Variations of the system properties of a high-rise building over 1 year using a single station 6C approach.

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1 Motivation

Structural health monitoring seeks to detect structural damage by tracking variations in the measured system properties; in vibration-based monitoring, such indicators stem from modal properties. However, dynamic properties are influenced by varying environmental (e.g. temperature) and operational conditions (EOC) (e.g. wind), often masking structural damage. Therefore, understanding how buildings react to EOC's is of utmost importance. While modal frequencies can be derived by a single, properly placed sensor, modal shapes typically require monitoring arrays of accelerometer sensors. We show, how to infer 6C mode shapes using collocated acceleration/rotation sensing, namely a 6C-station. Prime Tower, a 126 m high rise in Zurich, with a concrete shear core and an external concrete moment frame, supported on deep pile foundations, is used to demonstrate the proposed approach.

2 Why do we use a 6C-station approach?

We would get:
- natural frequencies f_n
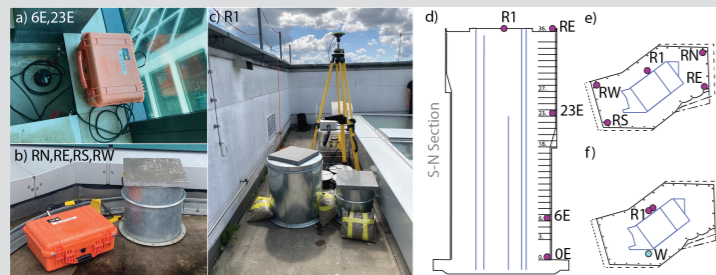- 6C mode shape of roof

We do not need:
- access to multiple floors
- many instruments
- time synchronisation of all instruments
- time for set up of arrays

We only need:
- 1 location on the roof
- 1 accelerometer
- 1 rotational sensor

6C = 3 components translation and 3 components rotation

a-b) Station locations. c) Location R1 (GNSS antenna, blueSeis-3A and accelerometer). d) S-N section with the vertical array (V) station location in pink. e-f) Roof floor plan.
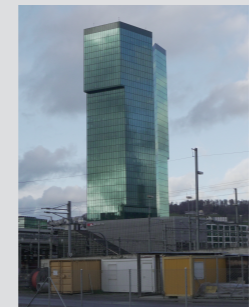
3 Mode Shapes of 6 Primary Modes.

The stochastic subspace identification (SSI) method was used to estimate the 6C eigenfrequencies and associated horizontal mode shapes on the roof. These match the standard array analysis.
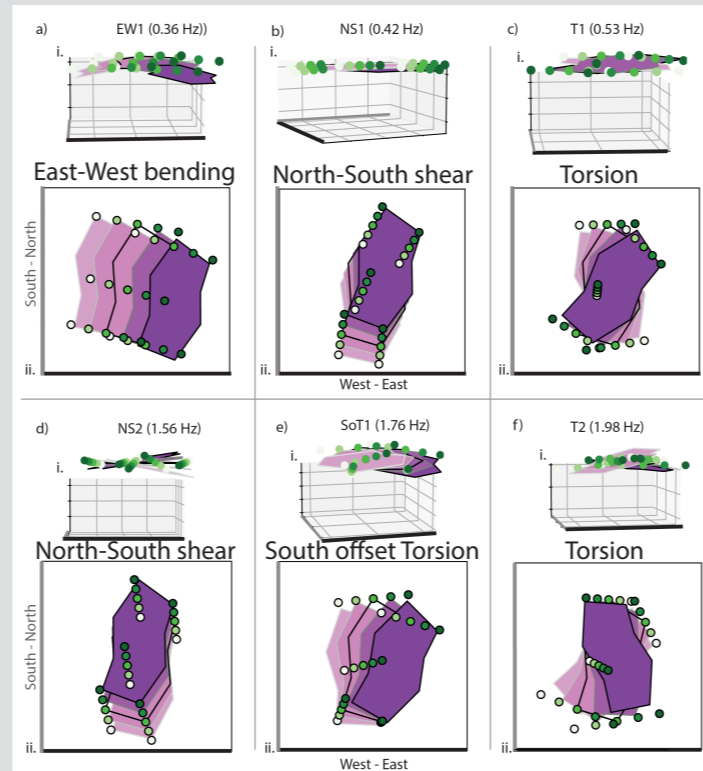
Rossi, Y., Tatsis, K., Clinton, J., Chatzi, E. and Rothacher, M., „A new paradigm for structural characterisation - including rotational measurements at a single site.", in review, BSSA.
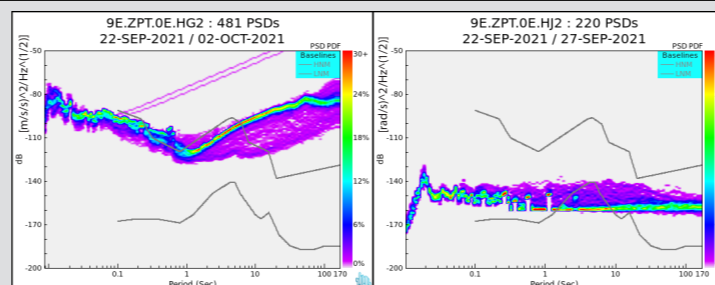
6C-station:

Horizontal array:

Right: Mode shapes of primary modes using a 6C-station and a horizontal array.

Description	Primary modal freqs.	Mode shapes: translation vs. torsion	Mode shapes: bending vs. shearing	Installation
6C-station	✓	✓	partly	simple
Horizontal array	✓	✓	partly	difficult
Vertical array	✓	✗	✓	very difficult

Top: Table comparing different instrument setups.

Right: SQLX derived PSD plots of the 6C-station, using all available data from station location 0E (North).
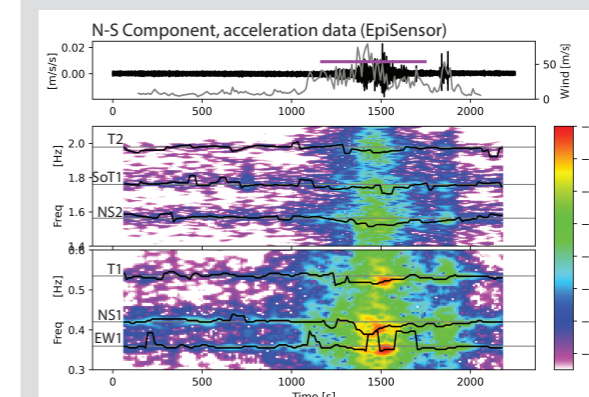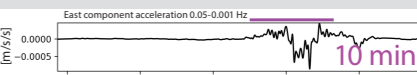
4 Annual Variation of EOC's
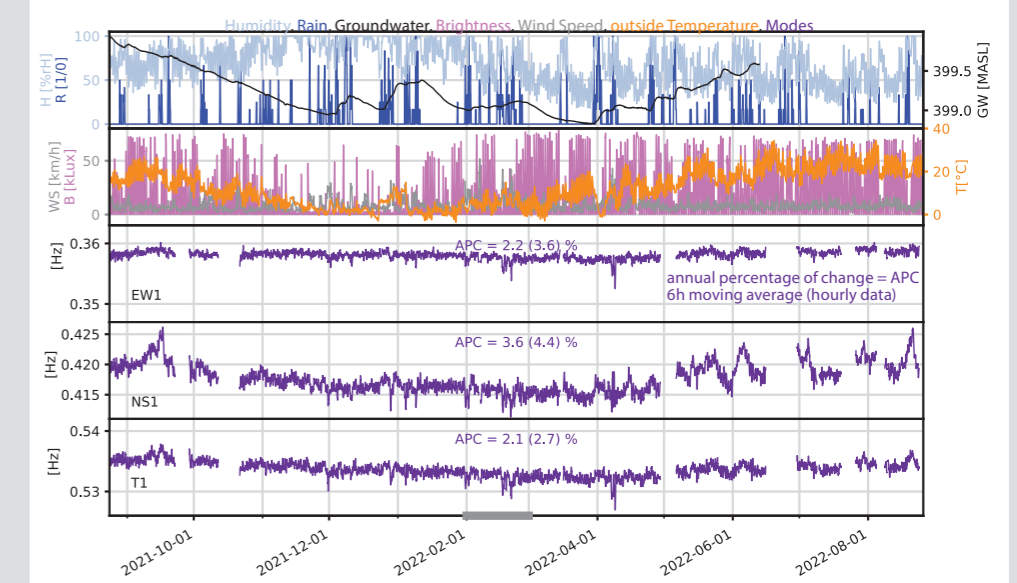
Rossi, Y., Tatsis, K., Reuland, Y., Hohensinn, R., Herrera-Pinzon, I., Clinton, J., Chatzi, E. and Rothacher, M., „Variation of modal properties over 1 year - using a single station 6C approach.", in prep.

5 Extreme Excitation Storm

- Storm, 12.07.21
- strong wind > 80km/h
- EW1, NS1, T1 excited
- clear dip in frequency
- recovery
- static tilt for 10 min

wind excites low frequencies

6 Conclusion

A 6C-station can reliably track the frequencies and modeshapes of a building including seasonal, daily and hourly variations. Additionally, it is capable of defining the frequencies of this building with a fidelity that is on par with a 5-sensor horizontal array, while it is much easier to install and operate than the traditional approach.

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