

# Passive monitoring using traffic noise recordings - case study on the Steinachtal Bridge

Johannes Salvermoser, Céline Hadzioannou, Simon C. Stähler

Institute for Earth and Environmental Sciences  
Ludwig Maximilians University Munich

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# Overview

## Objective

Is it possible to use ambient and/or traffic noise to monitor small-scale structures?

## Measurement Setup I

**lateral view** (Geophone positions)

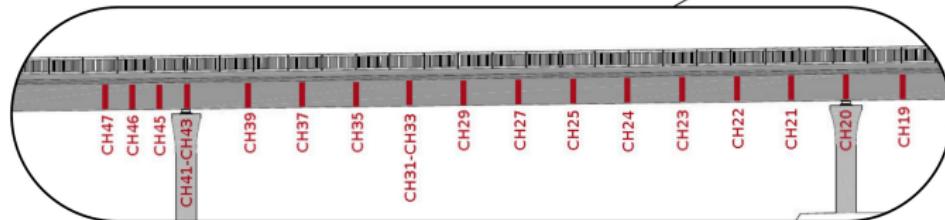
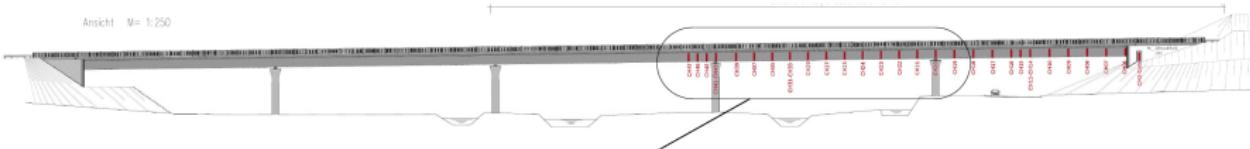
Ansicht M= 1:250



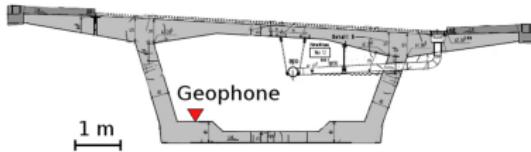
## Measurement Setup I

### **Lateral view** (Geophone positions)

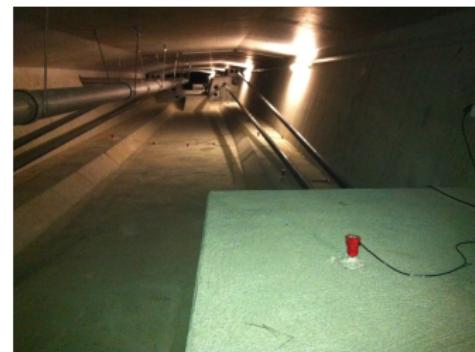
Ansicht M= 1:250



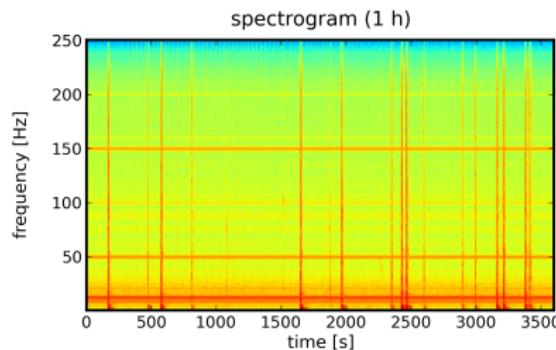
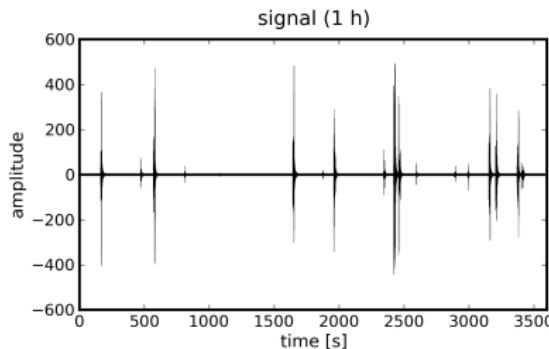
## **cross-section**



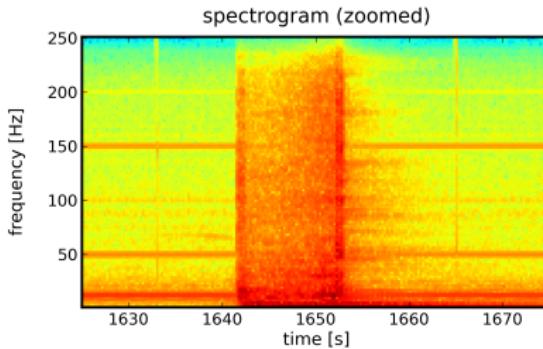
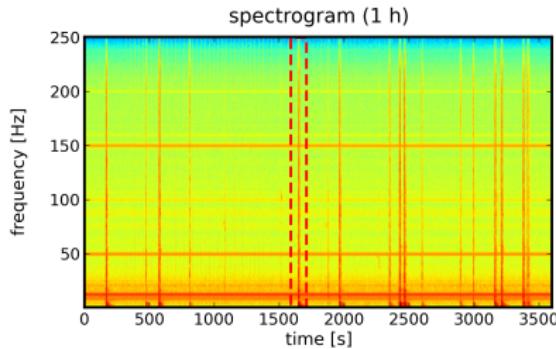
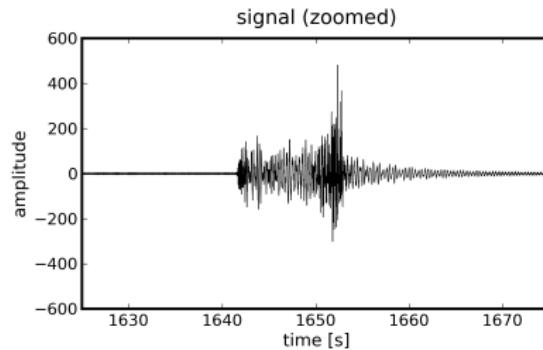
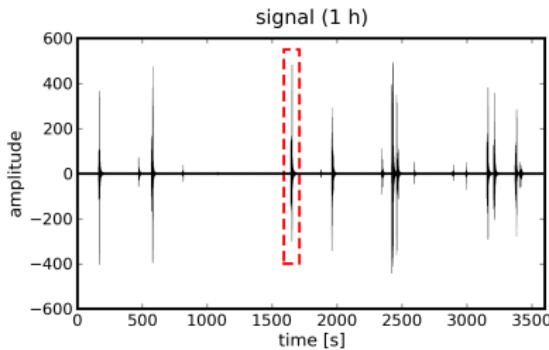
## Measurement Setup II: Steinachtal Bridge



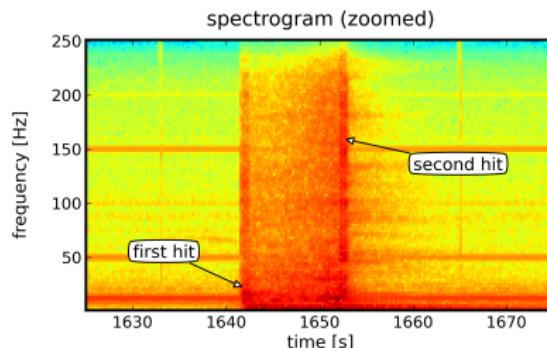
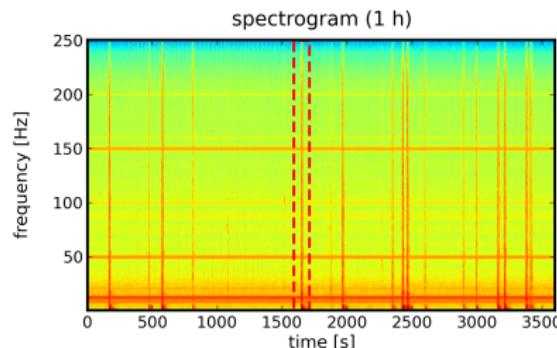
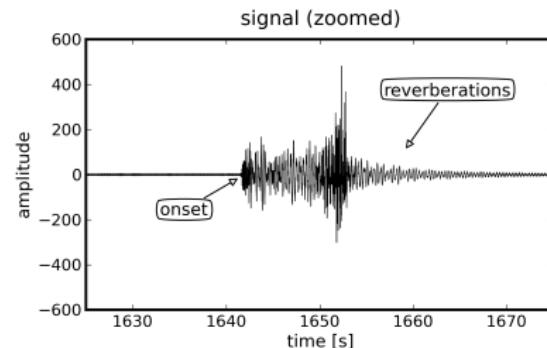
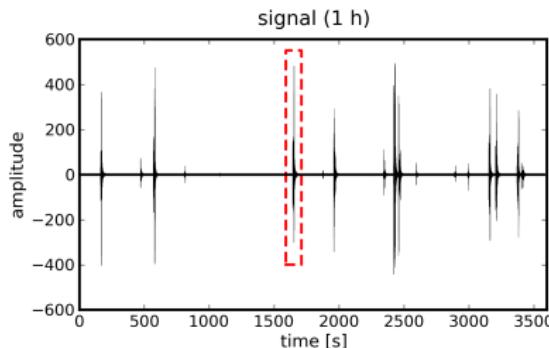
# Raw Signal



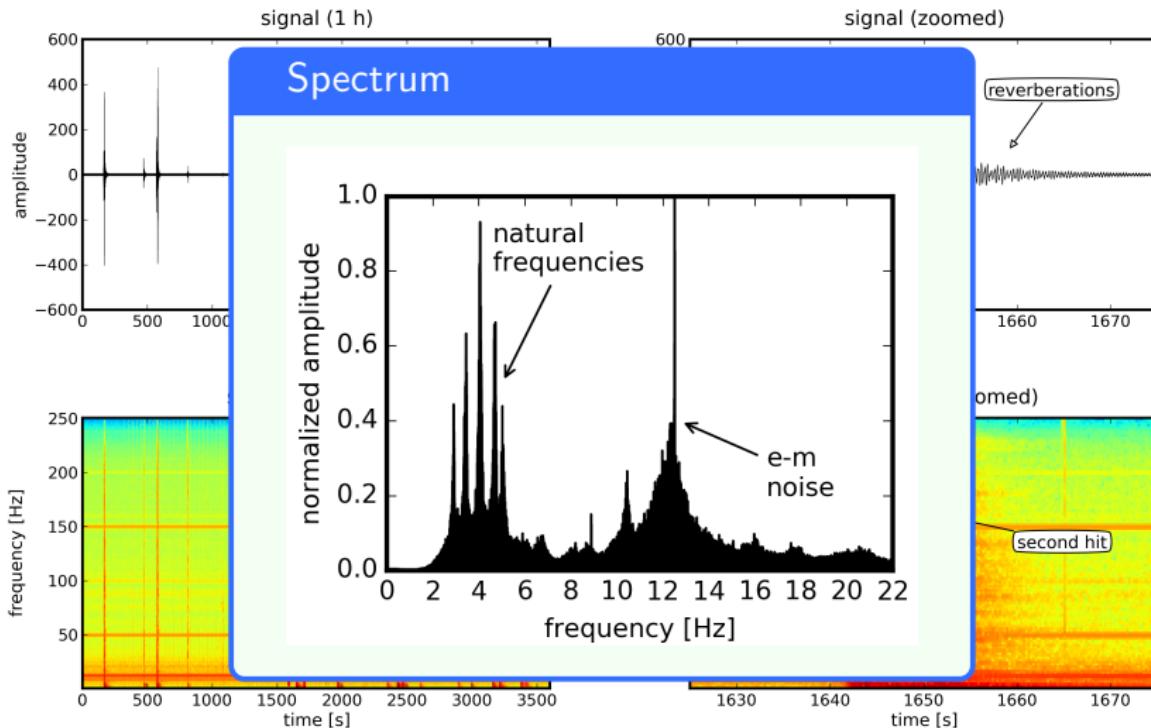
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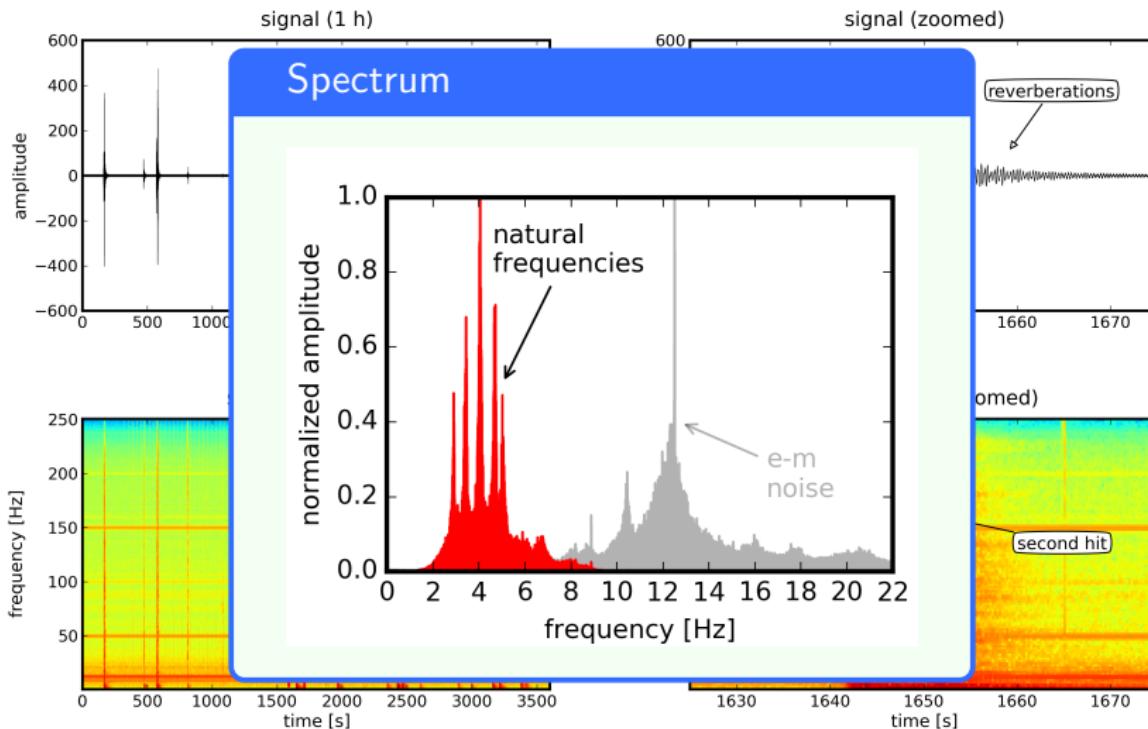
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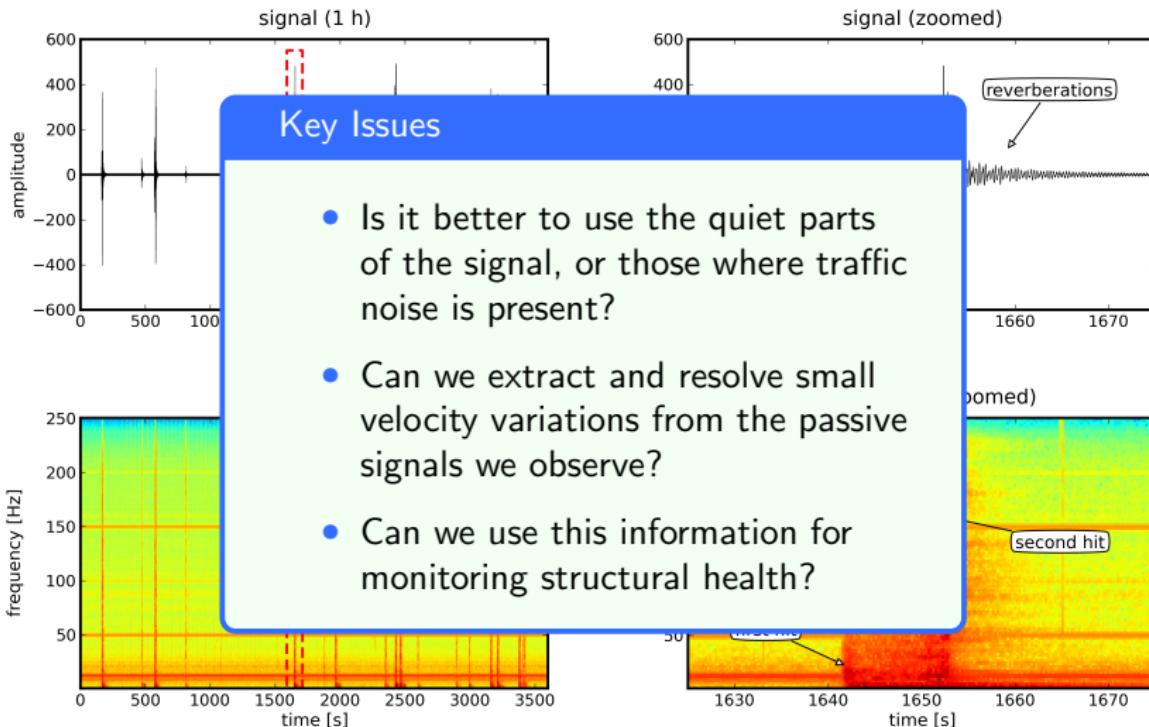
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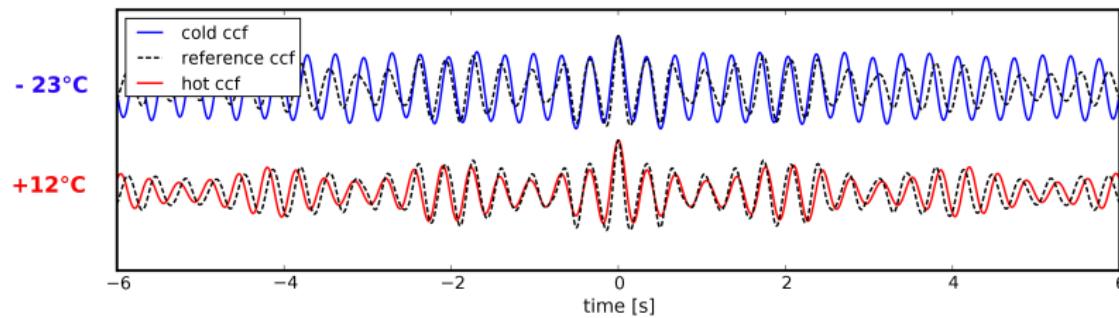
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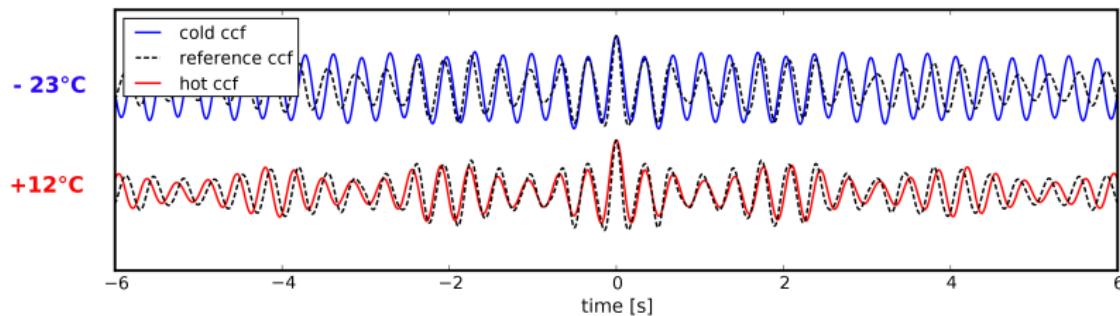
## Raw Signal



## CWI & Cross-correlations



# CWI & Cross-correlations

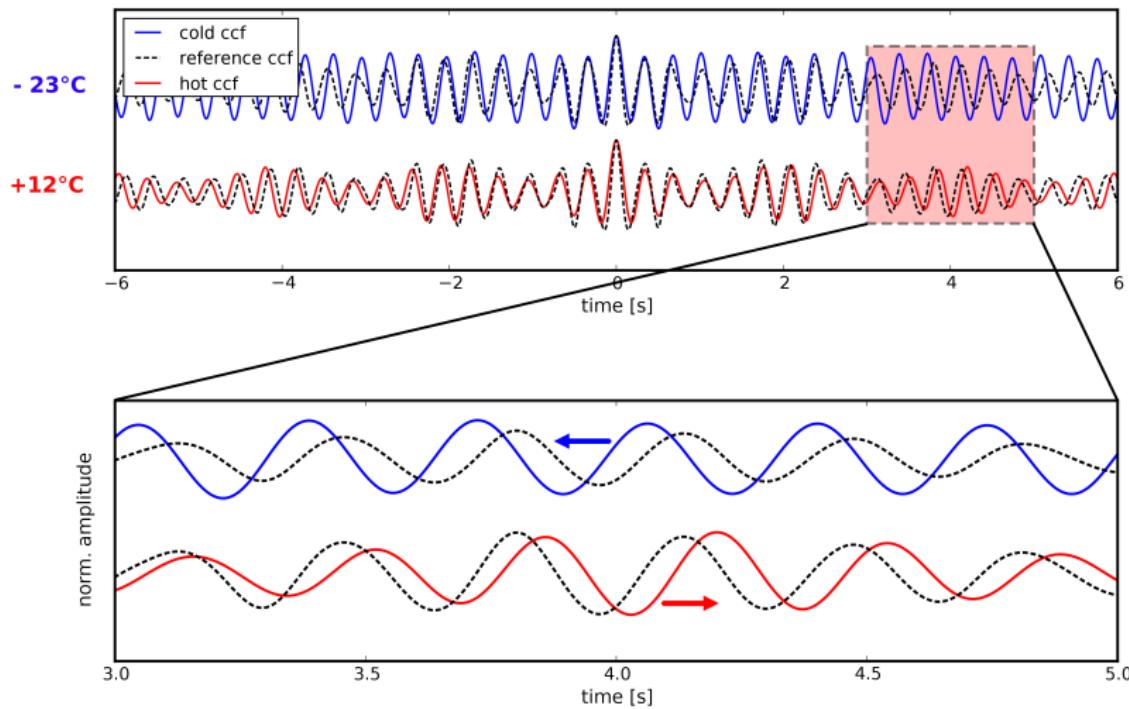


**Hourly** cross-correlations  
for receiver pairs

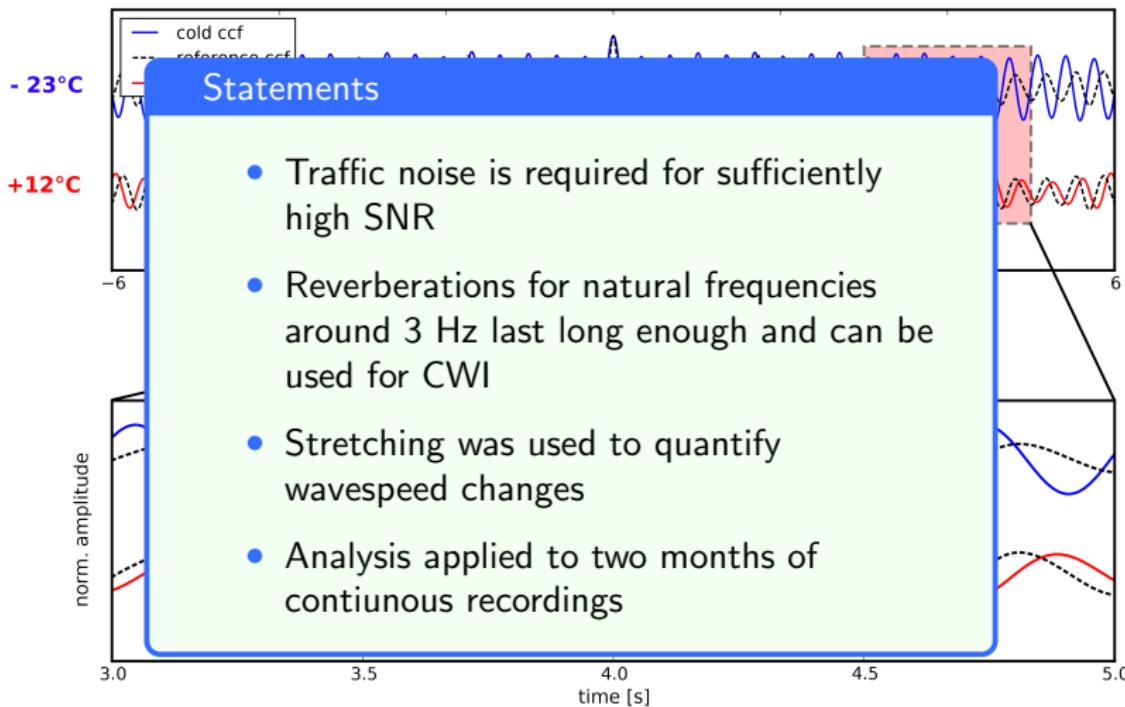


**Unilateral** sources  
and reverberations  
↓  
**No** Green's function retrieval

# CWI & Cross-correlations

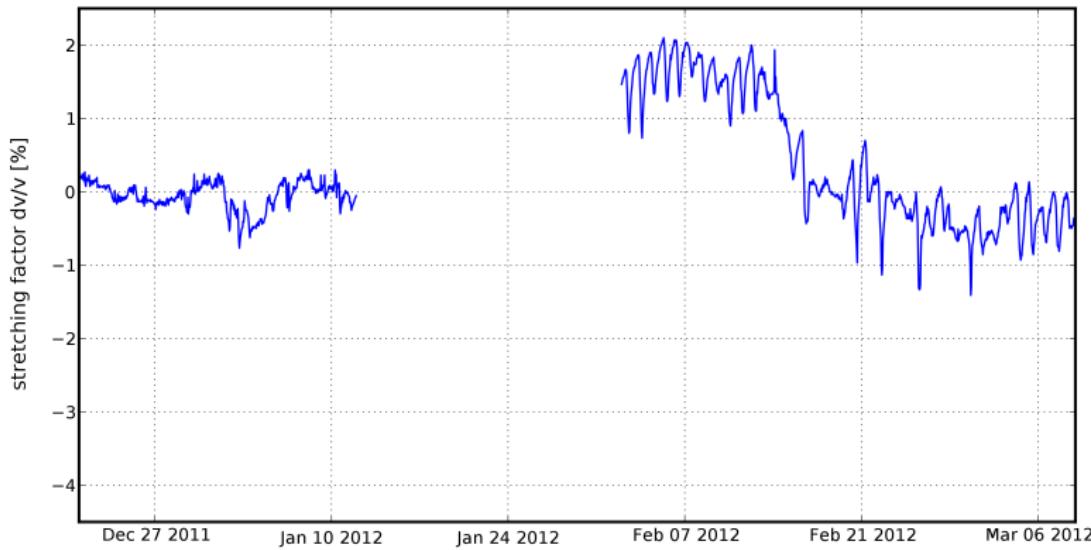


# CWI & Cross-correlations



## Observed Results

## Velocity variation $\frac{\Delta v}{v}$

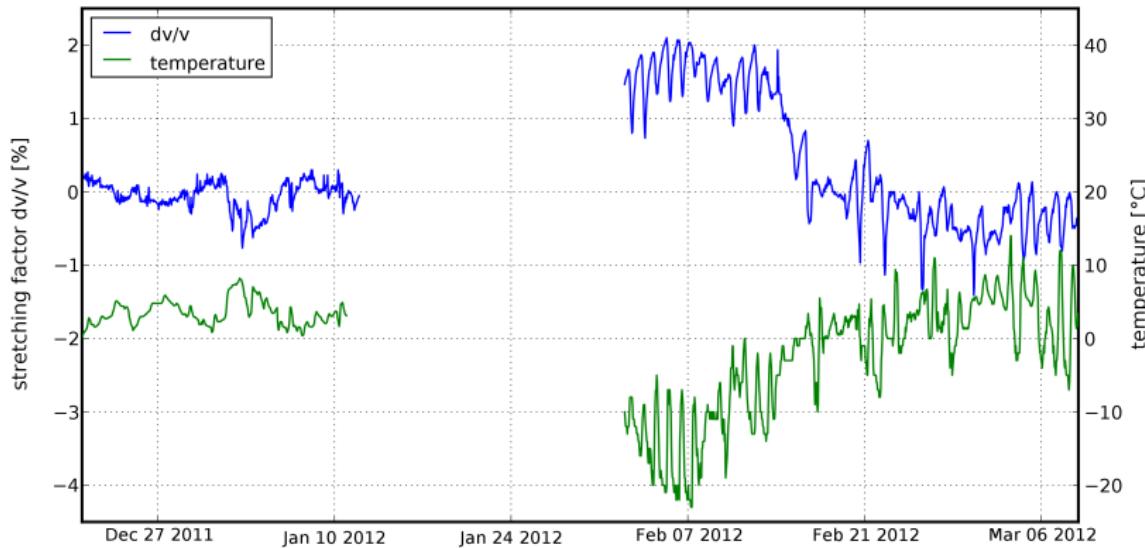


# Observed Results

Velocity variation  $\frac{\Delta v}{v}$



Temperature

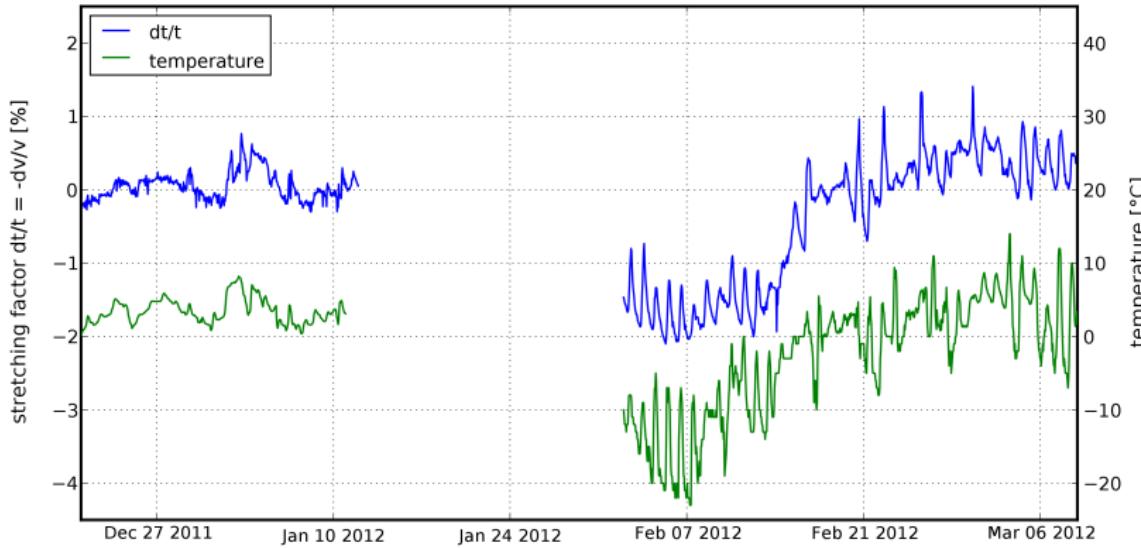


# Observed Results

**Velocity variation**  $\frac{\Delta t}{t}$



**Temperature**

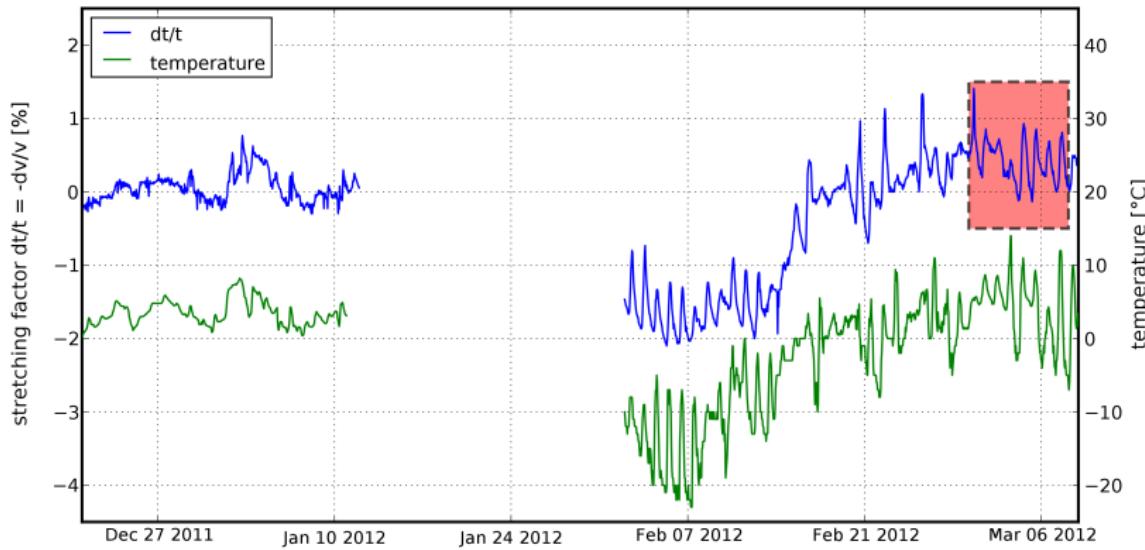


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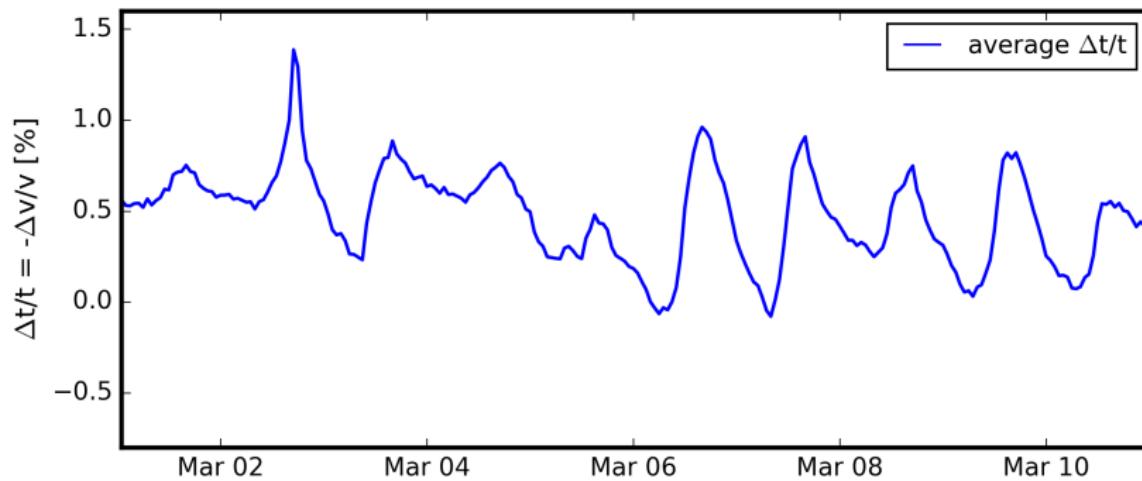


Temperature

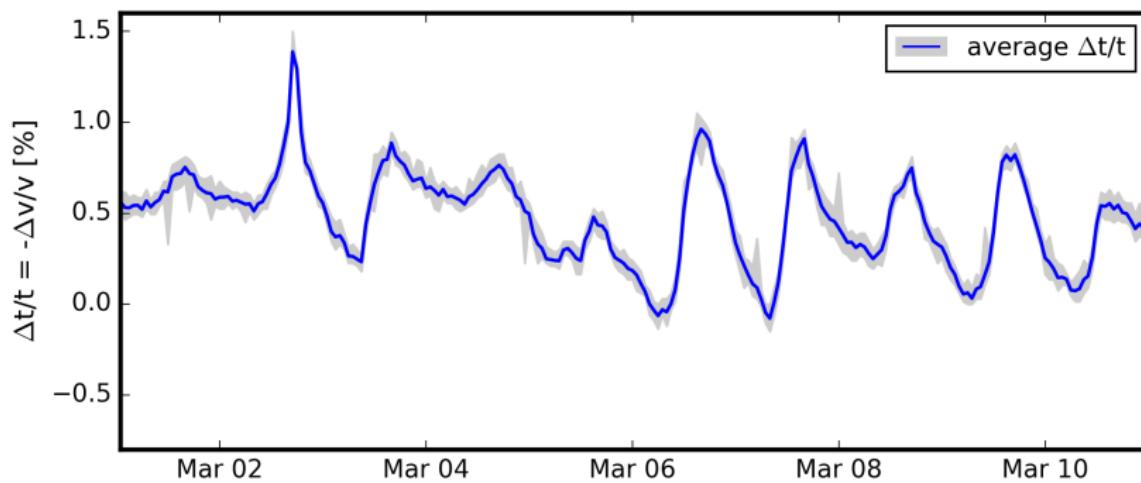


March 2012

## Velocity variation $\frac{\Delta t}{t}$



March 2012

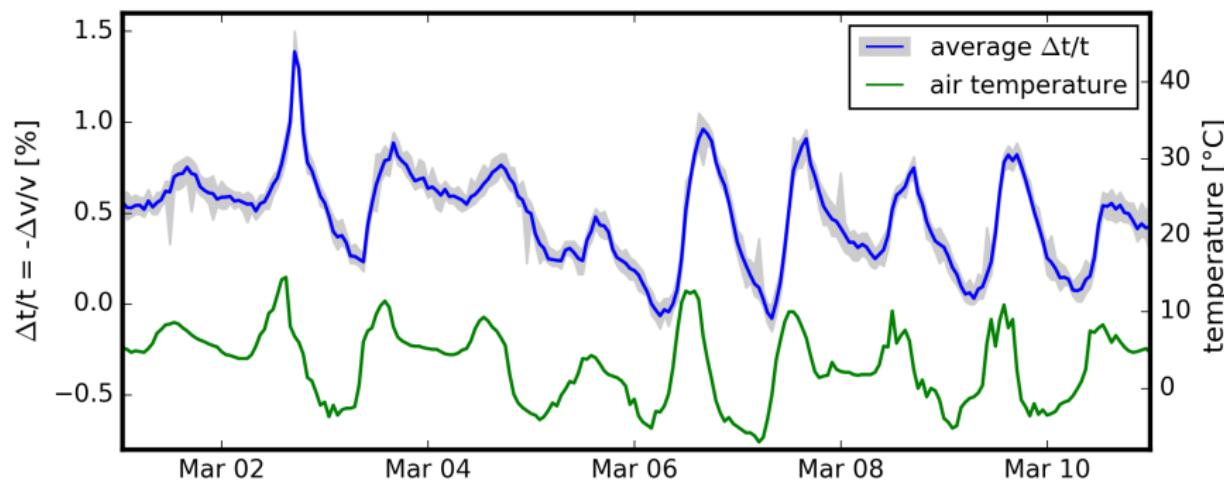
Velocity variation  $\frac{\Delta t}{t}$ Deviation  
(32 receiver pairs)

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Deviation  
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## Temperature

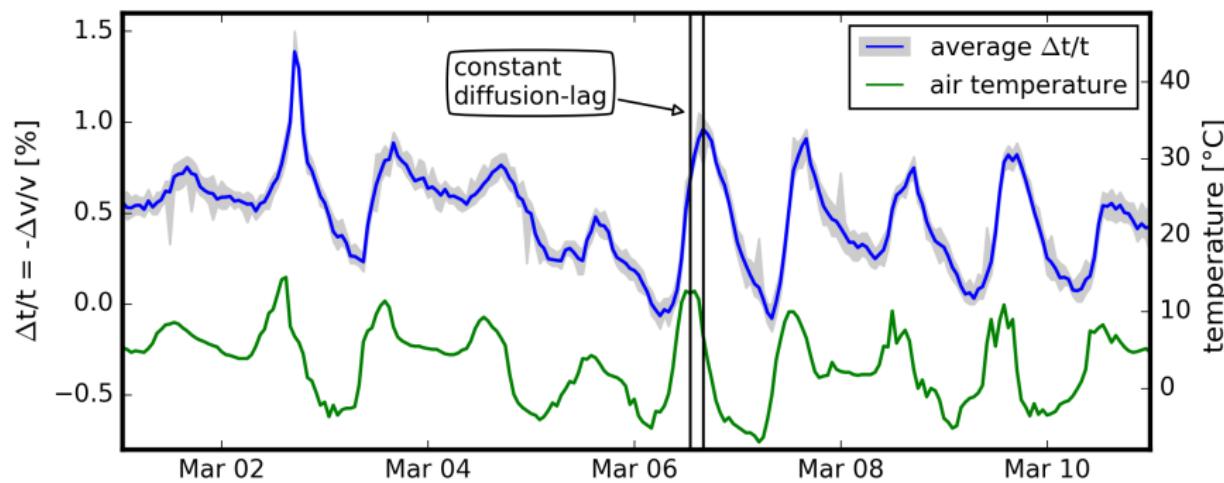


# March 2012

## Velocity variation $\frac{\Delta t}{t}$

Deviation  
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## Temperature



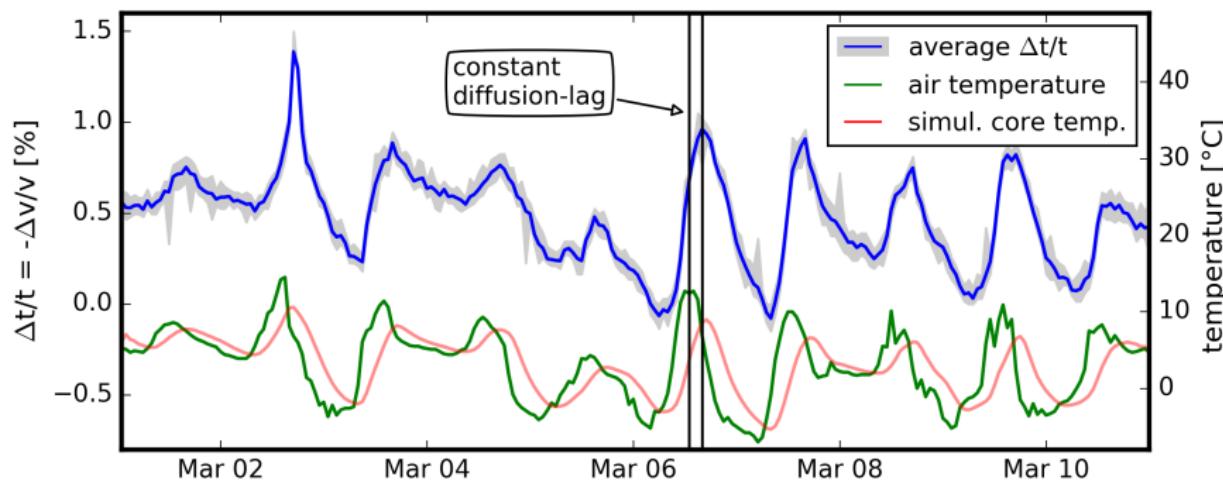
# March 2012

## Velocity variation $\frac{\Delta t}{t}$

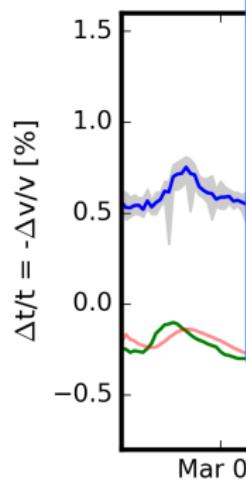
Deviation  
(32 receiver pairs)

## Temperature

## Simulated core temperature



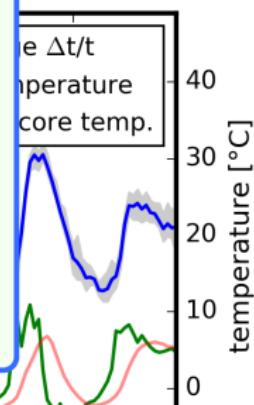
March 2012

**Velocity variation  $\frac{\Delta t}{t}$** Deviation  
(32 receiver pairs)**Temperature****Simulated core temperature****Overall Results** $\frac{\Delta v}{v}$  -1.5% to +2.1%

temperatures +14°C to -23°C

average rate 0.064 %/°C

diffusion lag ≈ 3 hours



# Reliability Tests I

## Thermal expansion

- Varying inter-receiver distances cause travelttime variations
- $\frac{\Delta t}{t} = -\frac{\Delta v}{v}$   
⇒ Effect in the order of  $6-14 \cdot 10^{-4} \frac{\%}{^{\circ}\text{C}}$   
for steel-reinforced concrete (cf. *Keller, T. and C. Menn (1992)*)

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reference range:  
-1.5 to +2.3 %



## Reliability Tests II

### Mathematical test of instrument stability

- Calculate temperature dependence of geophones
- Deconvolve impulse response and convolve with slightly different response ( $\Delta f_c = 0.2$  Hz)
  - ⇒ Correlation of original and simulated signal yielded an apparent delay of **4.8 · 10<sup>-2</sup> %.**

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# Conclusions

- Resolution of velocity variations is possible via cross-correlations from ambient traffic noise on a bridge
- Captured small velocity variations caused by temperature fluctuations:  
relative velocity  $\frac{\Delta v}{v}$ : -1.5% to +2.1%  
temperature range: +14°C to -23°C
- Strong correlation between temperature and  $\frac{\Delta v}{v}$  series
- Advantages: high temporal resolution, high accuracy, low logistical effort

# Perspective

## Aspired Project

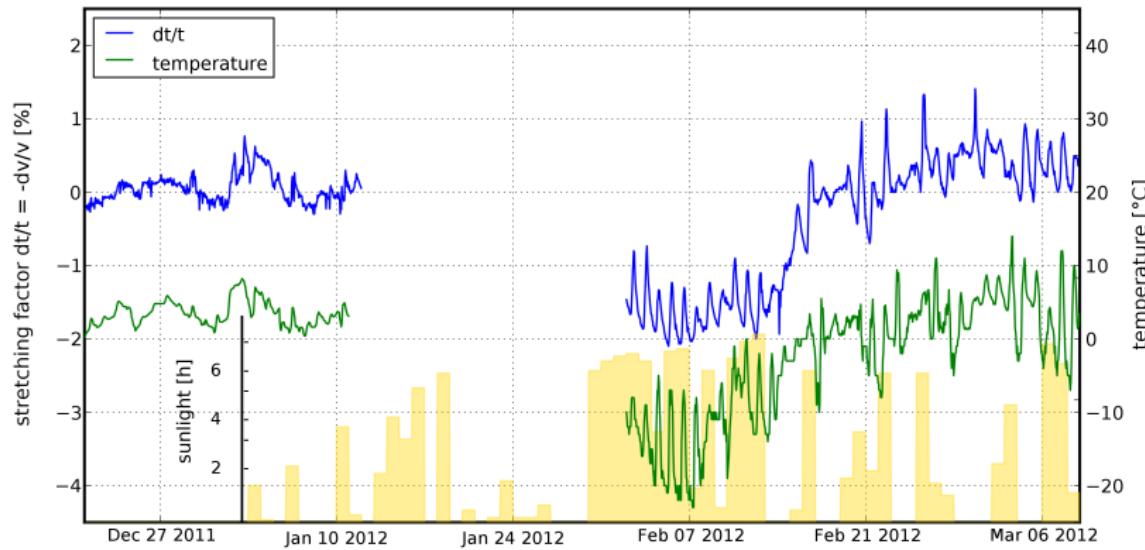
- Long-term ( $> 1$  year) monitoring of a highway bridge
  - ⇒ improve characterization of temperature effect
- Damage-scenario tests on sample bodies and expired structures
- Numerical simulations
  - ⇒ confirm reliability of damage detection

## Questions

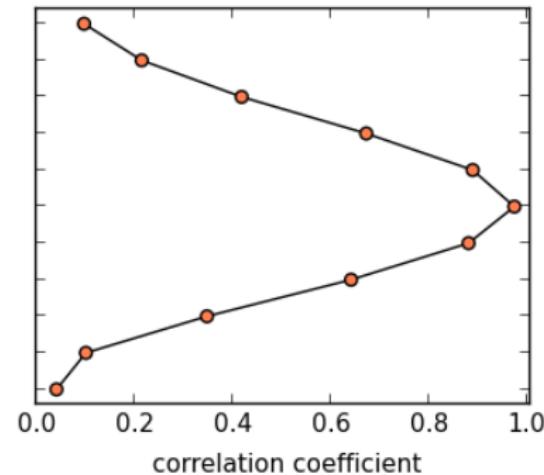
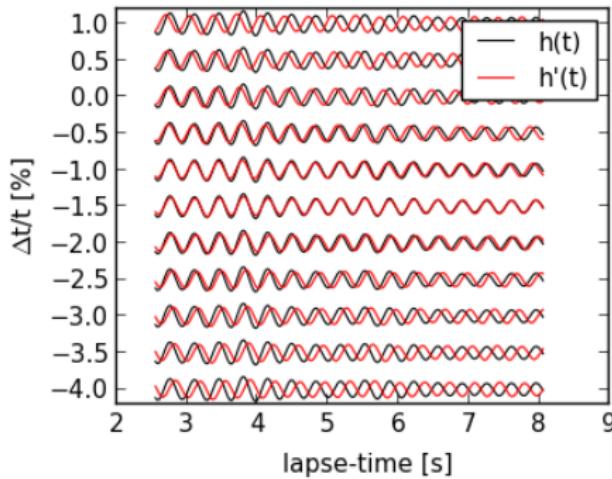
Thank you!



# Daily Sunlight

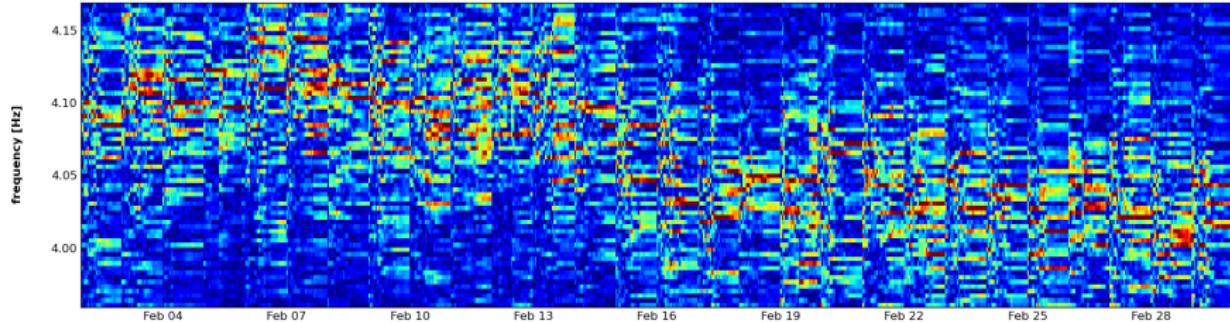


## Stretching Method

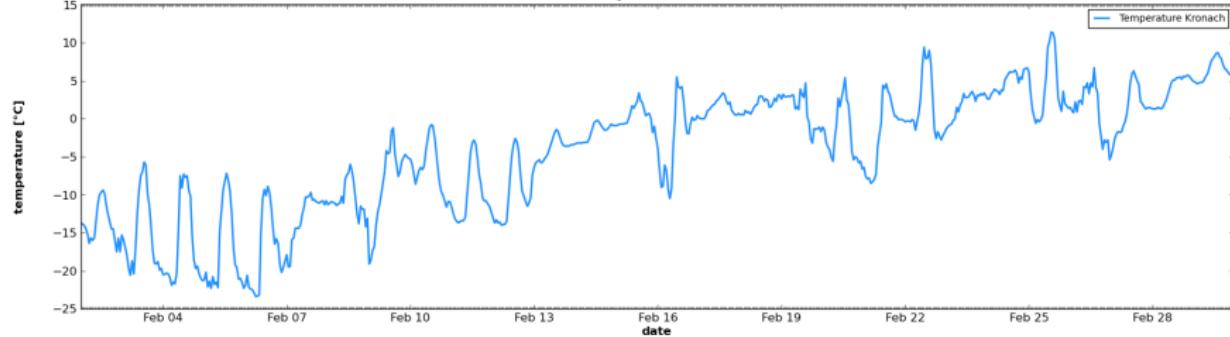


# Eigenfrequency Evolution

Eigenfrequency evolution with time for Channel 6



Temperature data



# Instrument Stability Test

## Frequency Response of GS-11D 4.5Hz 380 $\Omega$ vertical component Geophone

