

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

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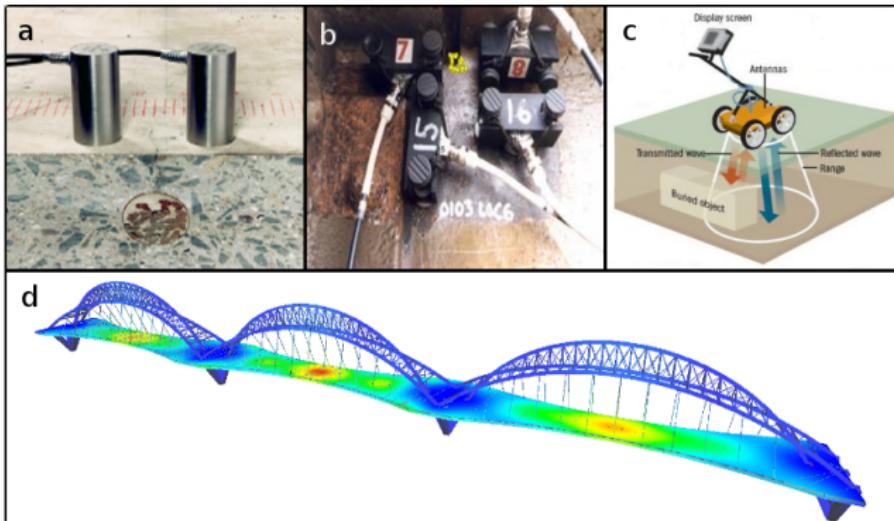
17.03.2016

Objective

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

Motivation

Issue: Combination of **precise** and **permanent** monitoring with a **simple** measurement setup and evaluation technique.



Measurement Setup I

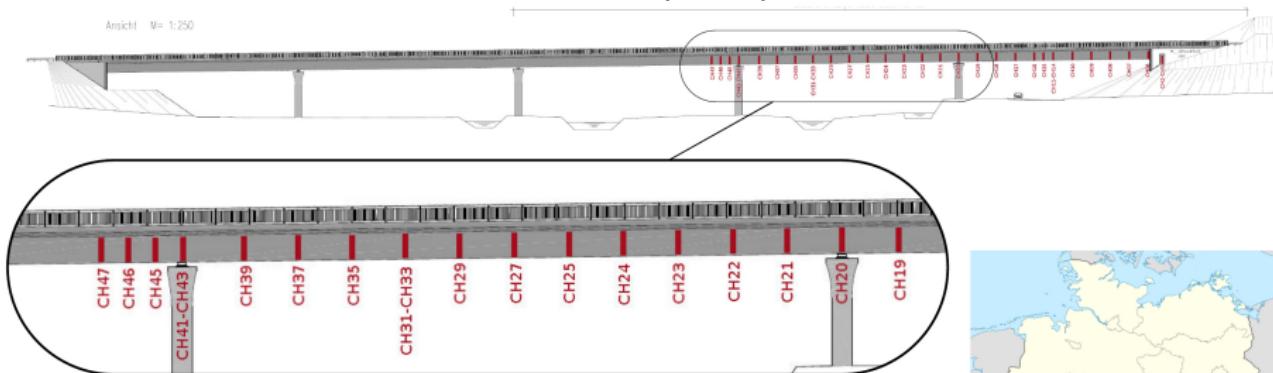
lateral view (Geophone positions)

Ansicht M= 1:250

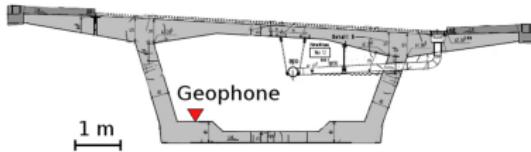


Measurement Setup I

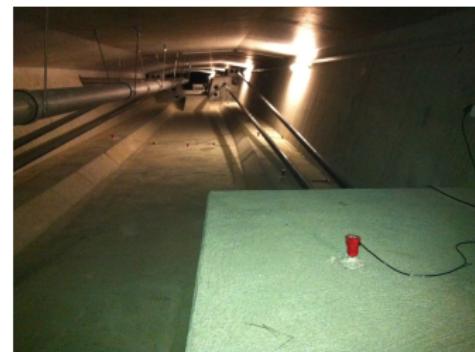
lateral view (Geophone positions)



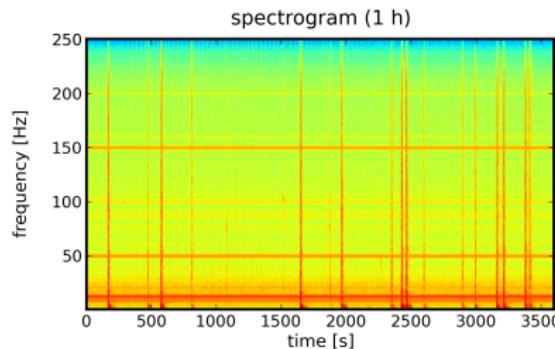
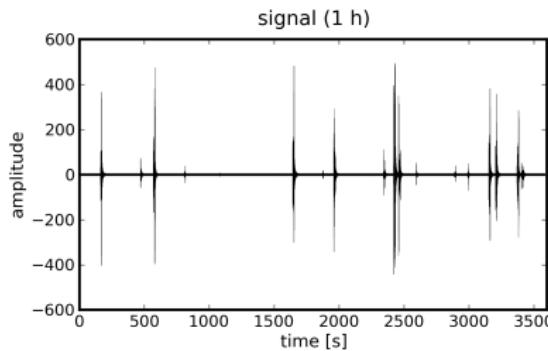
cross-section



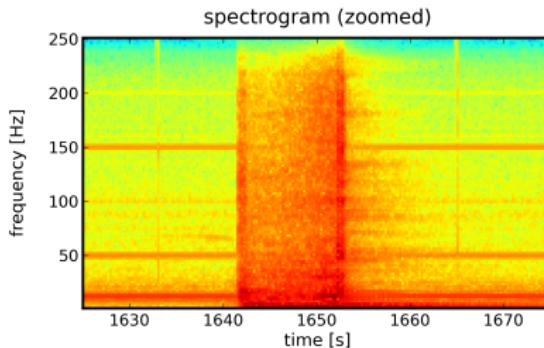
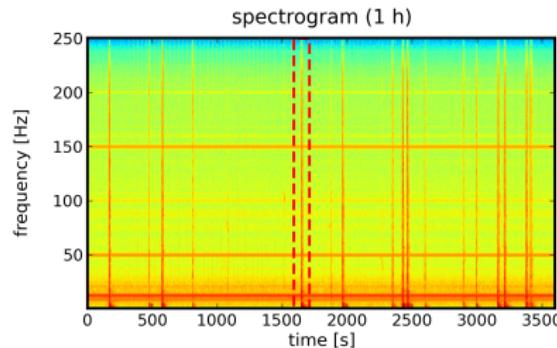
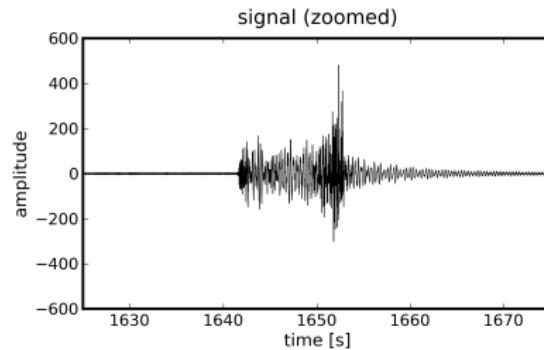
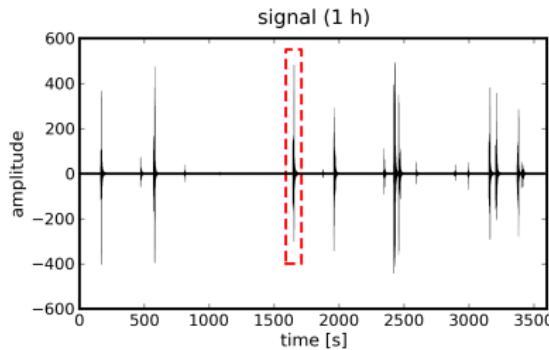
Measurement Setup II: Steinachtal Bridge



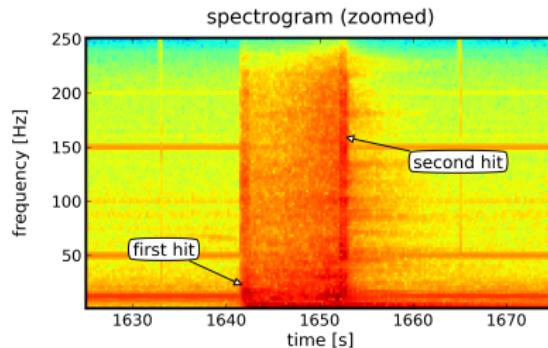
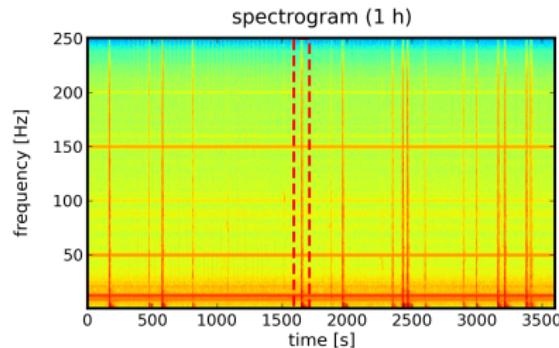
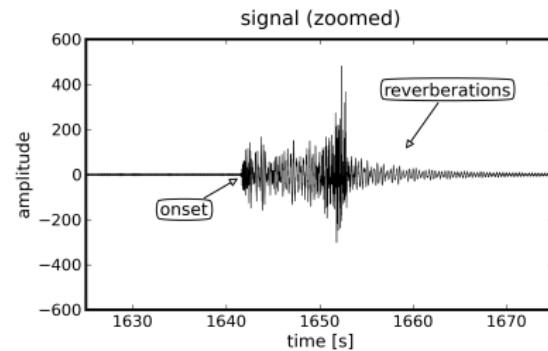
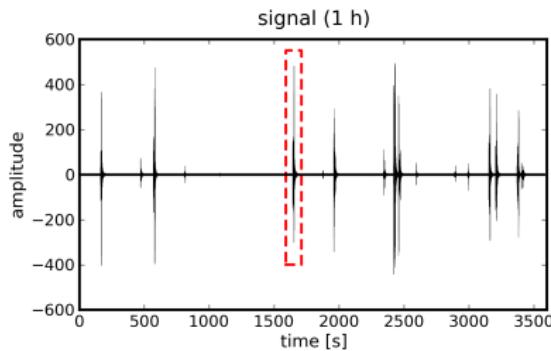
Raw Signal



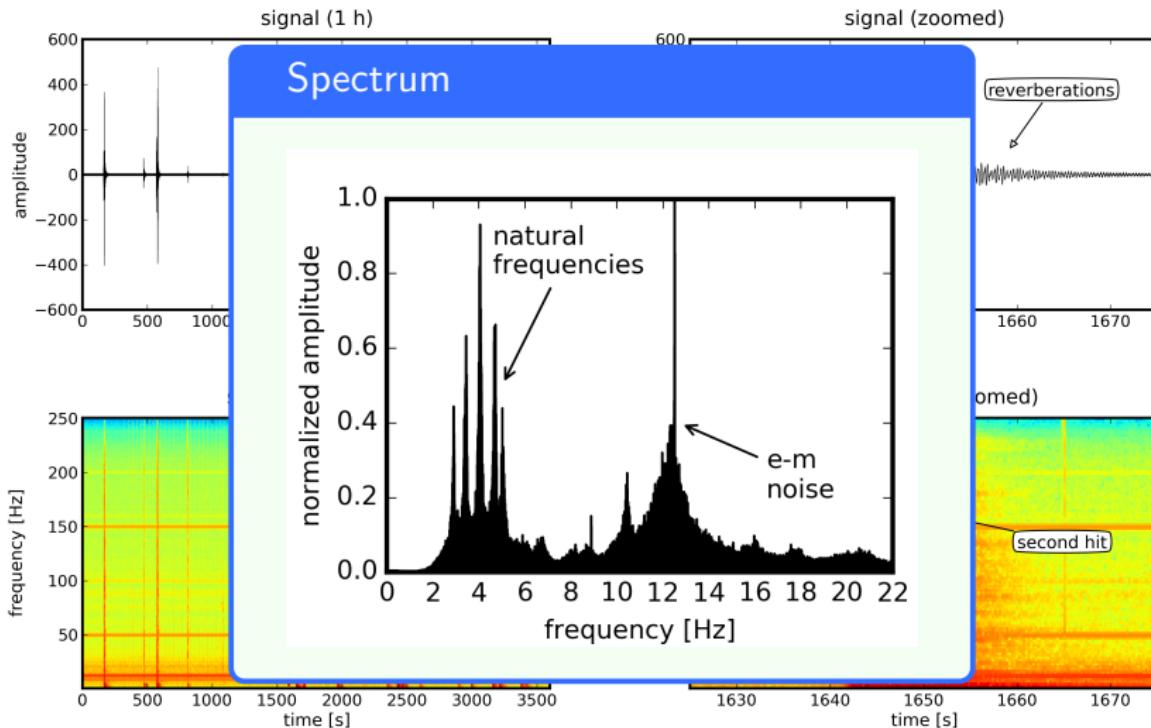
Raw Signal



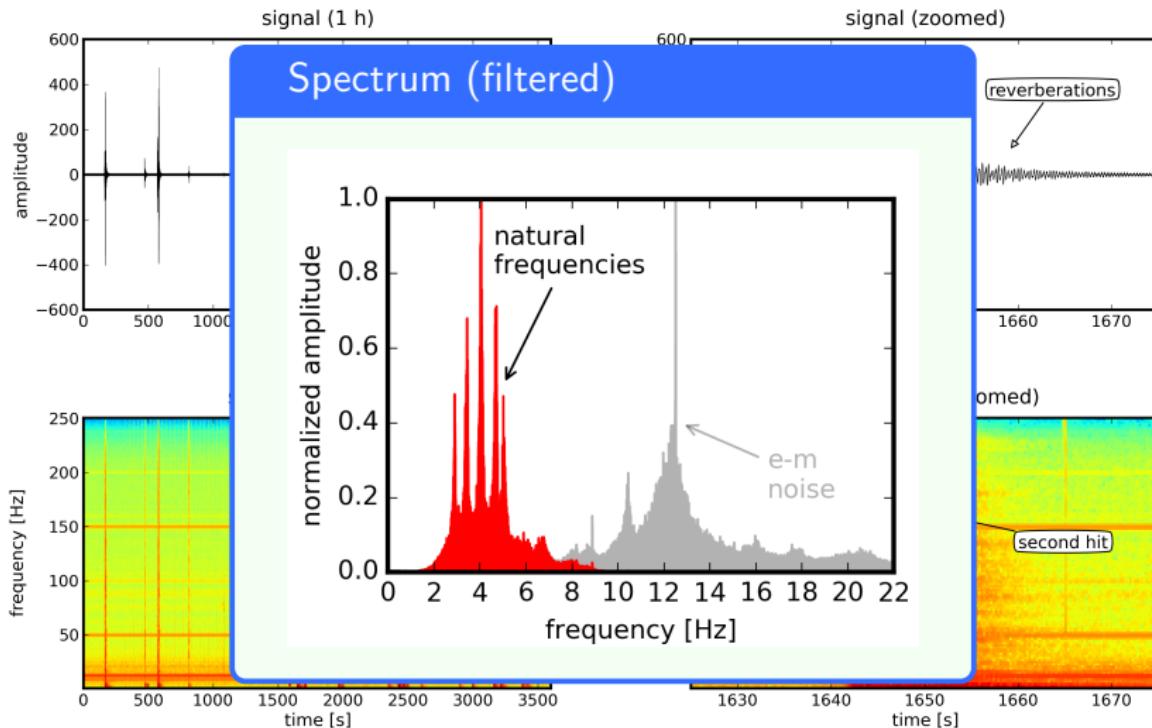
Raw Signal



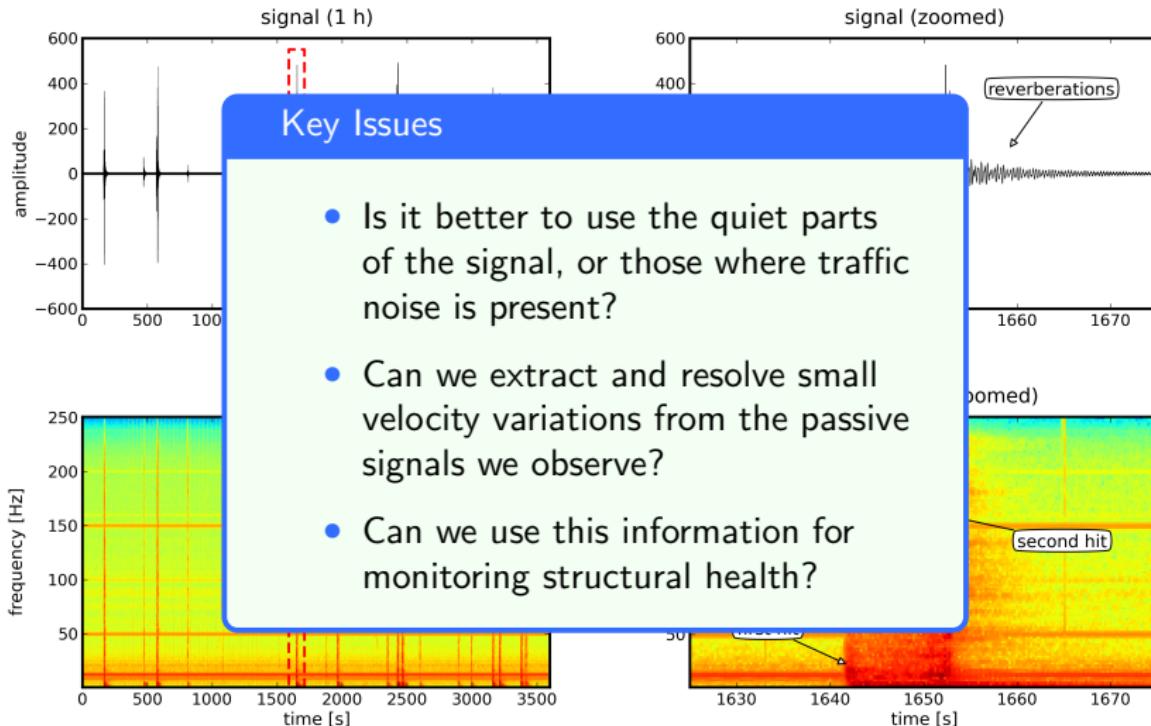
Raw Signal



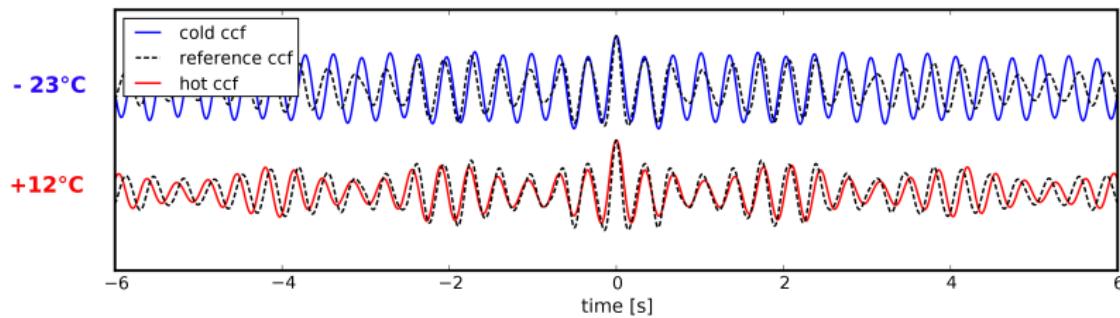
Raw Signal



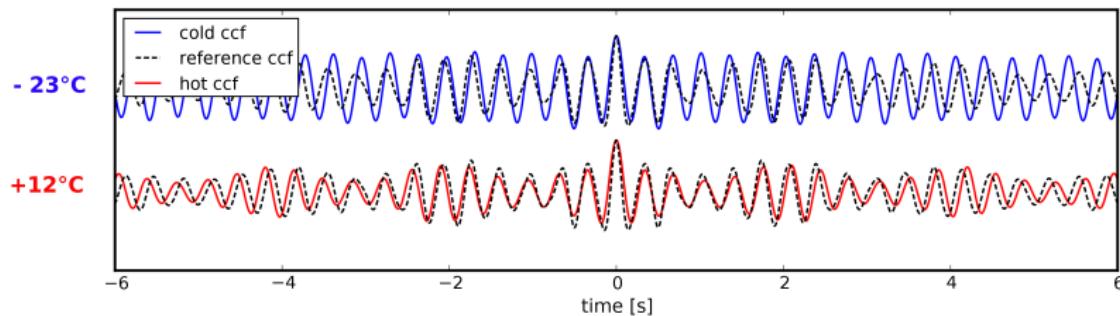
Raw Signal



CWI & Cross-correlations



CWI & Cross-correlations

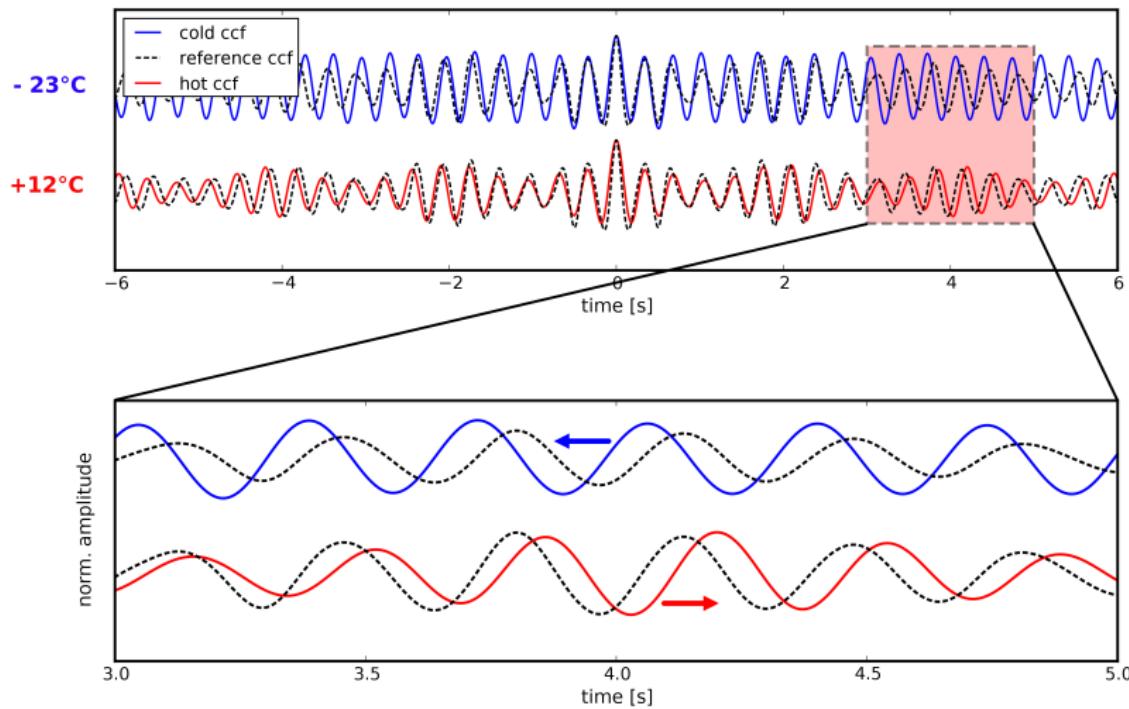


Hourly cross-correlations
for receiver pairs

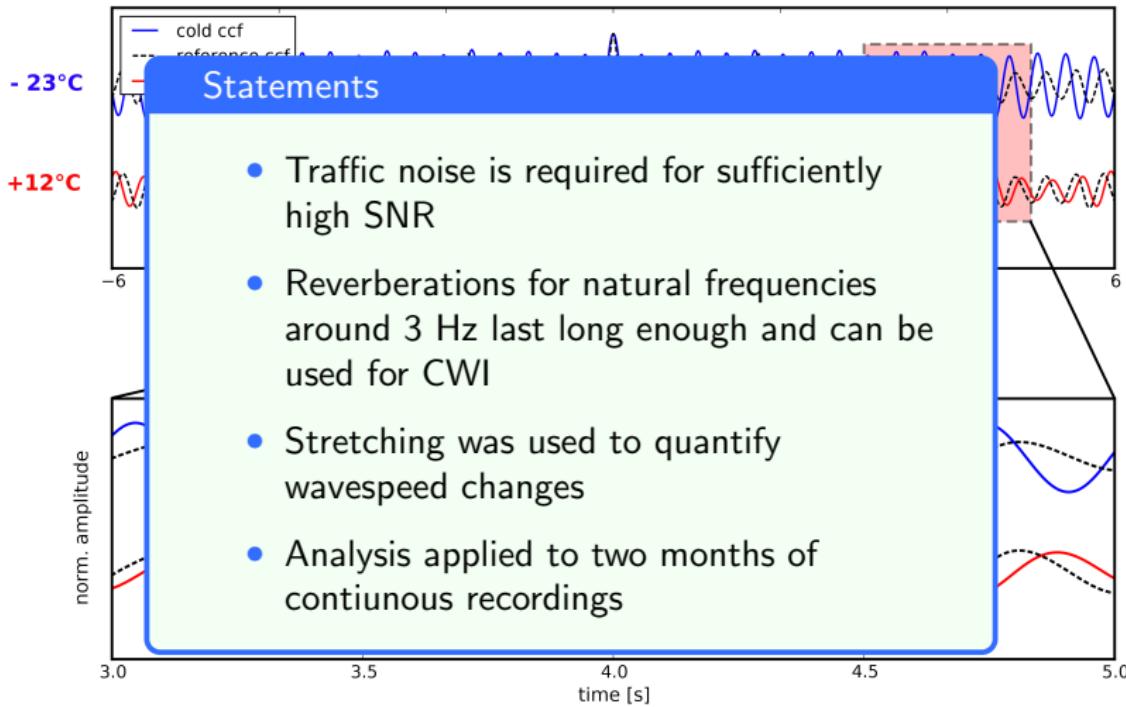


Unilateral sources
and reverberations
⇓
no perfect
Green's functions

CWI & Cross-correlations

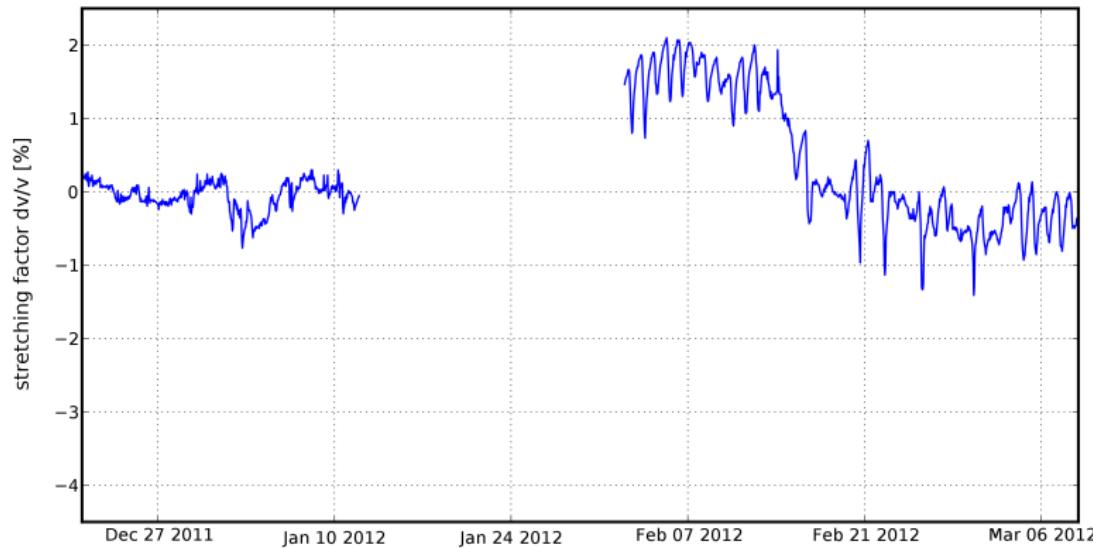


CWI & Cross-correlations



Observed Results

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

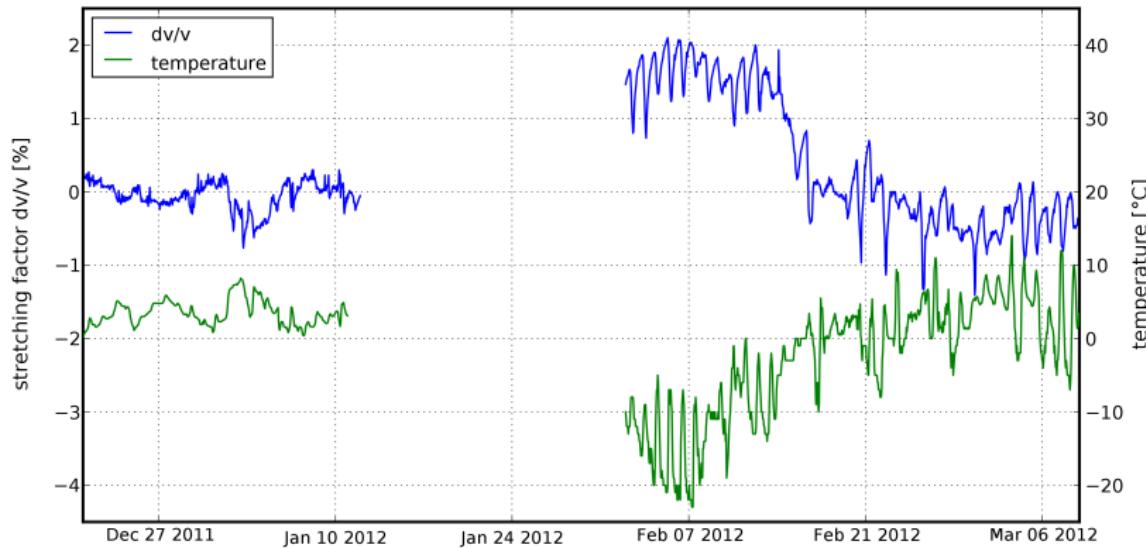


Observed Results

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



Temperature

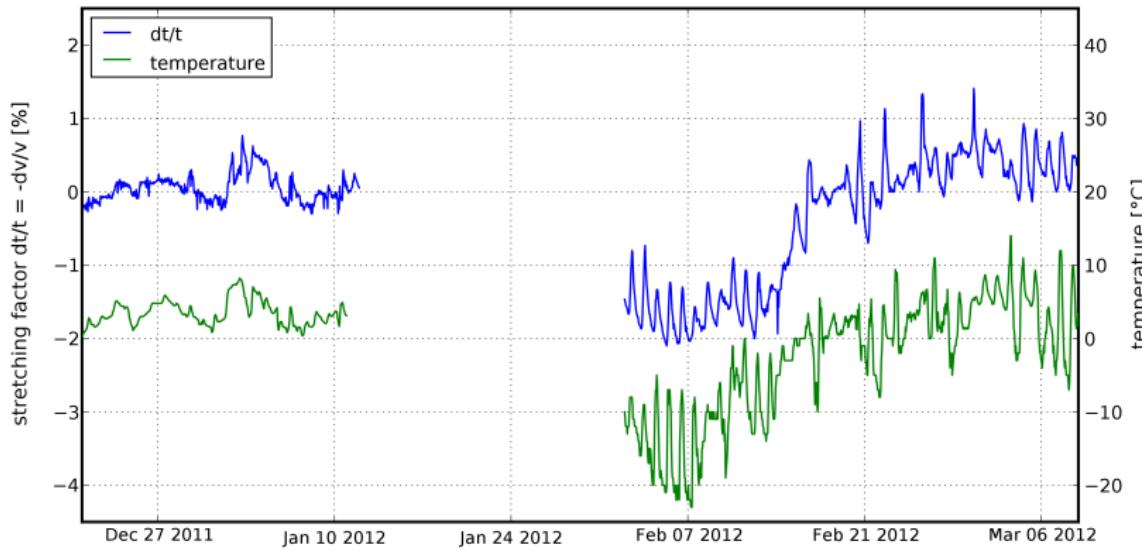


Observed Results

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



Temperature

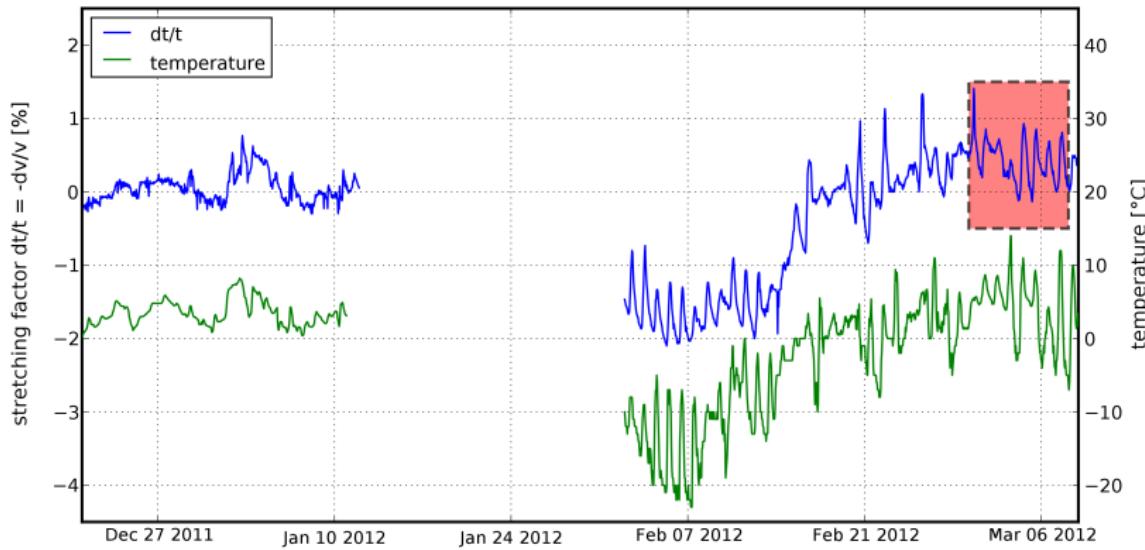


Observed Results

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

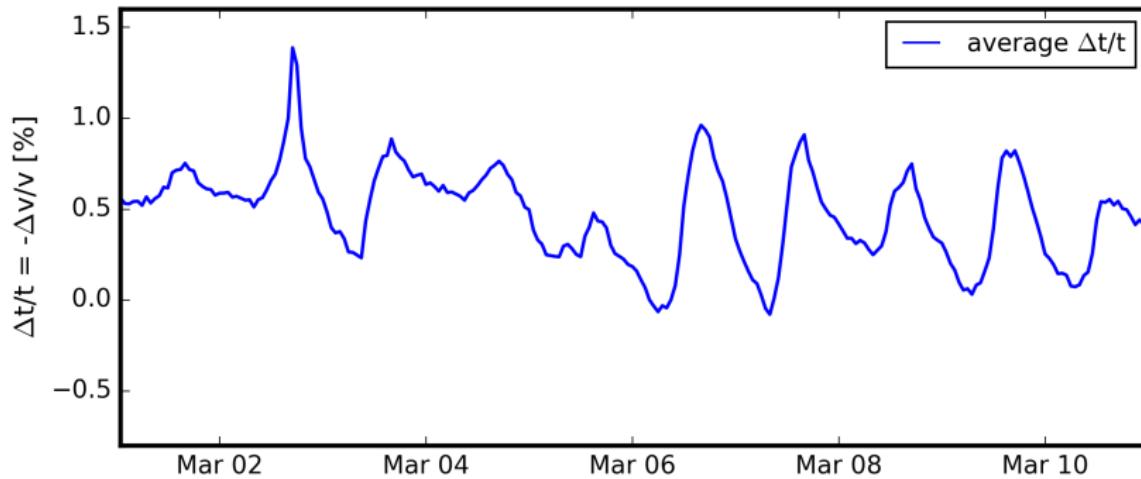


Temperature



March 2012

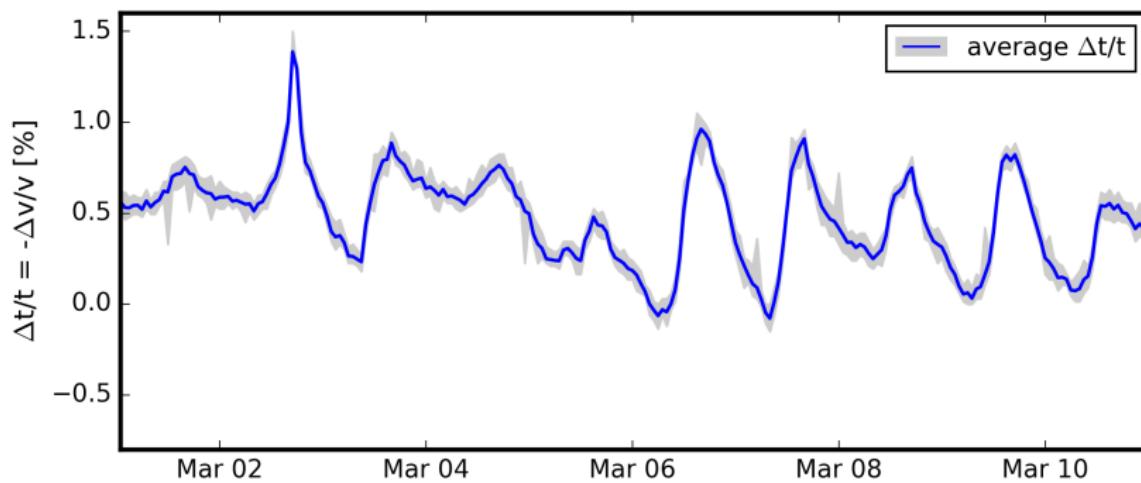
Velocity variation $\frac{\Delta t}{t}$



March 2012

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

Deviation
(32 receiver pairs)

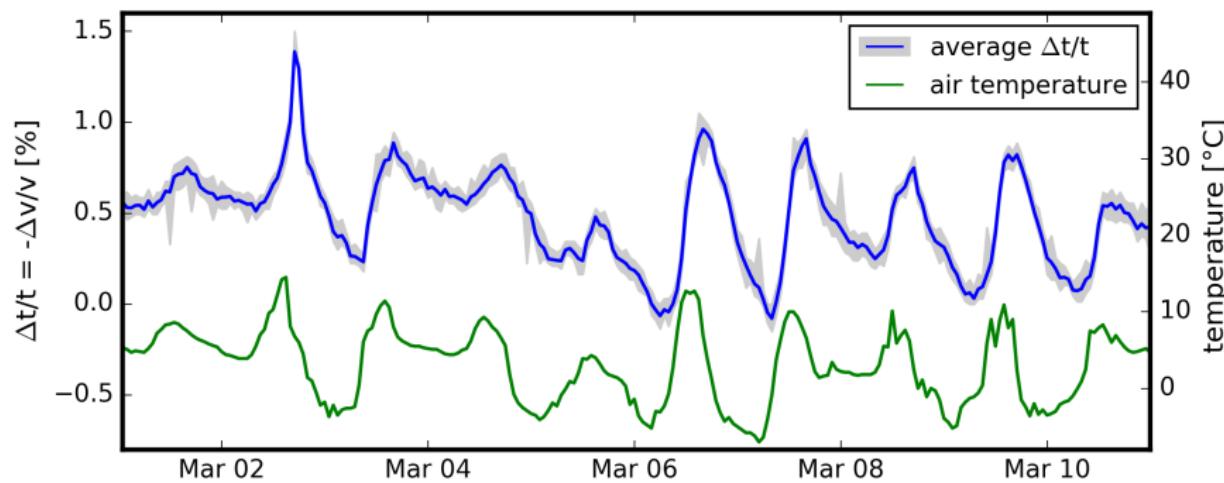


March 2012

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

Deviation
(32 receiver pairs)

Temperature

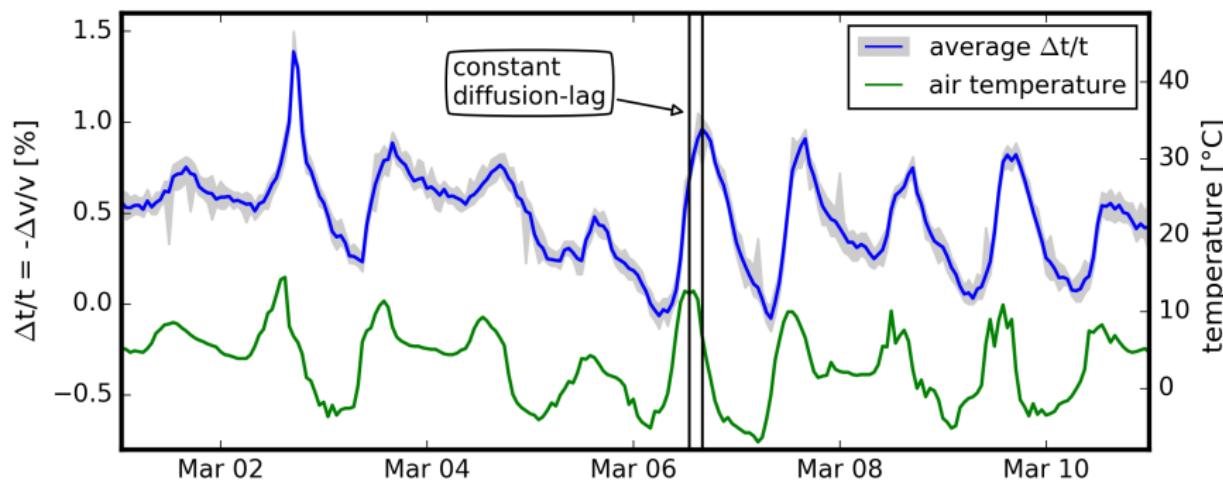


March 2012

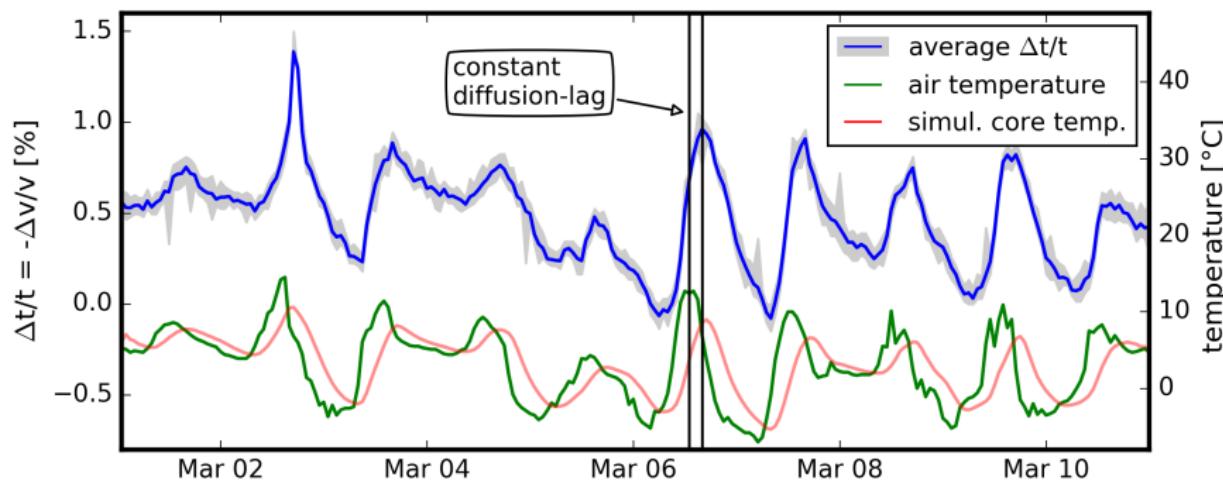
Velocity variation $\frac{\Delta t}{t}$

Deviation
(32 receiver pairs)

Temperature



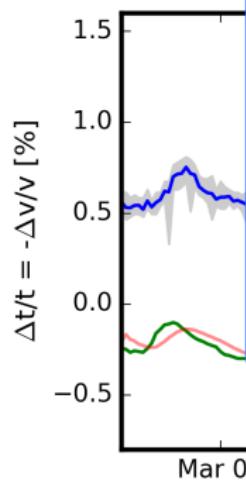
March 2012

Velocity variation $\frac{\Delta t}{t}$ Deviation
(32 receiver pairs)**Temperature****Simulated core temperature**

March 2012

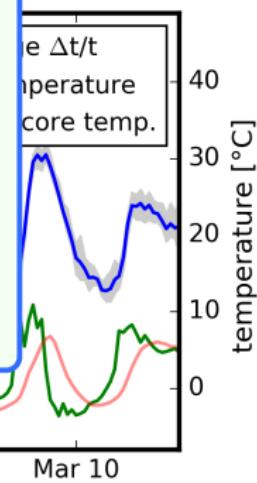
Velocity variation $\frac{\Delta t}{t}$

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

Thermal expansion

Expansion/Contraction of the bridge

Instrument stability

Temperature dependence of geophones

Msmt range

-1.5 to +2.3 %

Reliability Tests

Thermal expansion

Expansion/Contraction of the bridge

⇒ Effect in the order of $6\text{-}14 \cdot 10^{-4} \frac{\%}{^{\circ}\text{C}}$ for
steel-reinforced concrete



Msmt range

-1.5 to +2.3 %

Instrument stability

Temperature dependence of geophones

Reliability Tests

Thermal expansion

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Msmt range

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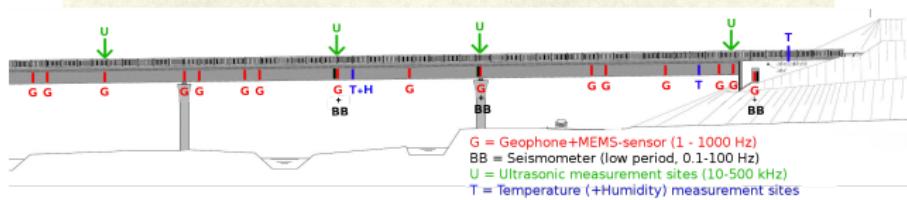
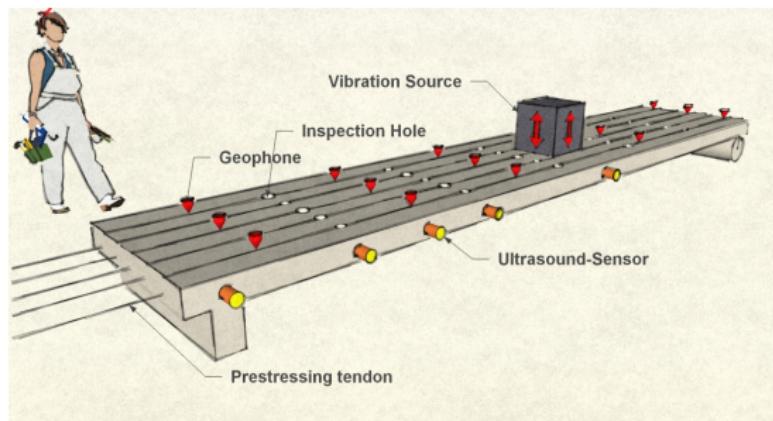
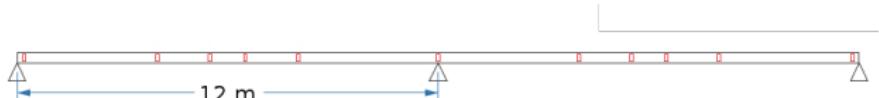
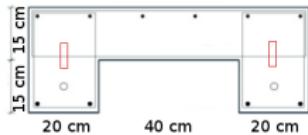
Instrument stability

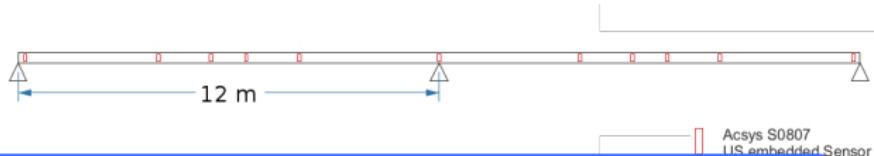
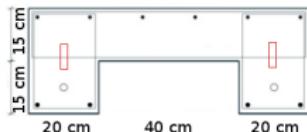
Temperature dependence of geophones

⇒ Apparent delay of max. **0.52 %** for extreme shifts in corner frequency.

Conclusions

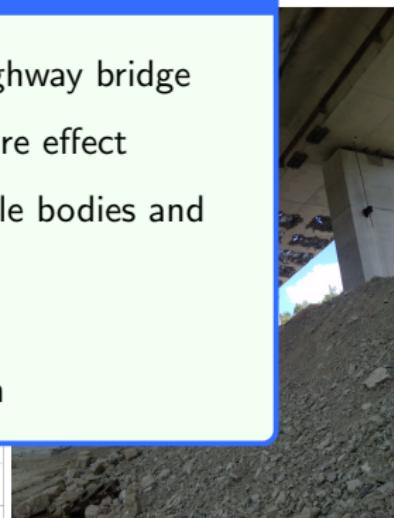
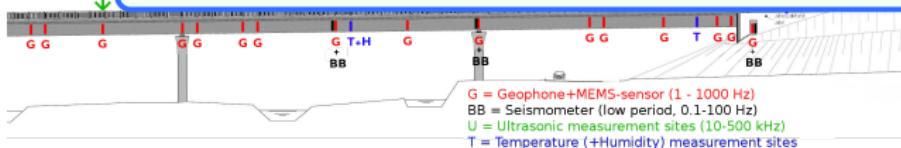
- Resolution of velocity variations is possible via cross-correlations from ambient traffic noise on a bridge
- Captured small velocity variations caused by temperature fluctuations:
relative velocity $\frac{\Delta v}{v}$: -1.5% to +2.1%
temperature range: +14°C to -23°C
- Strong correlation between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

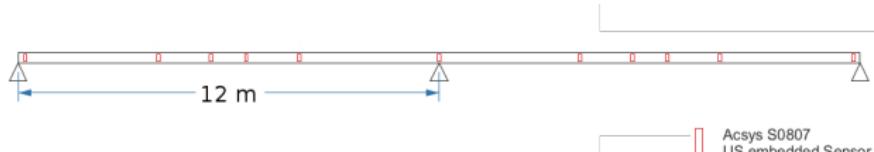
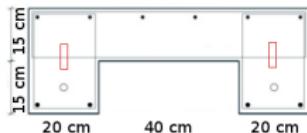




Perspective - aspired project

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





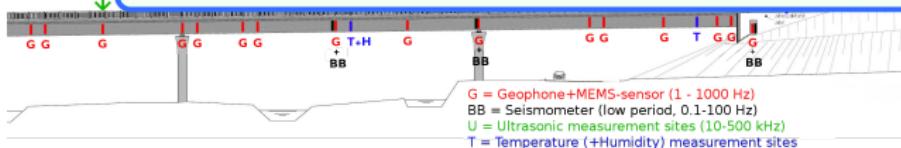
Acsys S0807
UUS embedded Sensor

Perspective - aspired project



Aim

Detect corrosion-induced **decrease in prestressing**
and associated **concrete crack evolution**



G = Geophone+MEMS-sensor (1 - 1000 Hz)
BB = Seismometer (low period, 0.1-100 Hz)
U = Ultrasonic measurement sites (10-500 kHz)
T = Temperature (+Humidity) measurement sites

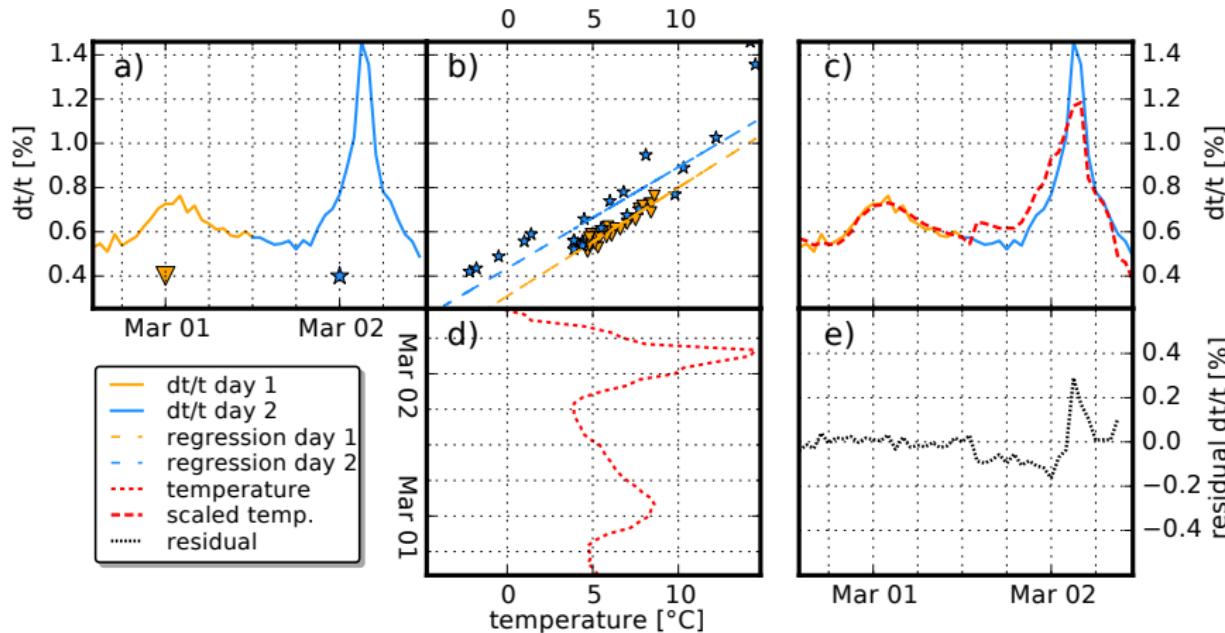


Questions

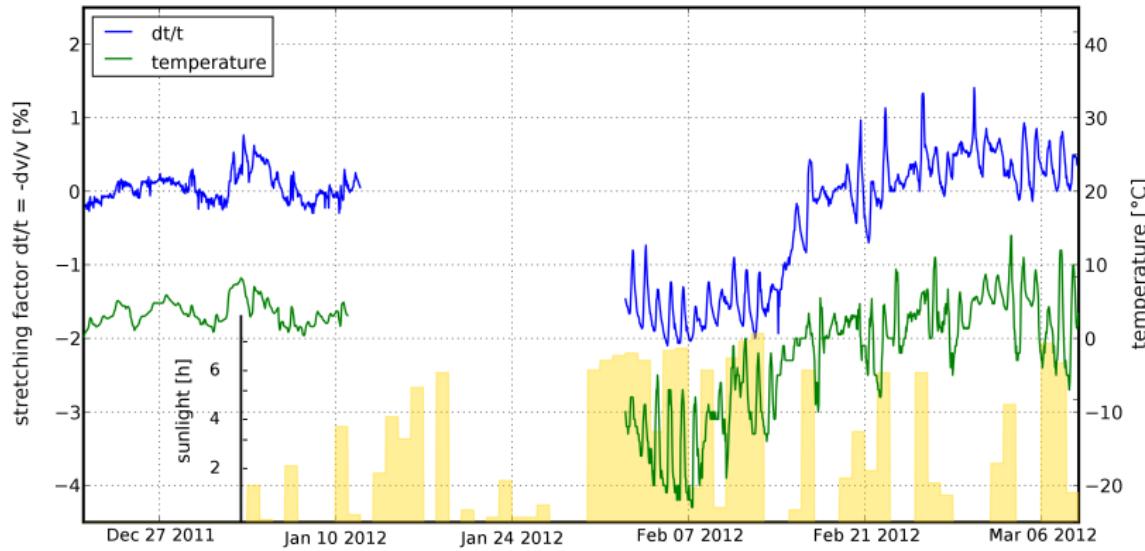
Thank you!



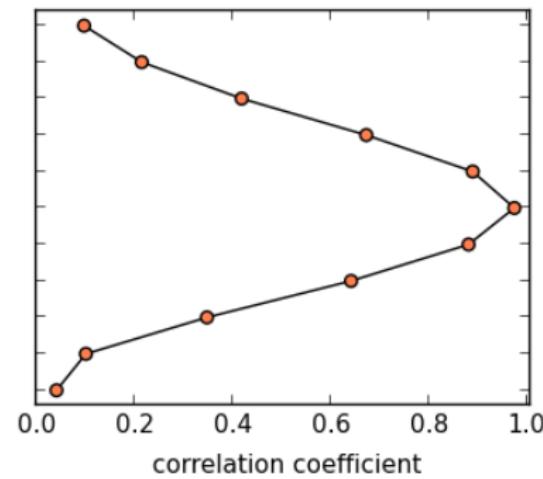
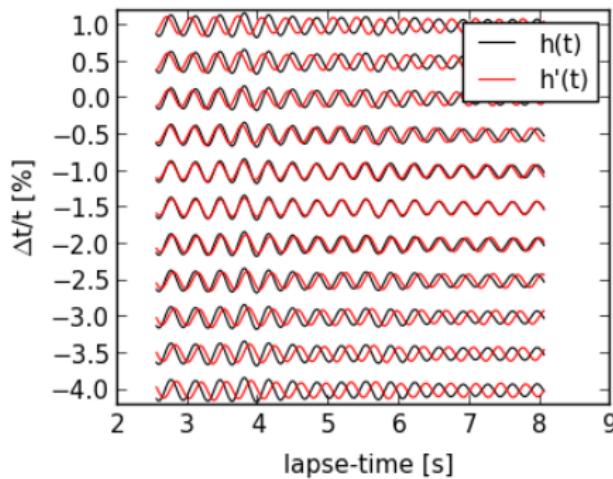
Temperature reduction



Daily Sunlight

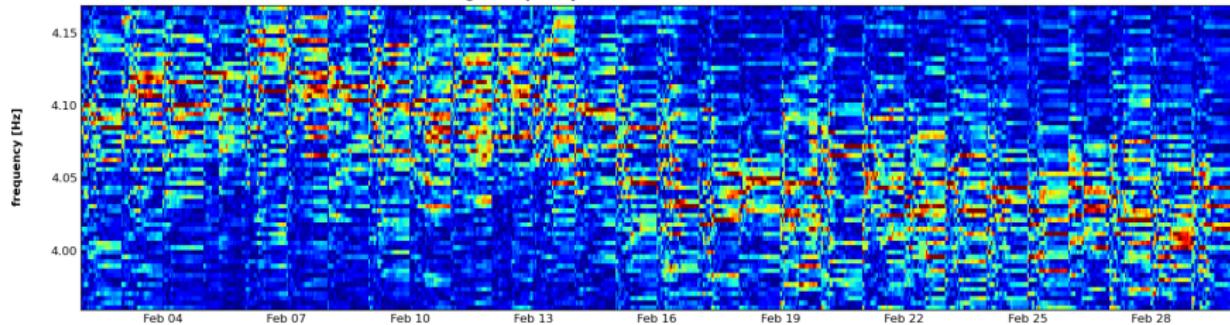


Stretching Method

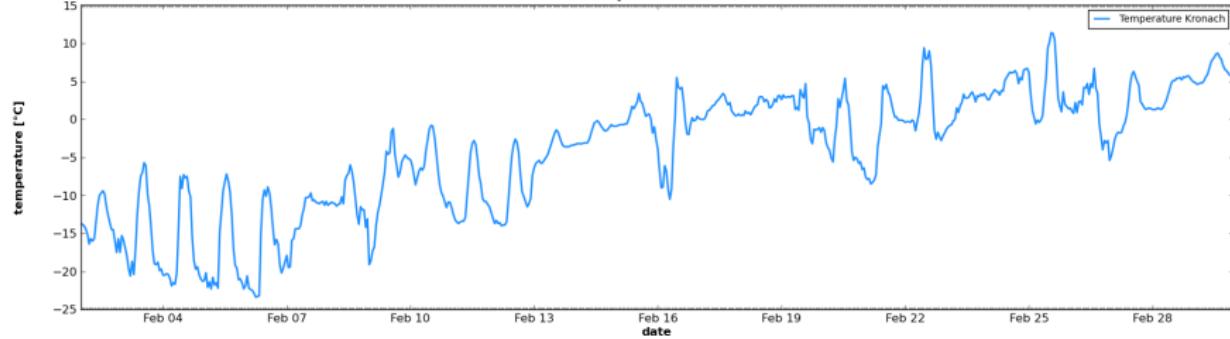


Eigenfrequency Evolution

Eigenfrequency evolution with time for Channel 6



Temperature data



Instrument Stability Test

Frequency Response of GS-11D 4.5Hz 380 Ω vertical component Geophone

