycles

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Thermographie infrarouge appliquée à l'Automobile

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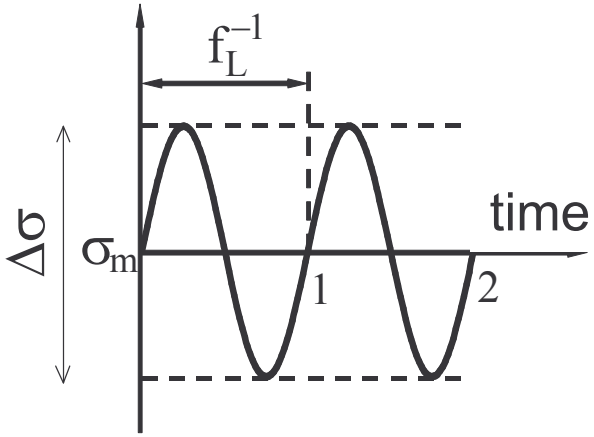
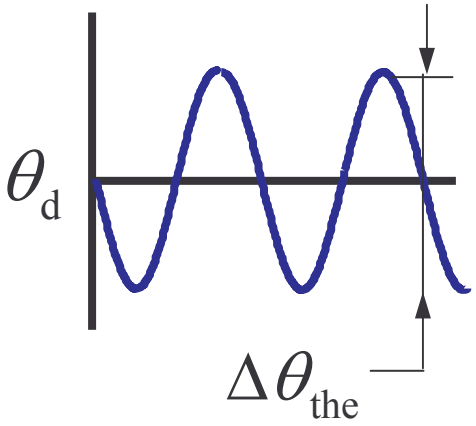
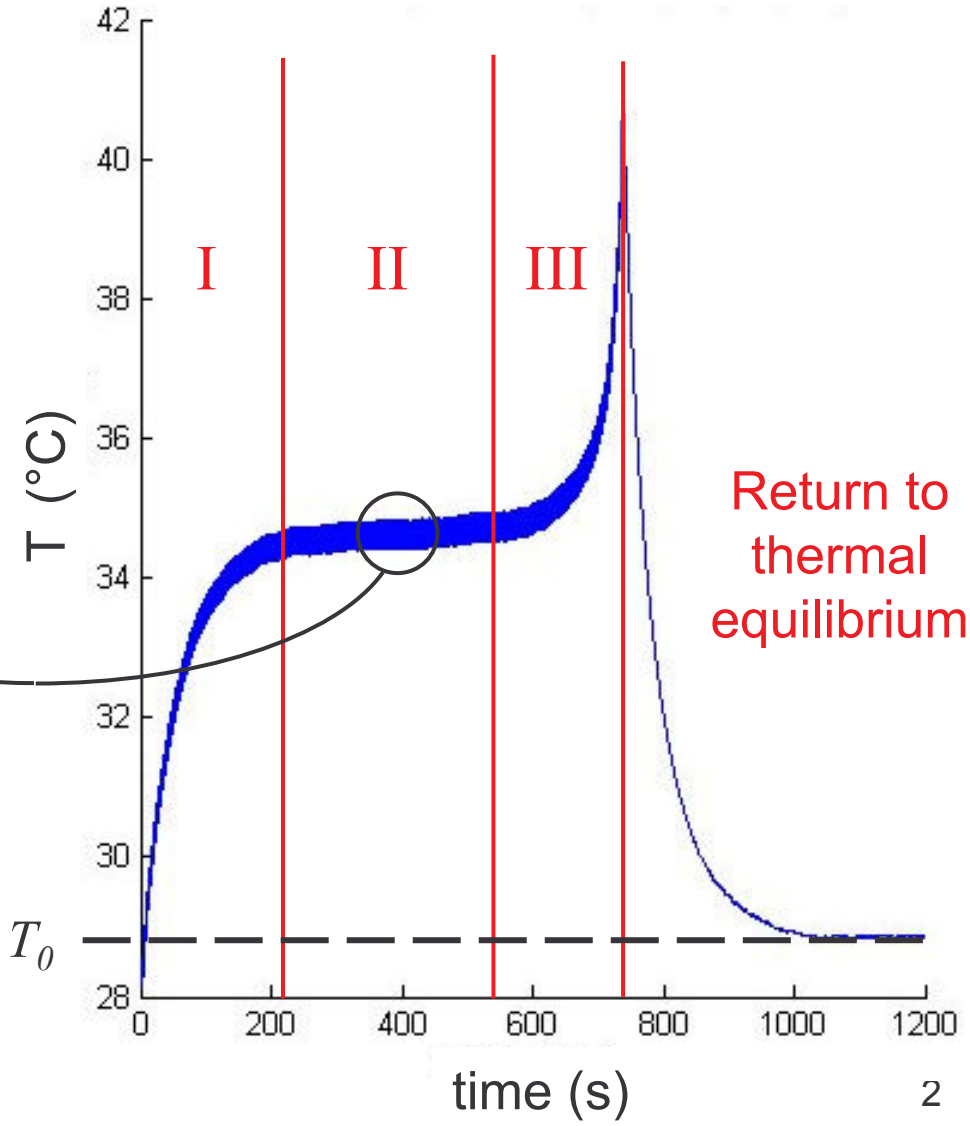
Introduction

Evolution of the temperature during a cyclic loading





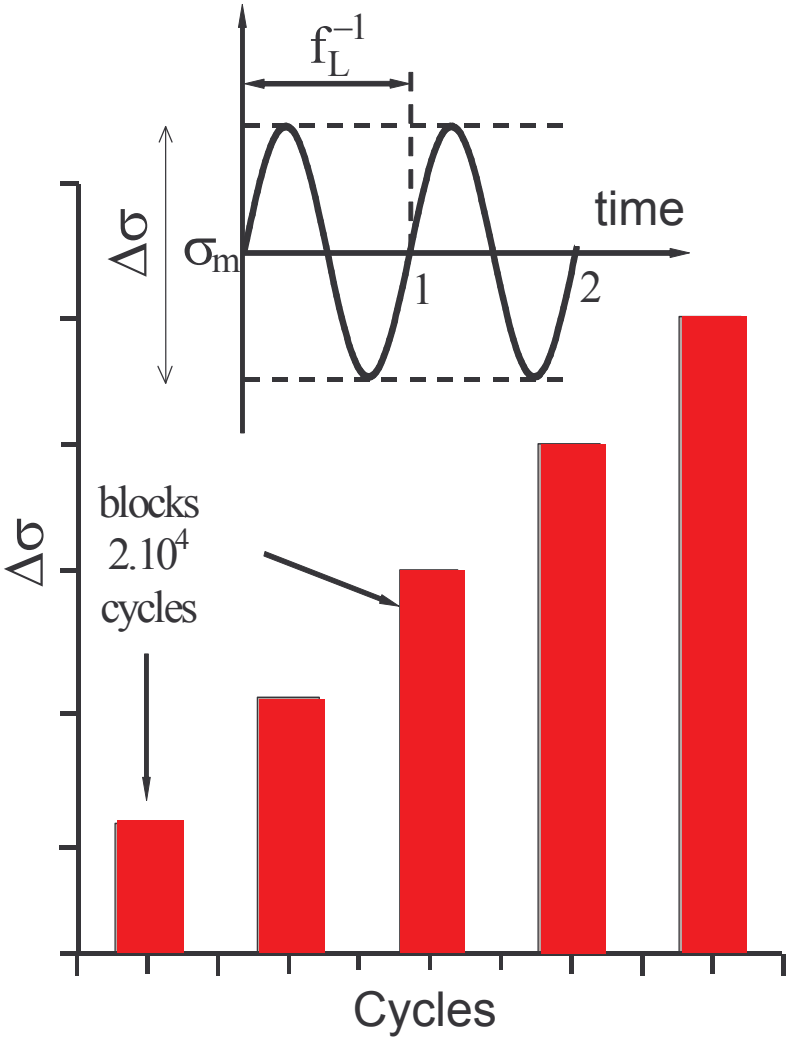
$$\theta = T - T_0 \quad (°C)$$



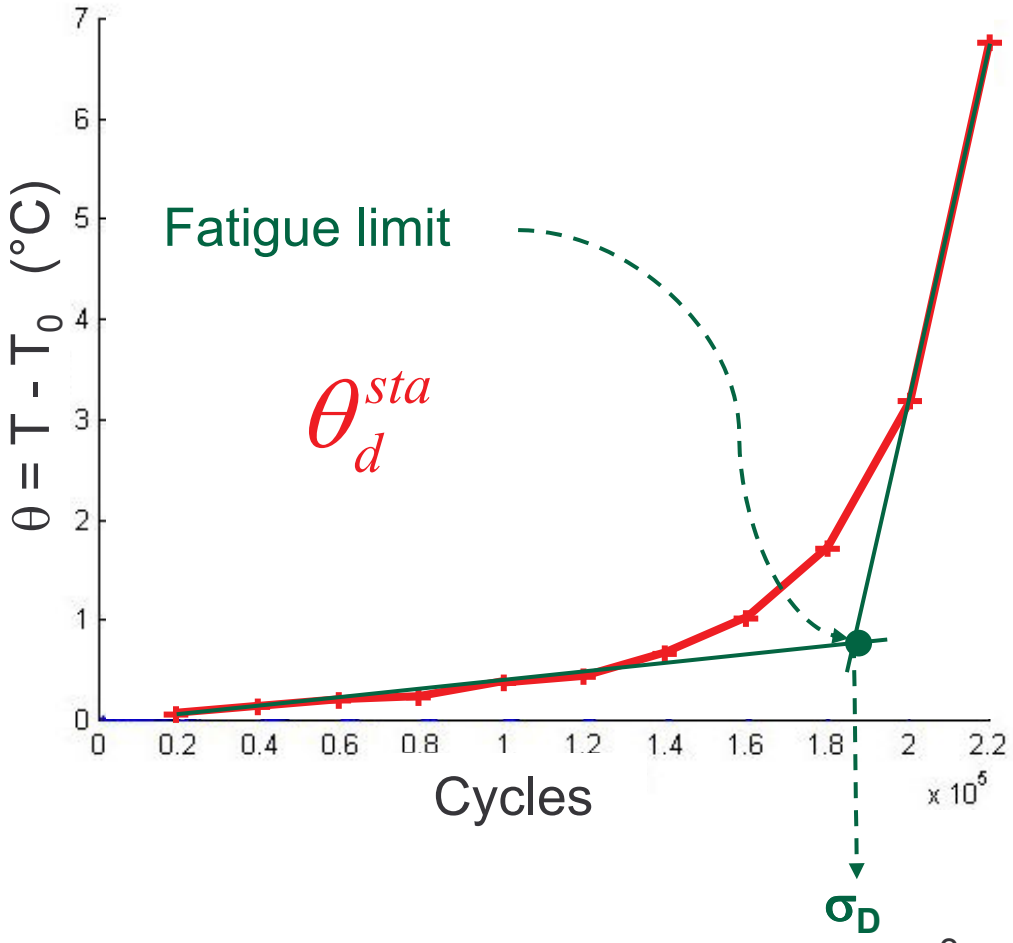
Return to thermal equilibrium

[Luong,1998], [Risitano, 2000], …

Trend of the mean temperature drift



[Luong,1998] [Risitano, 2000]



Objectives

- Analysis of fatigue mechanisms in terms of heat rather than in terms of temperature
- Separate estimate of dissipative and thermoelastic sources (dissipation $\ll$ thermoelasticity)
- Quantization of fatigue mechanisms (constitutive equations)
- New data and criteria for behaviour characterization and structure design

Thermodynamic aspects

1-Small Perturbation Hypothesis (SPH)
2-Fatigue : quasi-static process

GSM formalism

$$\rho C\dot{T} - div(k : \mathrm{grad}\, T) = d_1 + s_{the} + \cancel{s_{ic}} + r_e$$

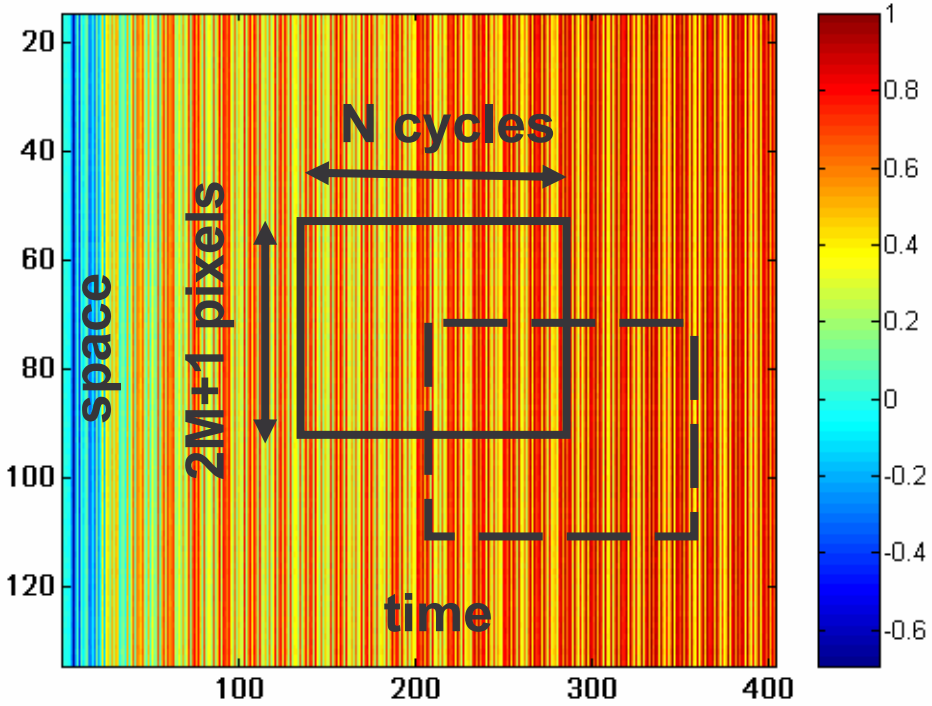
Thermal aspects

1D diffusion problem

$$s(x,t) \approx \rho C\left(\frac{\partial\theta}{\partial t} + \frac{\theta}{\tau_{th}^{1D}} - \delta_{th}\frac{\partial^2\theta}{\partial x^2}\right)$$

Image processing (1D)

$$\rho C\left(\frac{\partial\theta}{\partial t}+\frac{\theta}{\tau_{th}}-\delta_{th}\frac{\partial^2\theta}{\partial x^2}\right)=d_1+s_{the}$$



In phase with the loading

$$w_{the}=\oint_{Cycle}s_{the}\,d\tau=0$$

Slow evolution of mean dissipation

$$\oint_{Cycle}f_L.d_1\,d\tau=\bar{d}_1$$

Local least-squares fitting

N ≈ 5, 30 cycles

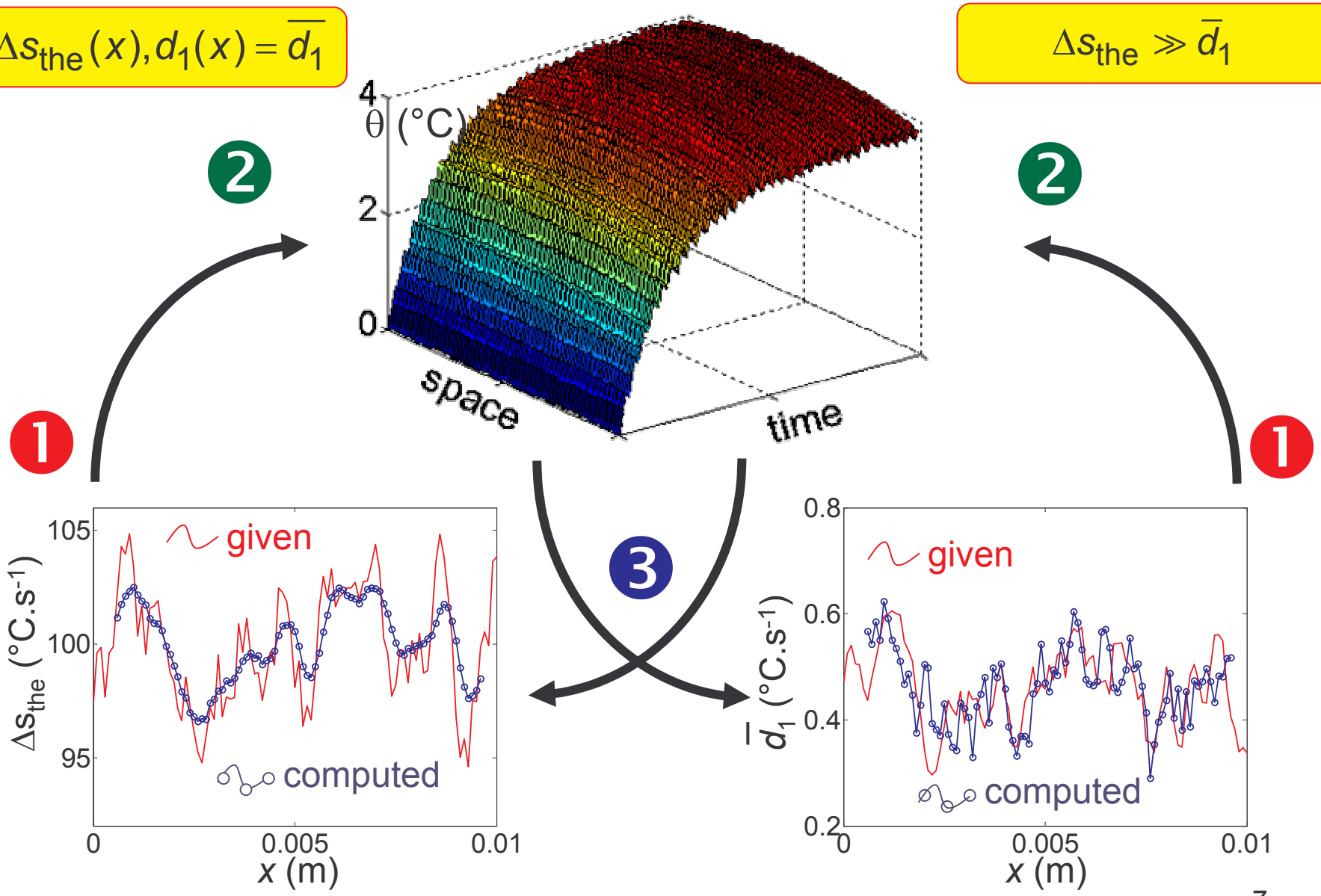
M ≈ 3, 15 pixels

$$\theta(x,t)=\underbrace{p_1(x)t+p_2(x)}_{\text{drift}}+\underbrace{p_3(x)\cos(2\pi f_L t)+p_4(x)\sin(2\pi f_L t)}_{\text{periodic response}}$$

Data processing validation (1D)

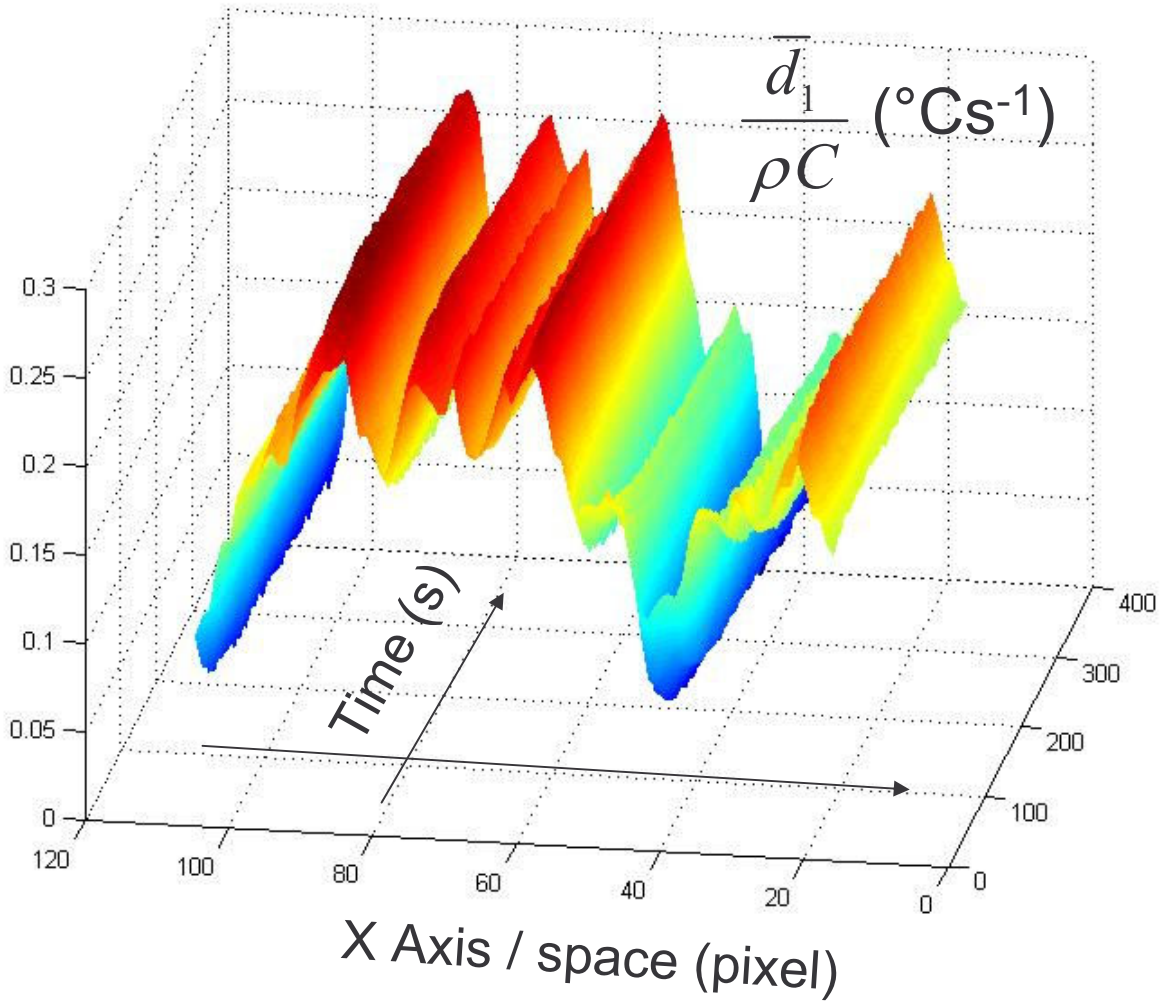
$\Delta s_{the}(x), d_1(x) = \overline{d_1}$

$\Delta s_{the} \gg \overline{d_1}$

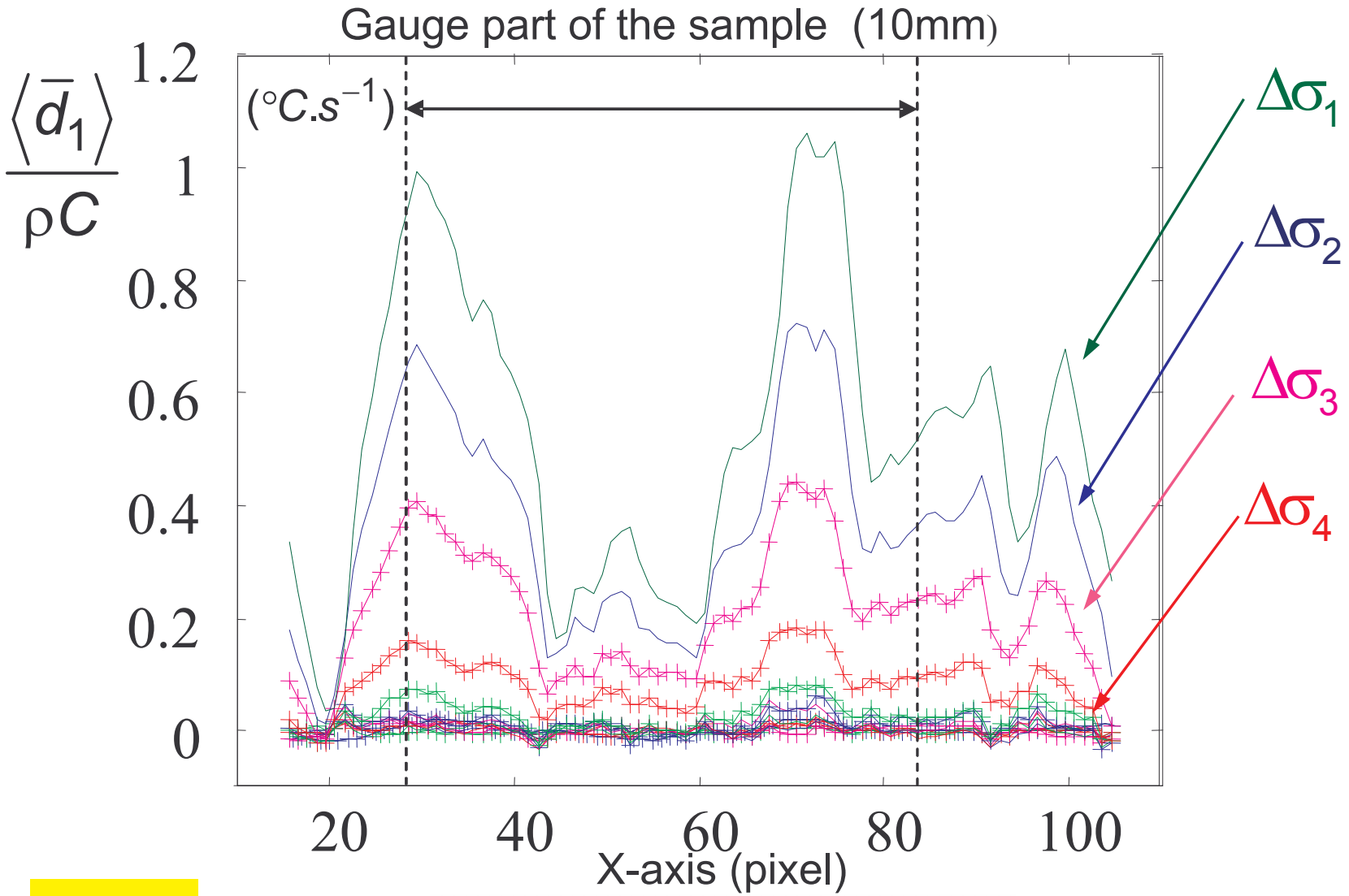


Distribution of $\overline{\ }$ during a loading block

Steel



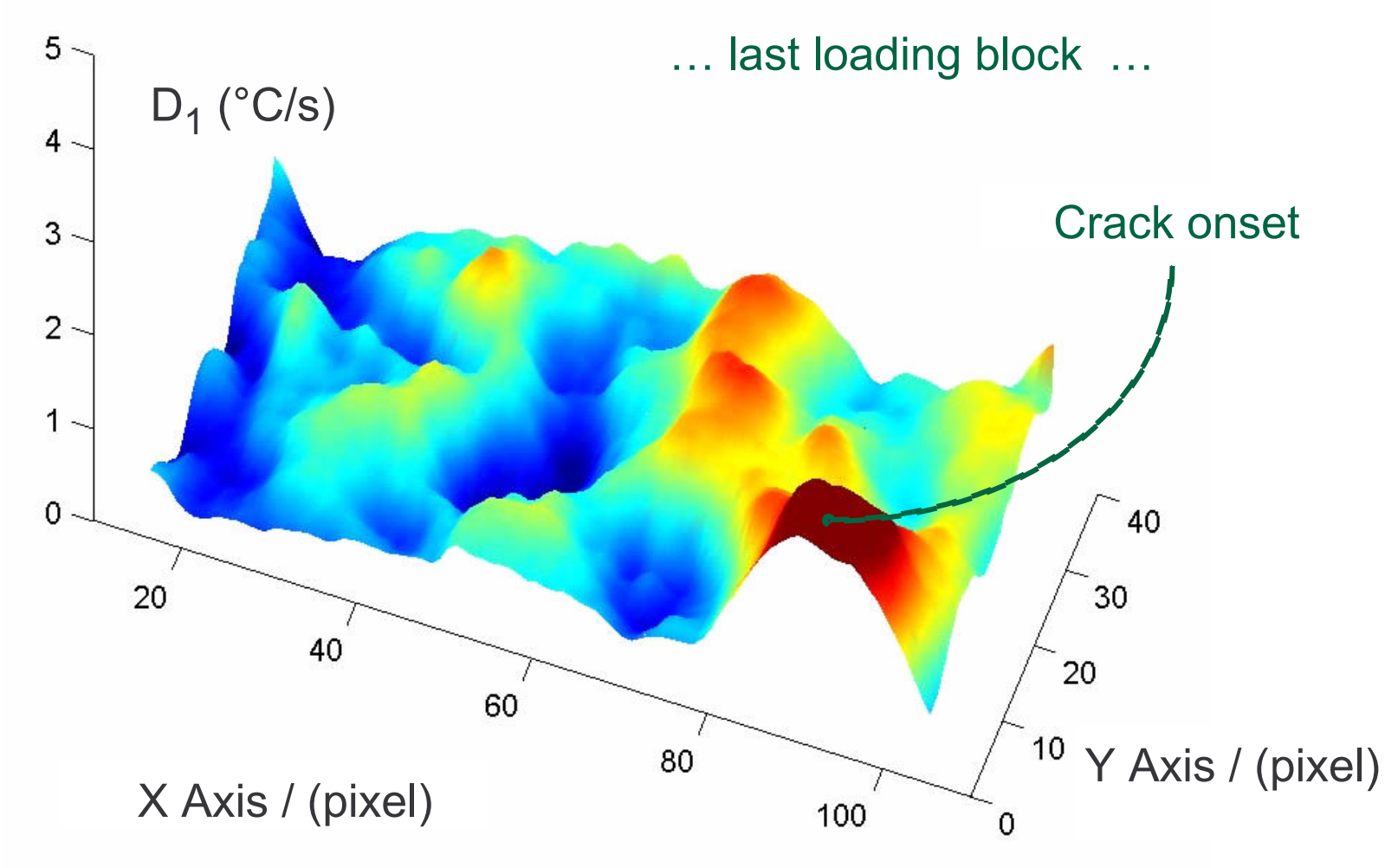
Mean profiles of $\langle \bar{\ } \rangle$ for different loading blocks



Steel

$$\Delta\sigma_1 > \Delta\sigma_2 > \Delta\sigma_3 > \Delta\sigma_4$$

First trial of 2D distribution of dissipation
1D½ !!

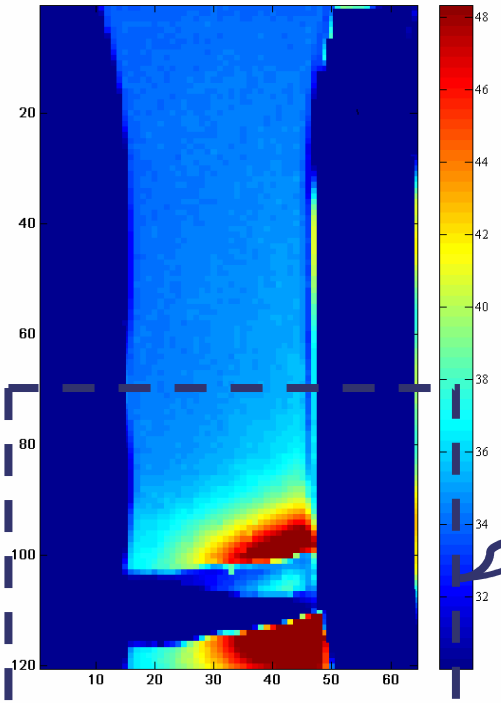


Steel

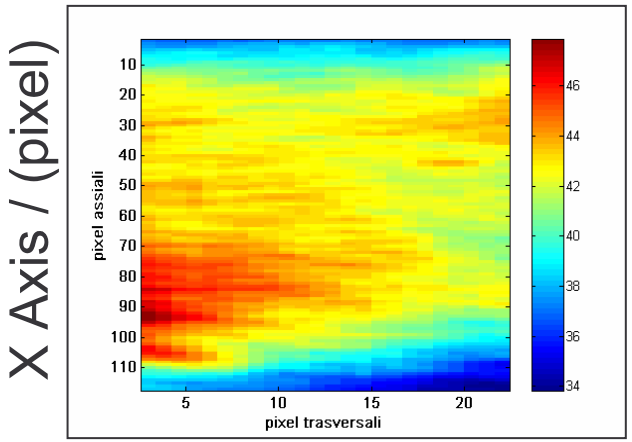
2D distribution of thermoelastic source
« True » 2D !

A. E. Morabito, UMII + Lecce, Italy

Failure ; block # 15



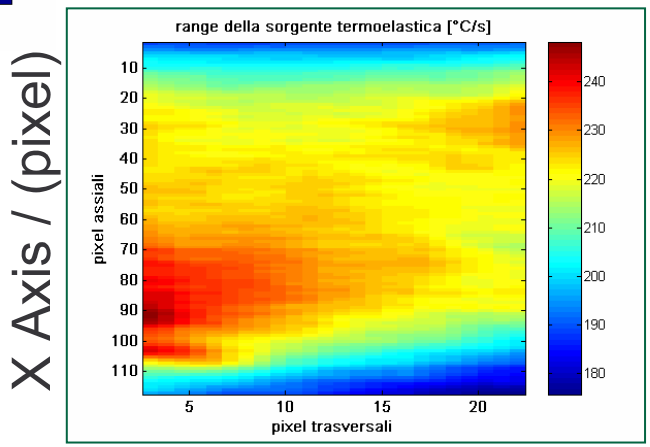
Block 3



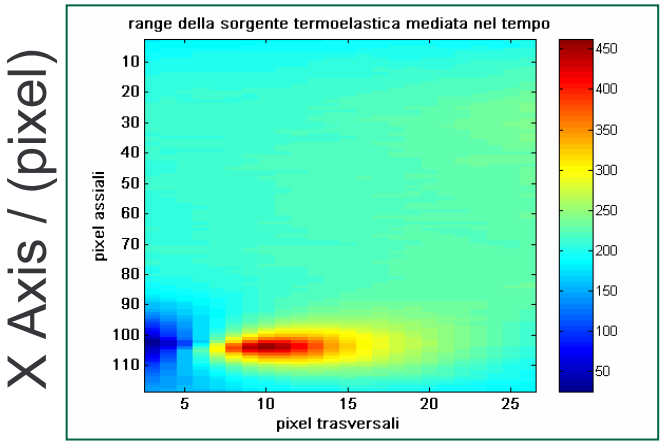
[°C/s]

$$\frac{\Delta s_{the}}{\rho C}$$

Block 15



Block 15: failure



Pre-localization of crack onset

Aluminium

Concluding comments

- **Image processing** : s_{the} , $đ_1$ separately identified ($|s_{the}| >> đ_1$)
- **Thermoelastic coupling** ⇔ state équation
- **Dissipation** ⇔ evolution equation
- **Fatigue limit** : **? ? ?**

heterogeneous fatigue tests
1D, 2D (near future)
(0D : *Int. J. of Fatigue 2004*)

Local analysis : material/structure

DIC + IRT : combined image processing