City-scale assessment of tunnelling-induced building deformations

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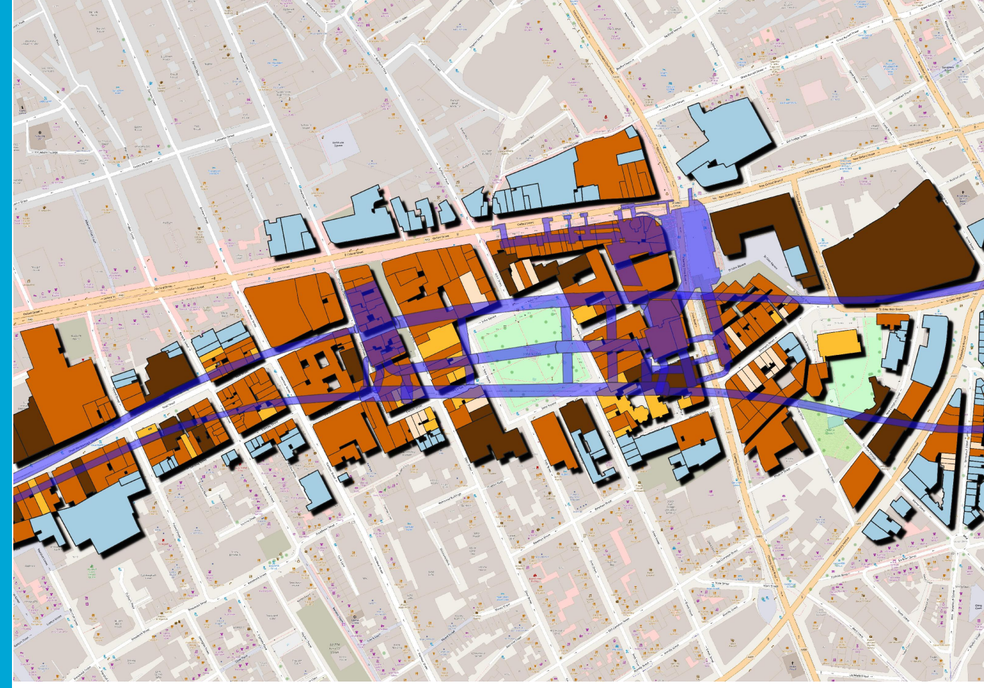
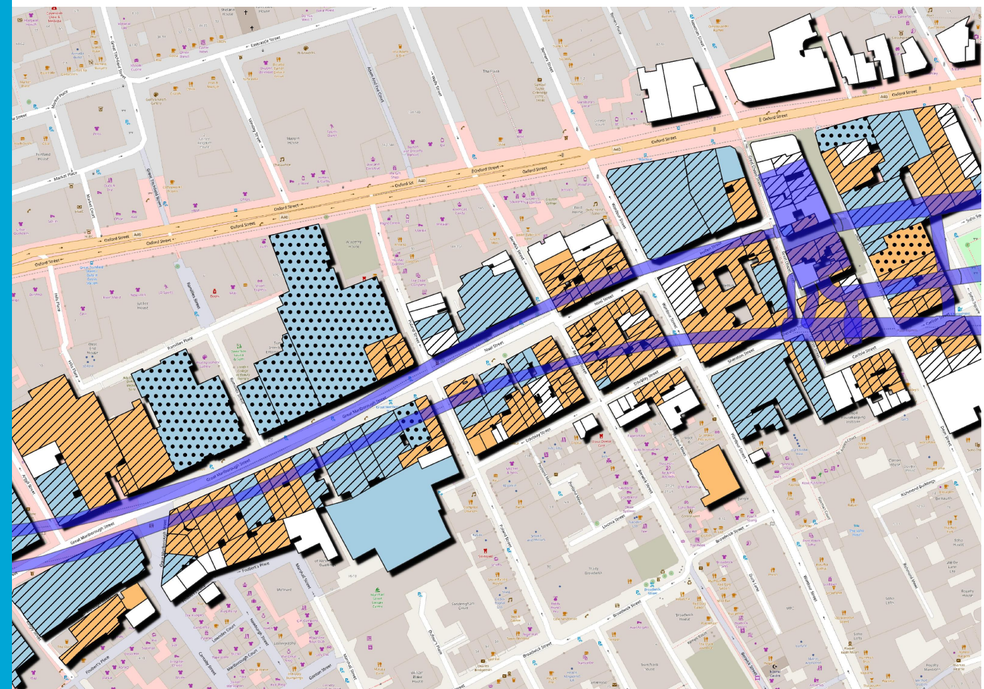
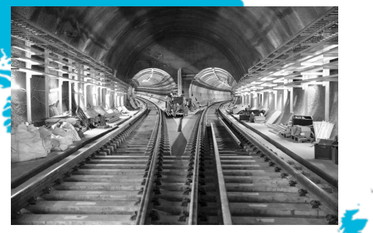
Delft University of Technology







Amsterdam

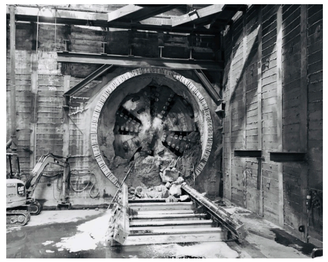
London

Paris

New York

Los Angeles

Doha



San Paulo

Sidney

Victoria Dock Portal

Canary Wharf

Whitechapel

Liverpool Street

Farrington

Tottenham Court Road

Bond Street

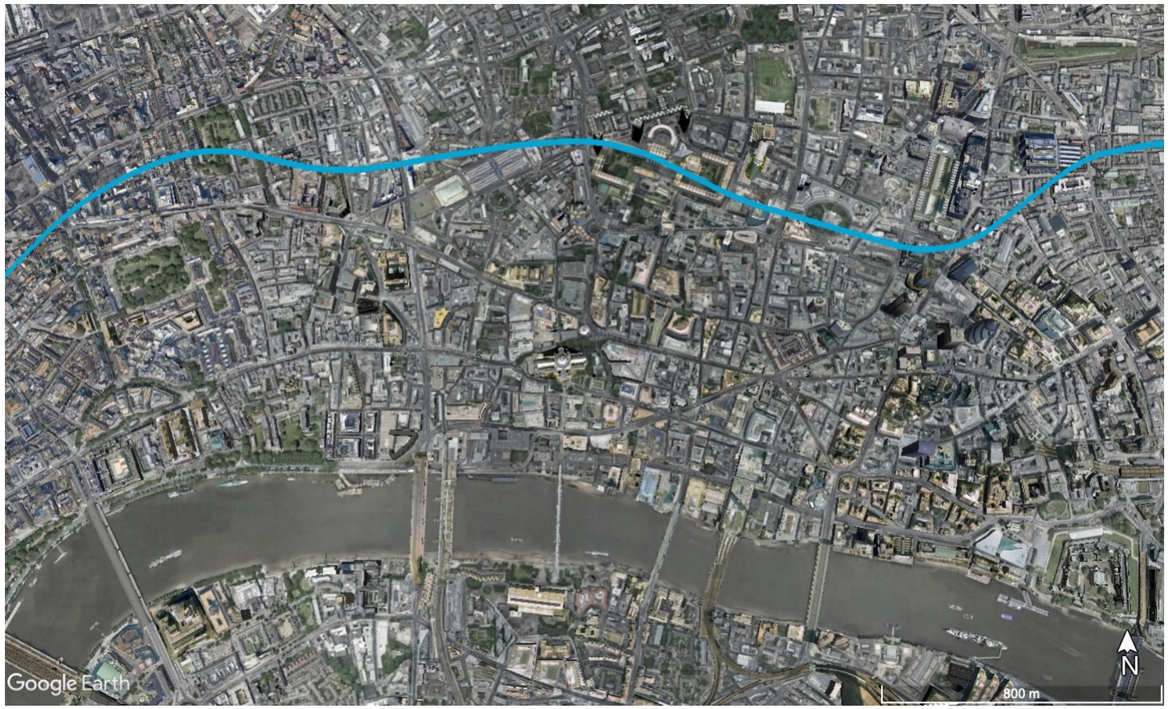
Paddington

Royal Oak Portal

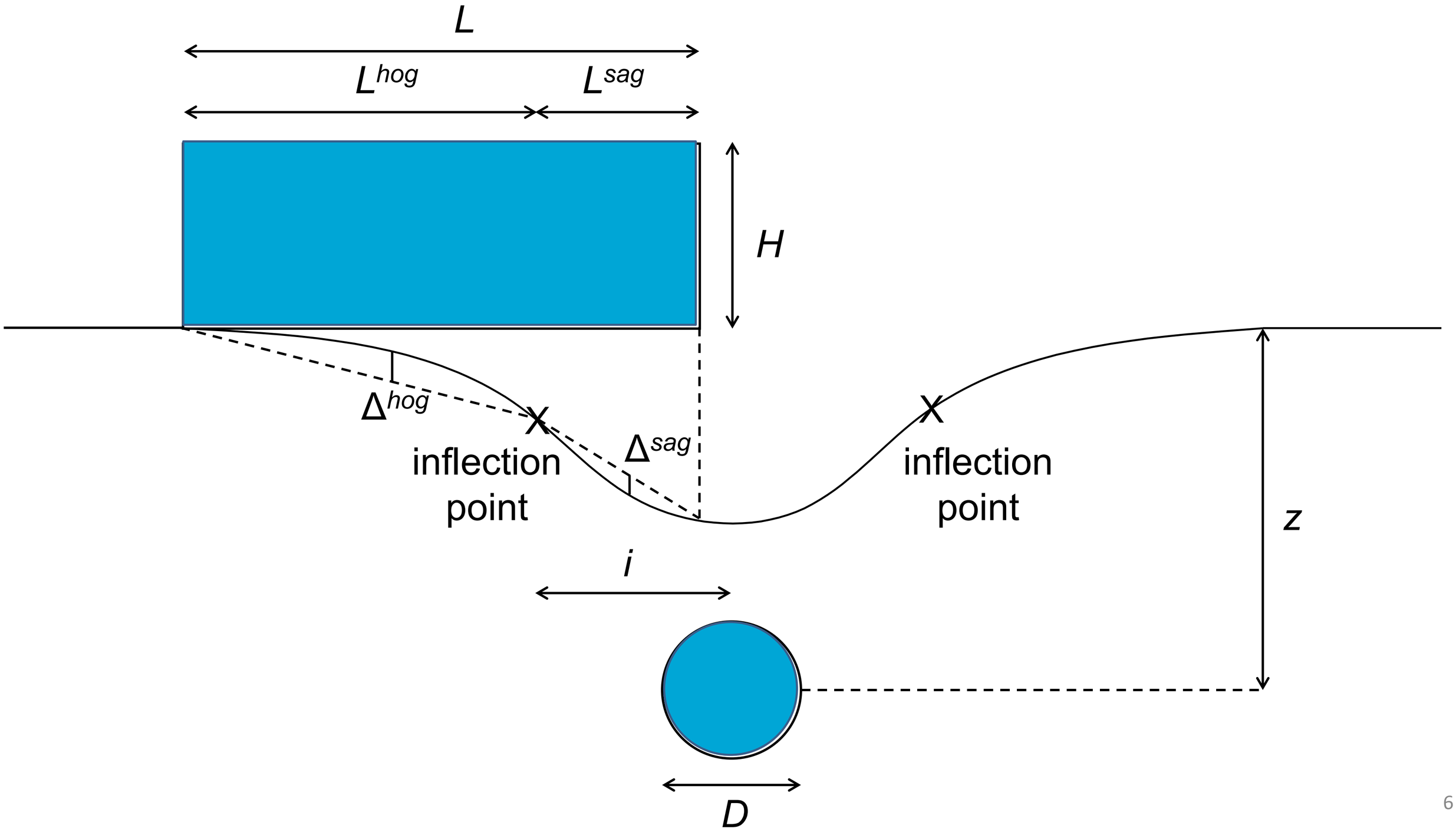
Building deformation monitoring

- Post-tunnelling damage assessment
- Building damage prediction

Current data availability



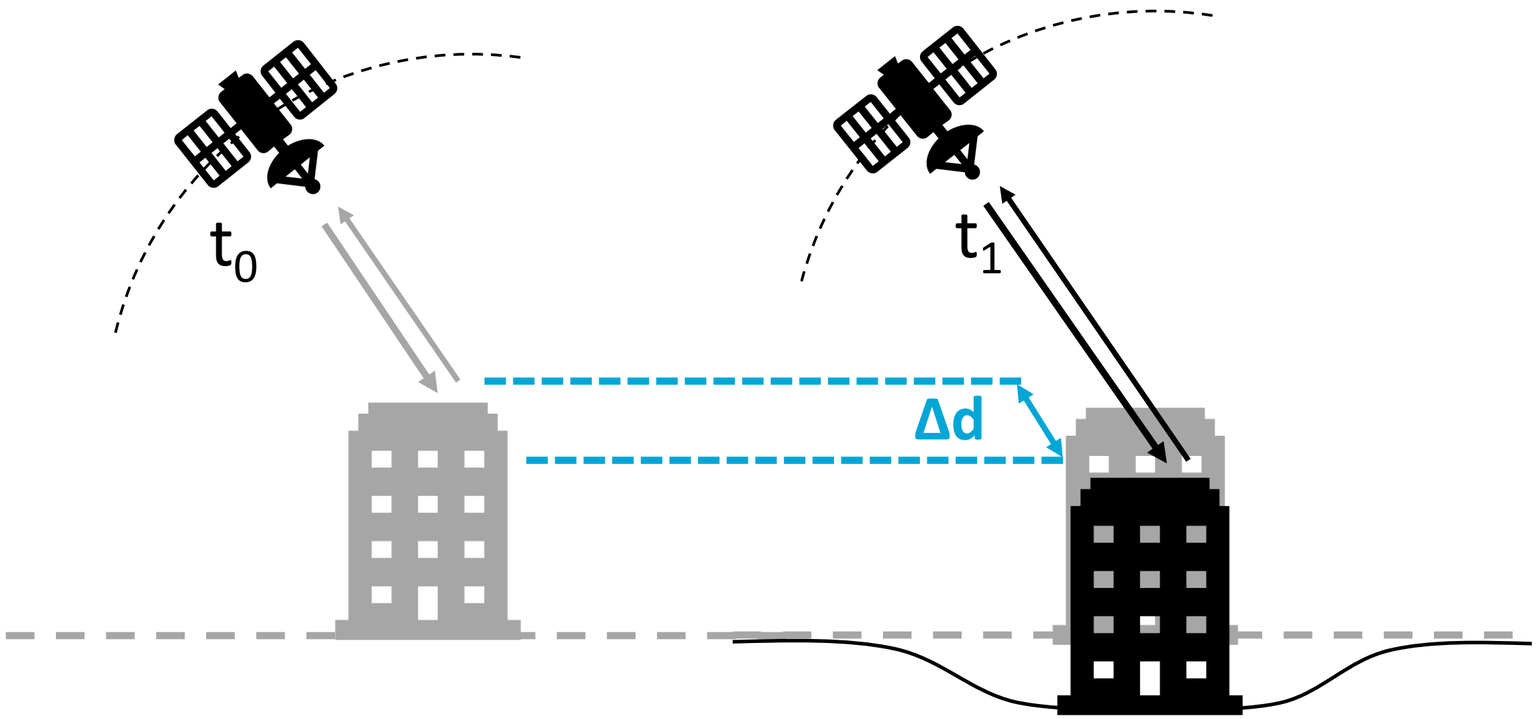
Many points on few buildings **OR** Few points on many buildings


L
L hog
L sag
H
Δ hog
Δ sag
inflection point
inflection point
z
i
D

Building deformation monitoring

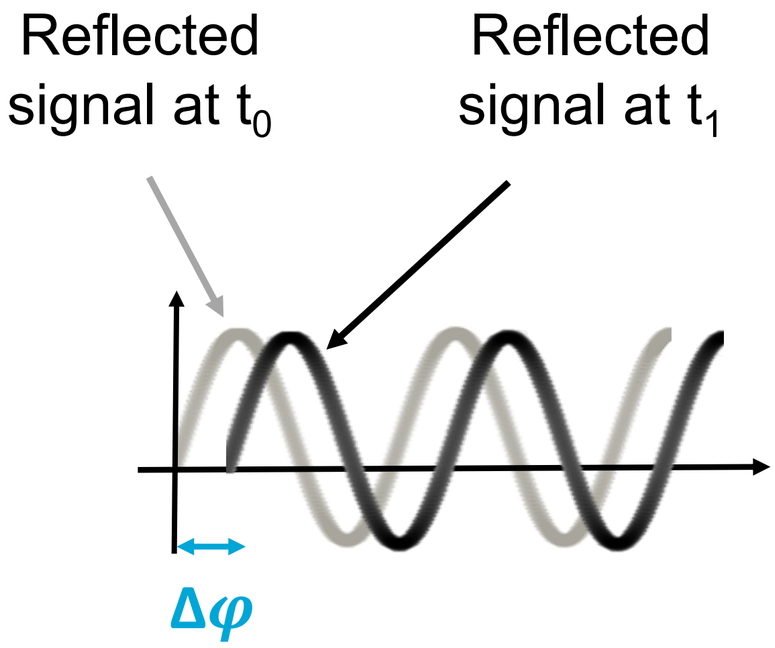
- Post-tunnelling damage assessment
- Building damage prediction

Satellite Radar (InSAR)



Satellite
first acquisition

Satellite
second acquisition



Phase difference → MILLIMETRIC DISPLACEMENT

High accuracy

High spatial density

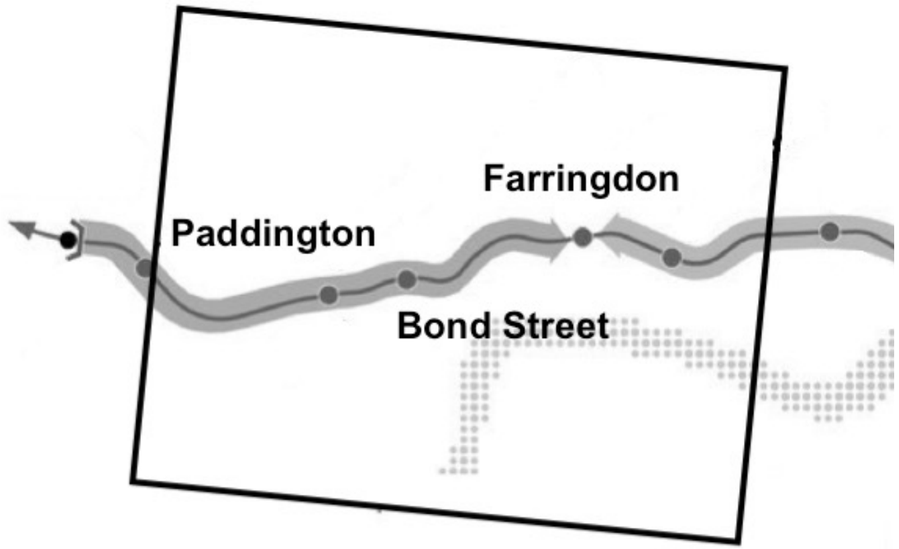
Large scale coverage

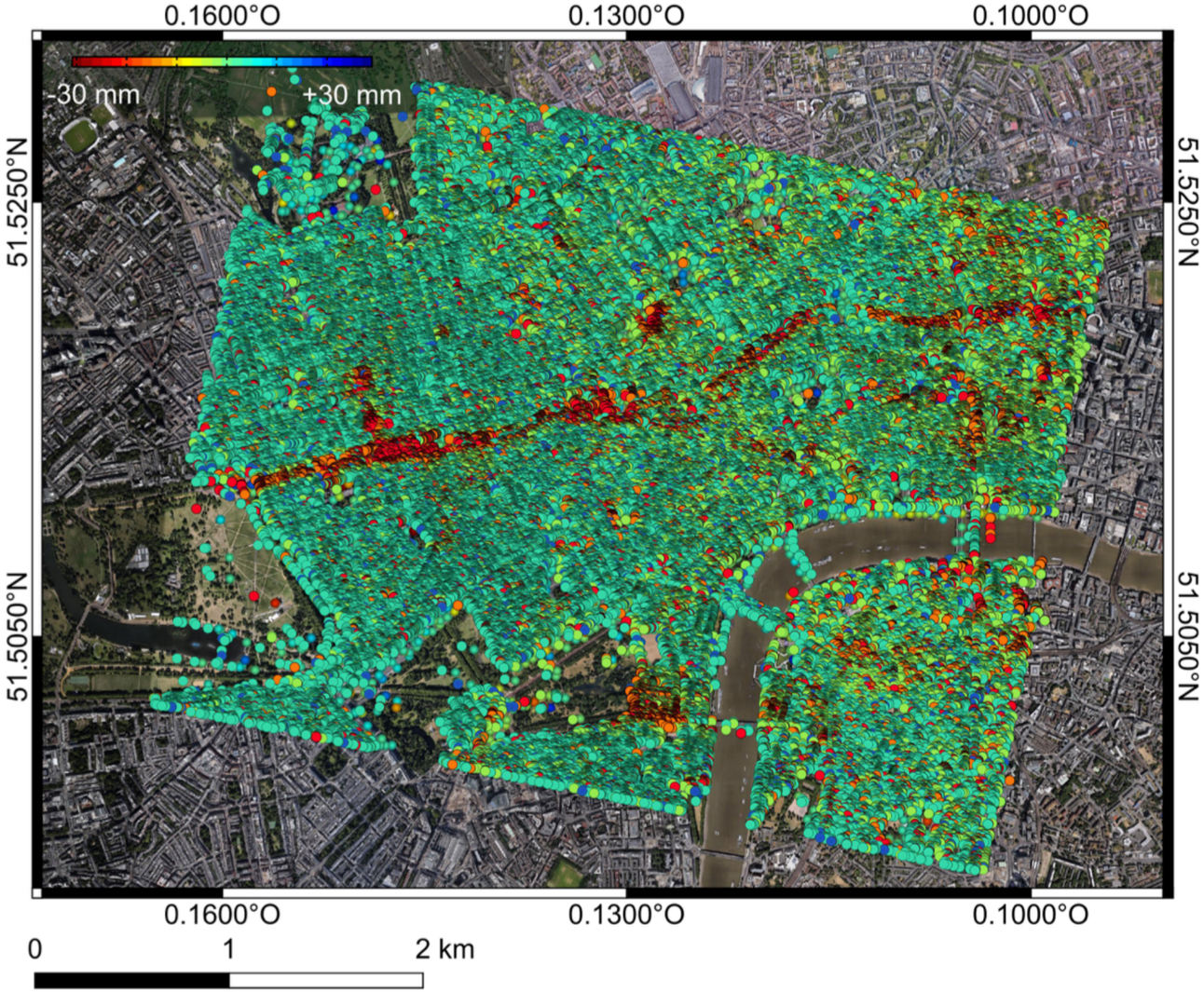
Short revisit time

Objective

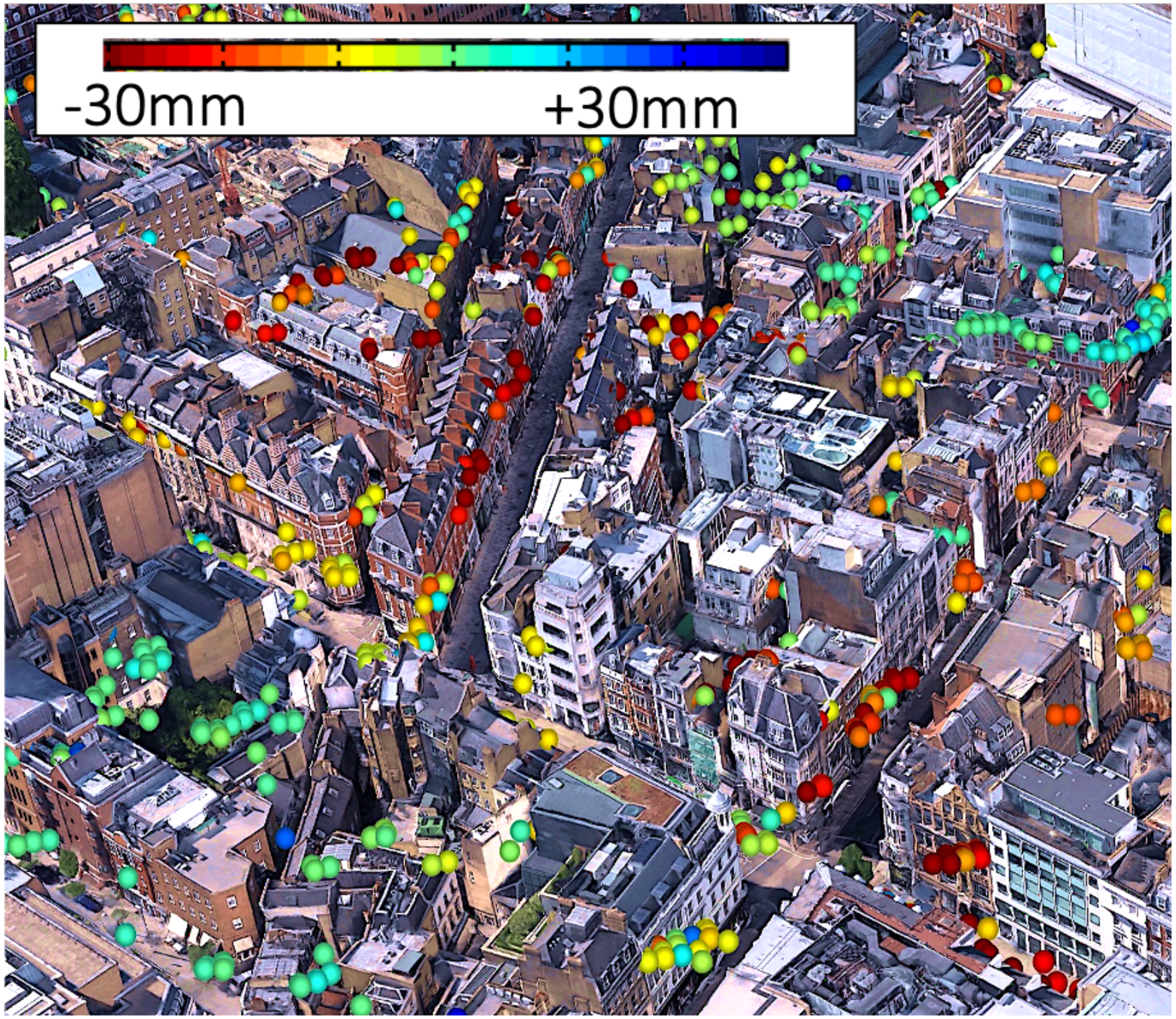
New automated methodology integrating InSAR-based building deformations and assessment procedures to evaluate settlement-induced damage to buildings adjacent to tunnel excavations on city-scale.

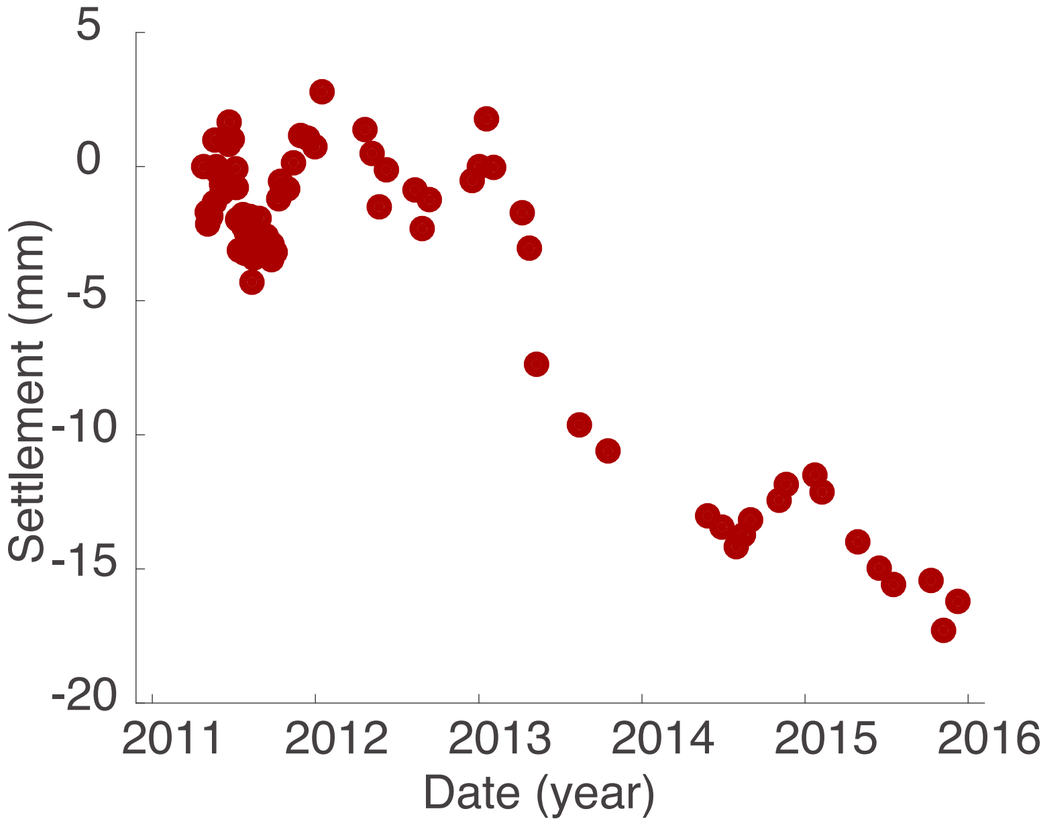
Crossrail tunnels, London



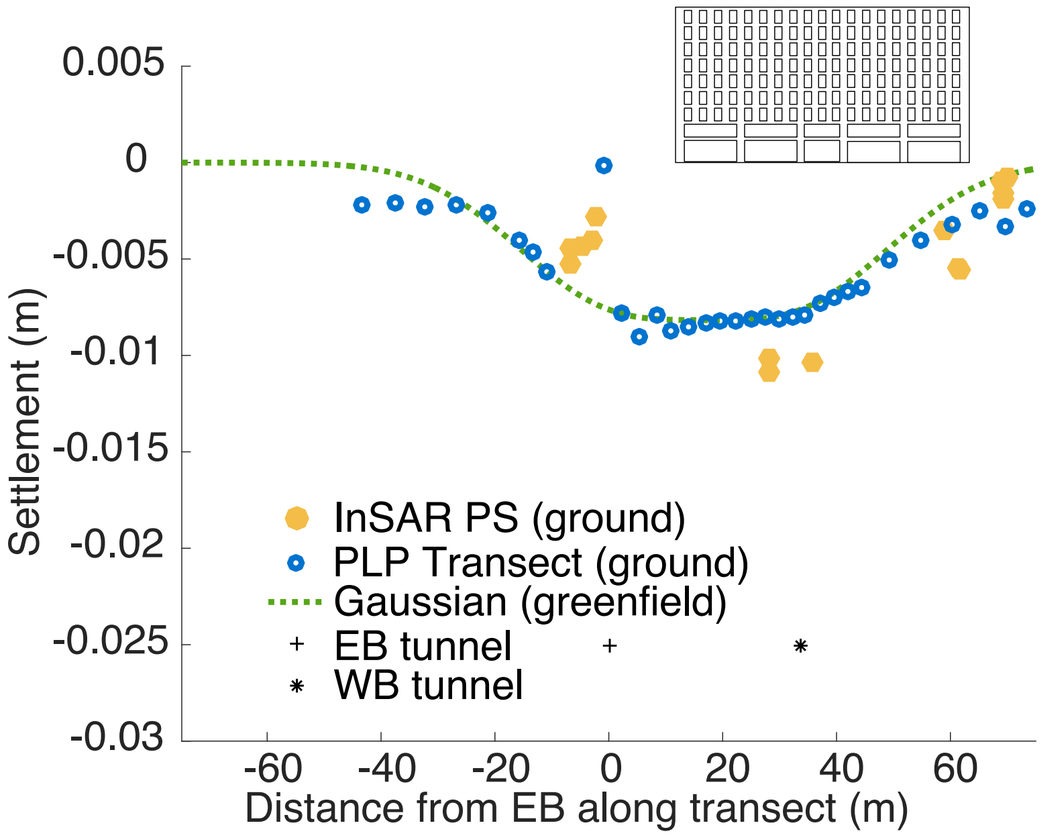


Giardina, G, Milillo, P, DeJong, MJ, Perissin, D and Milillo, G 2019, Evaluation of InSAR monitoring data for post-tunnelling settlement damage assessment, *Structural Control and Health Monitoring*

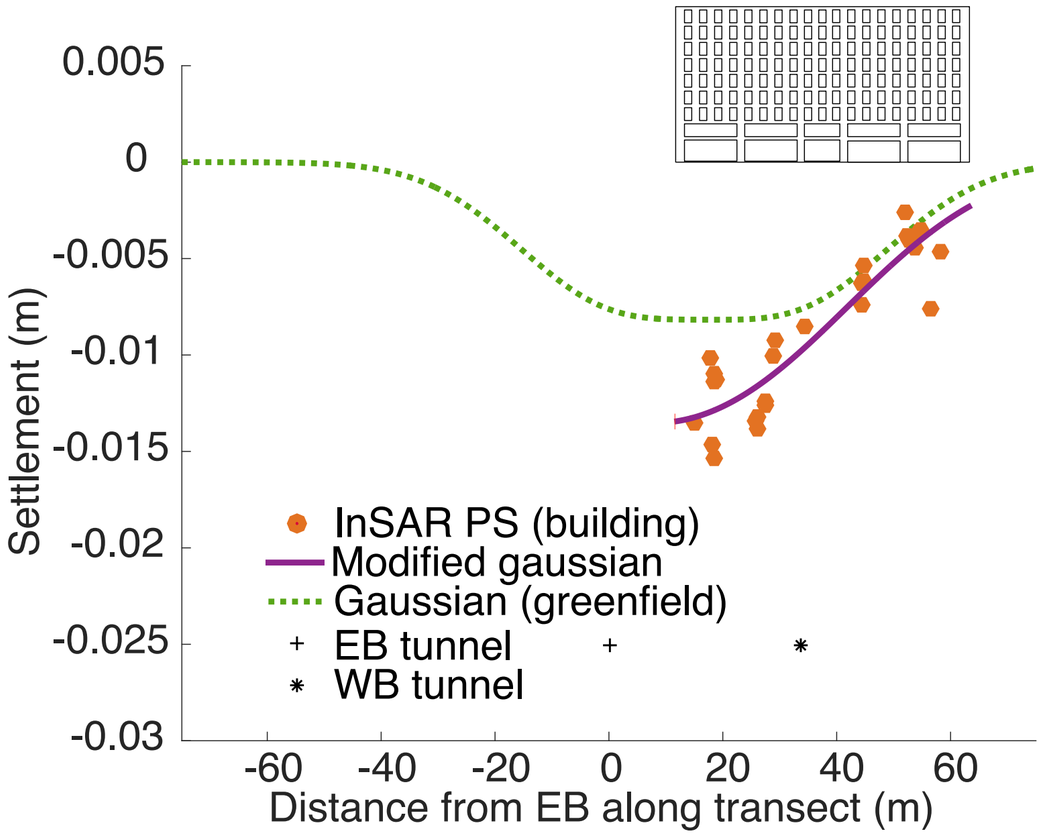

-30mm
+30mm


5
0
-5
-10
-15
-20
Settlement (mm)
2011
2012
2013
2014
2015
2016
Date (year)

Ground settlement



Building settlement



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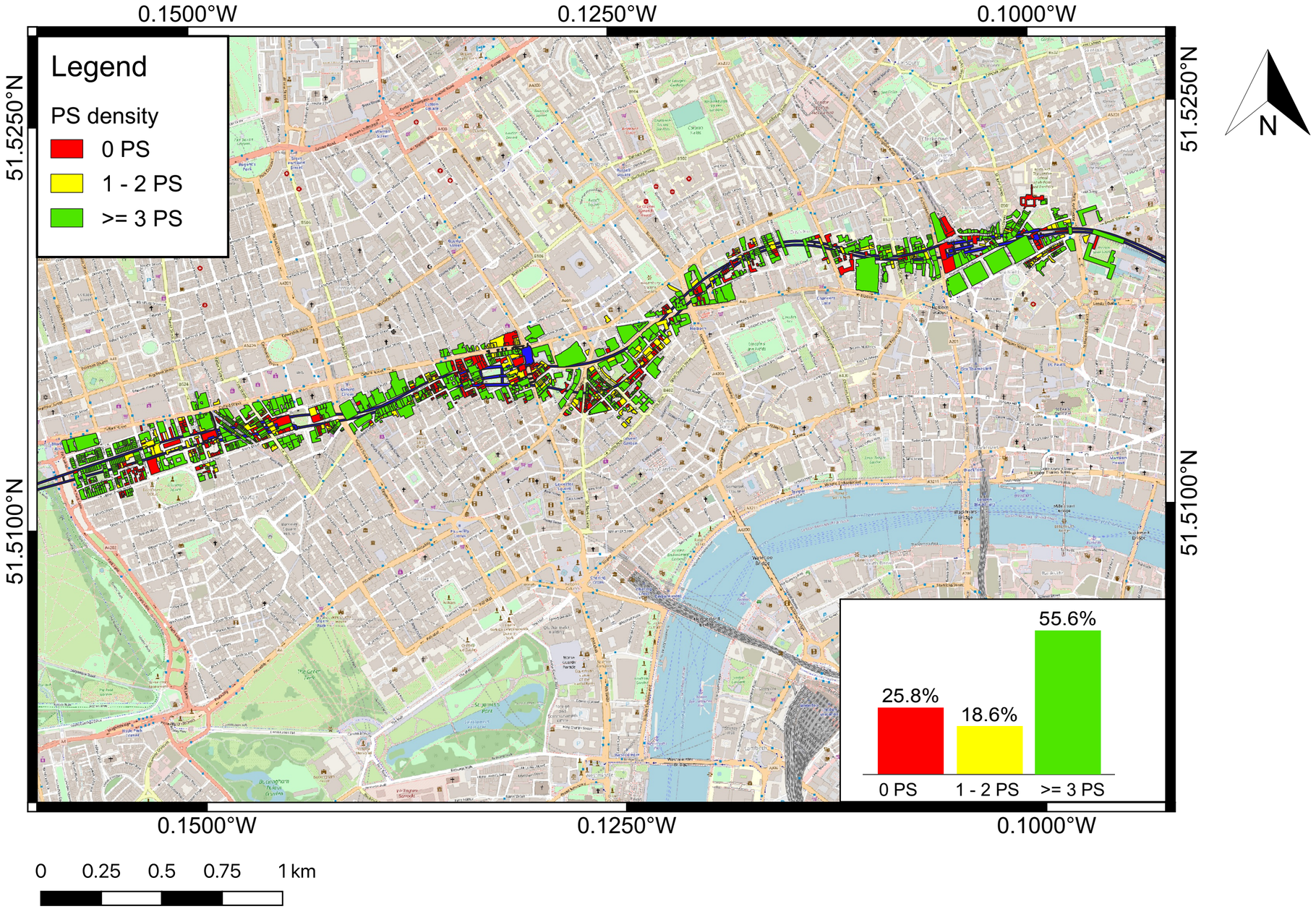
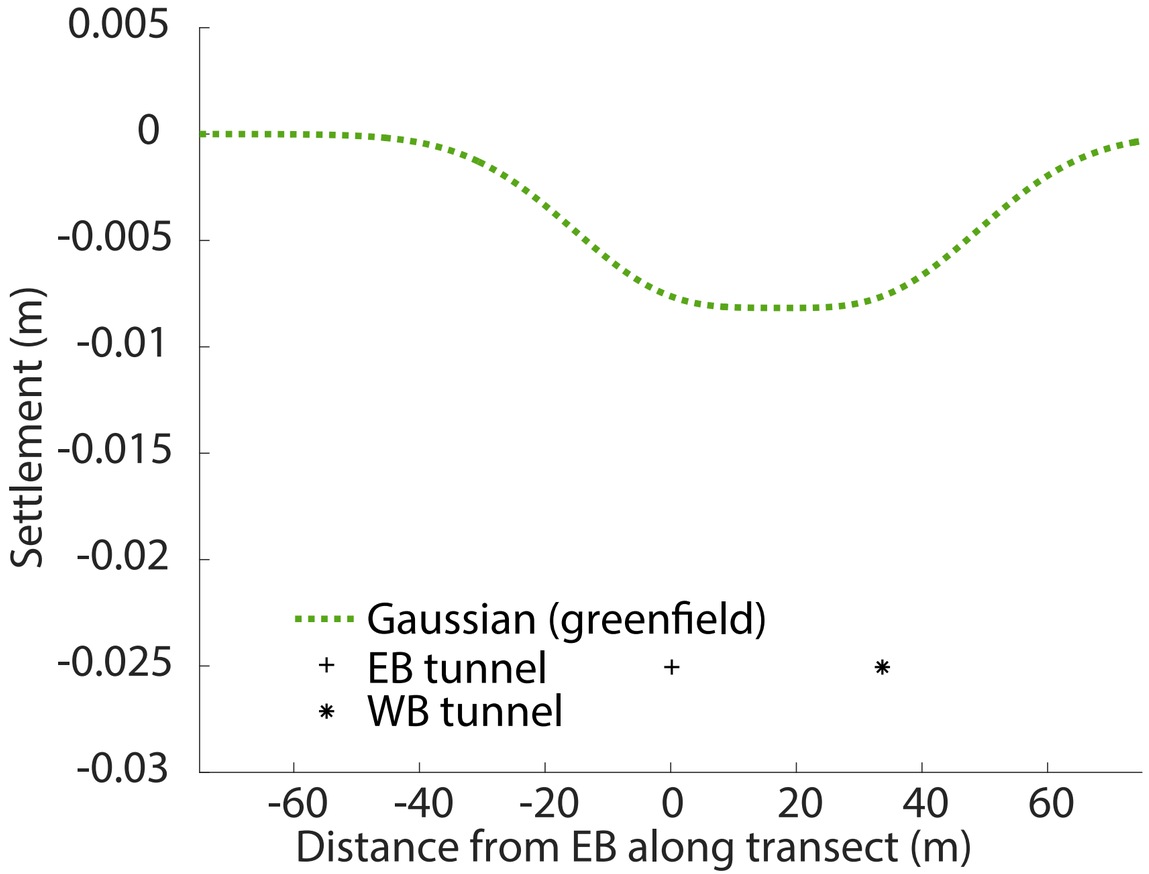


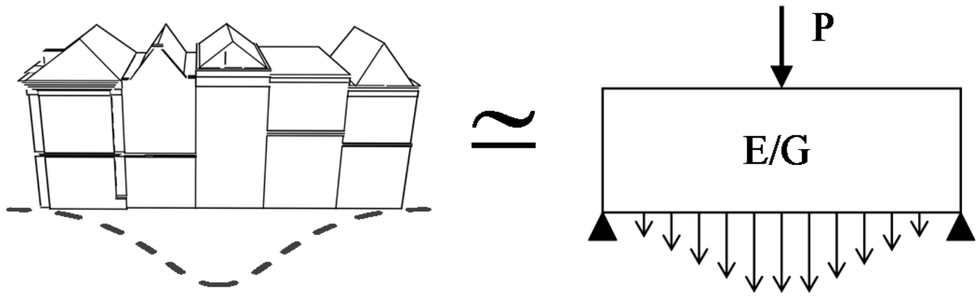
Macchiarulo, V, Milillo, P, DeJong M, Gonzalez Marti, J, Sanchez, J and Giardina, G 2021, Integrated InSAR monitoring and structural assessment of tunnelling-induced building deformations, *Structural Control and Health Monitoring*

1. Tunnelling-induced settlement profile in the absence of surface structures:

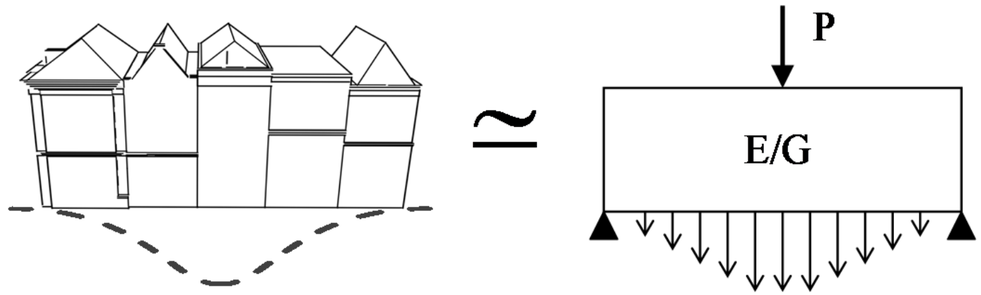
$$S(x) = \sqrt{\frac{\pi}{2}} \frac{V_L D^2}{4i} \mathrm{e}^{-\frac{x^2}{2i^2}}$$



2. Maximum bending strain $\varepsilon_{b,\max}$ and diagonal strain $\varepsilon_{d,\max}$:

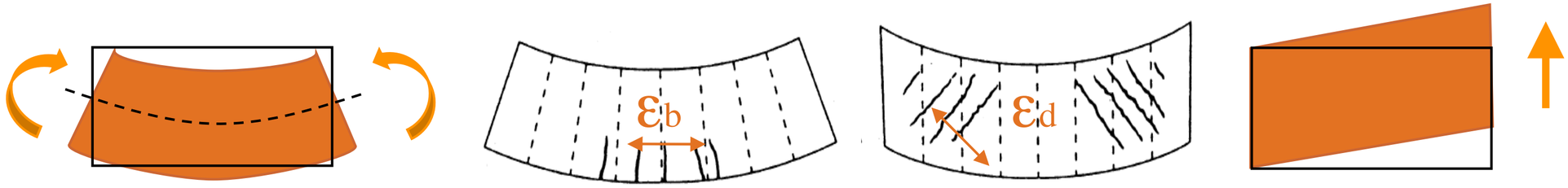


2. Maximum bending strain $\varepsilon_{b,\max}$ and diagonal strain $\varepsilon_{d,\max}$:



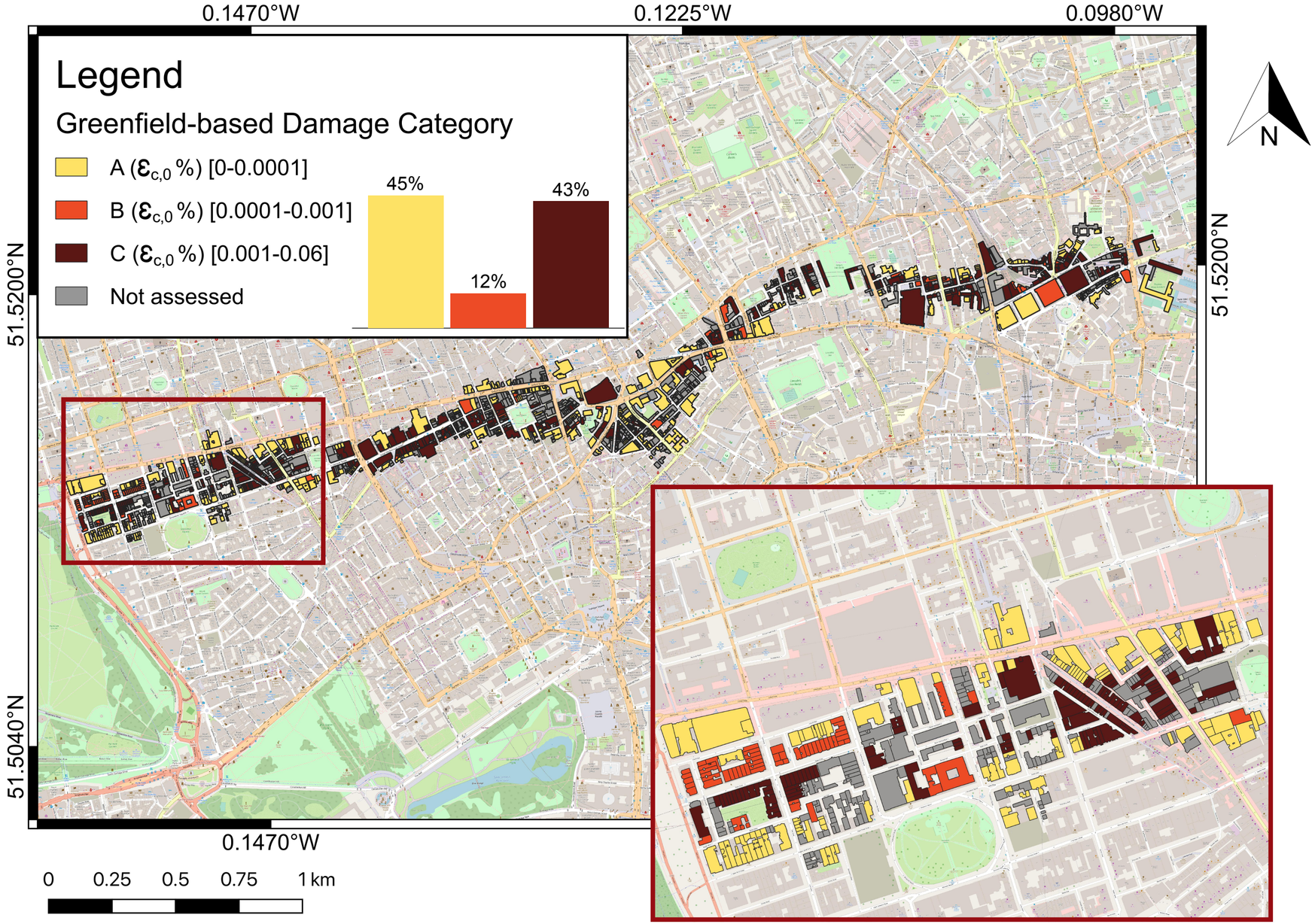
Bending

Shear



$$\varepsilon_{b,\max} = \frac{\Delta/L}{\frac{1}{12}\frac{L}{t} + \frac{3}{2}\frac{I}{tLH}\frac{E}{G}}$$

$$\varepsilon_{d,\max} = \frac{\Delta/L}{1 + \frac{1}{18}\frac{HL^2}{I}\frac{G}{E}}$$



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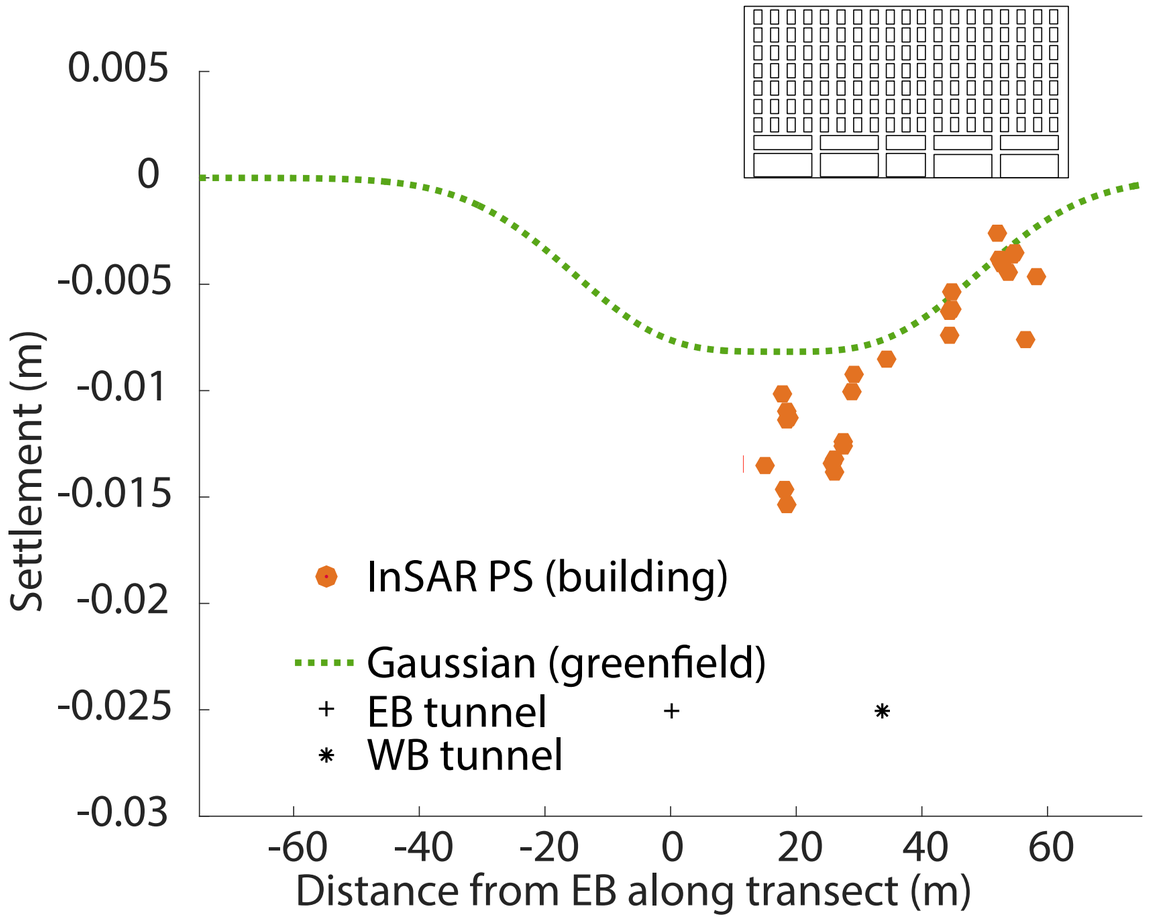
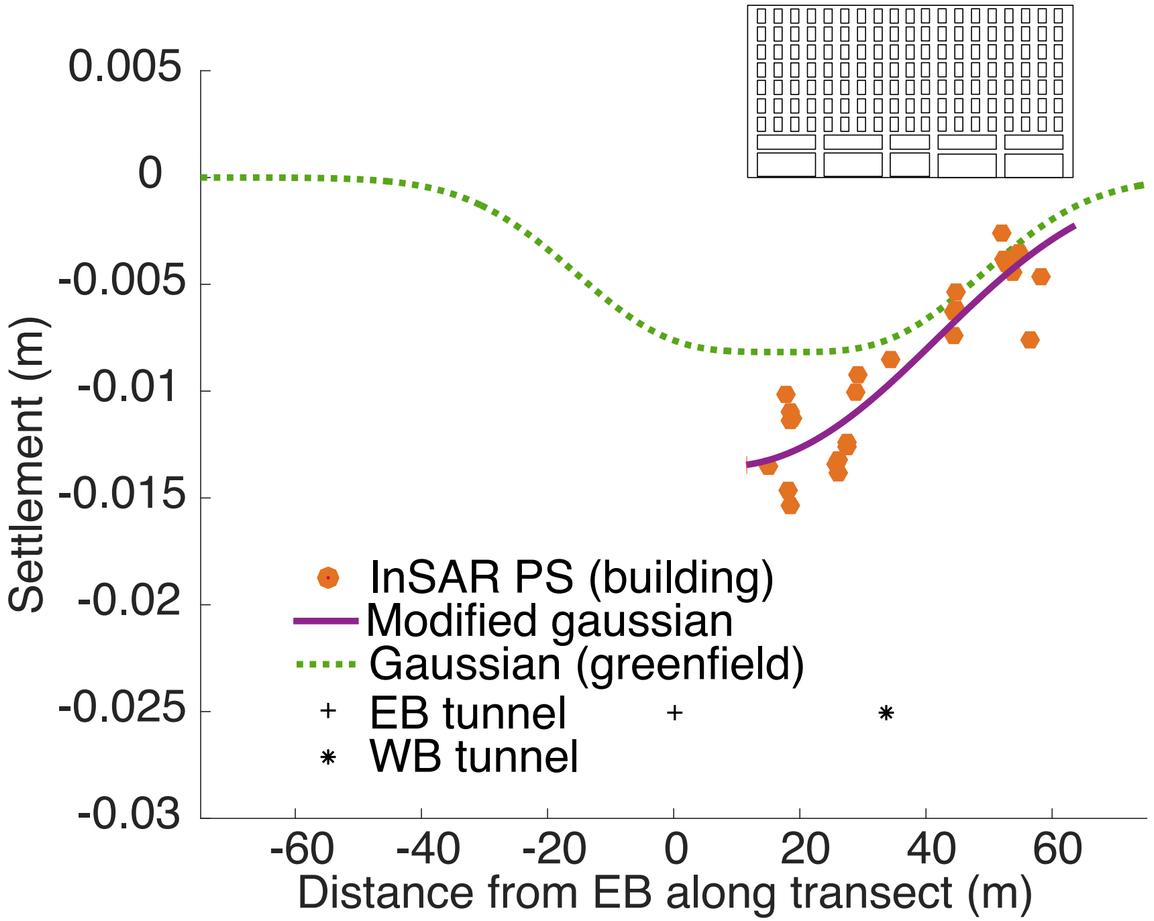
3. Actual (InSAR) building displacements

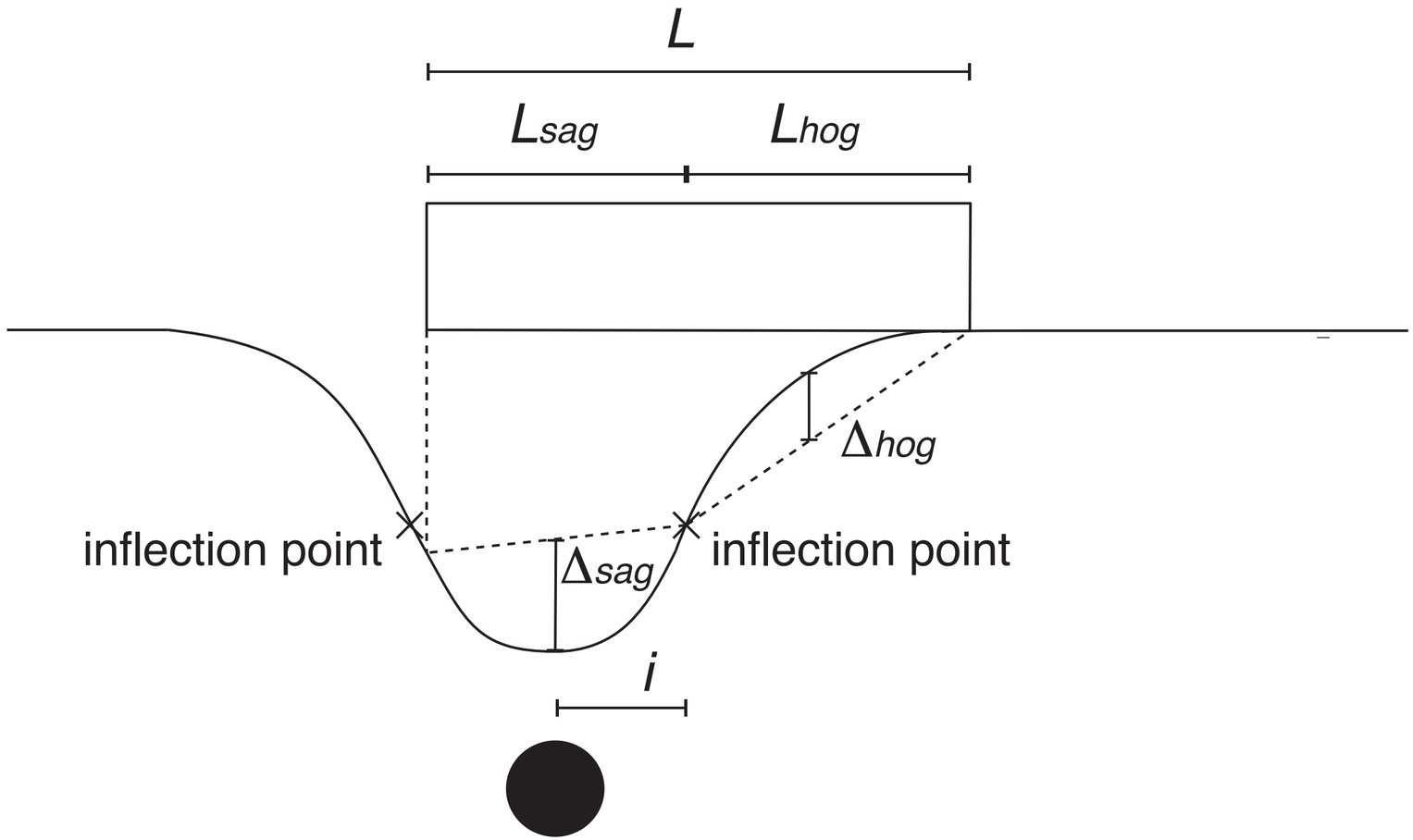


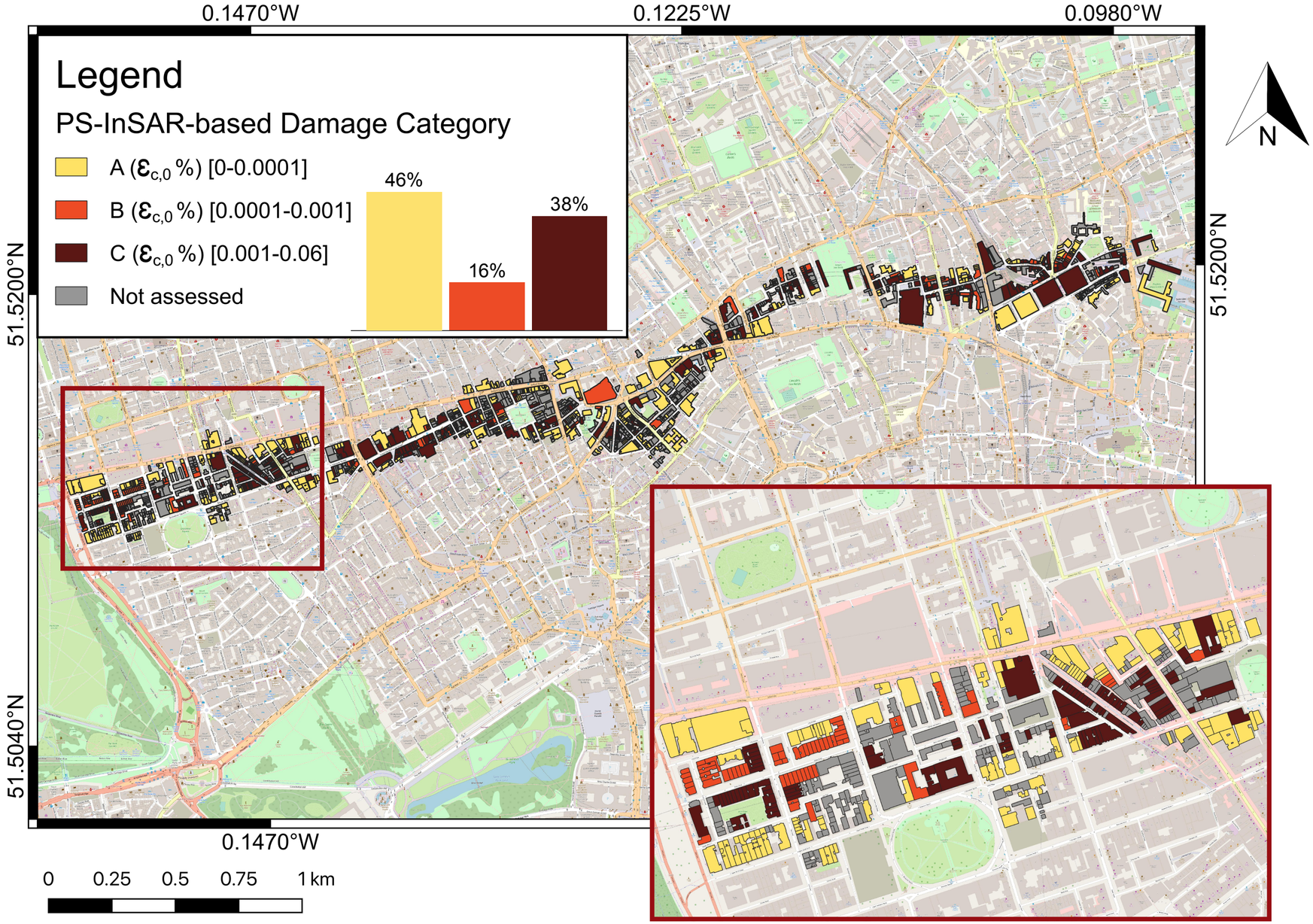
4. Fitting with a modified Gaussian function

$$S(x) = \sqrt{\frac{\pi}{2}} \frac{V_{Lm} D^2}{4 i_m} \mathrm{e}^{-\frac{x_m^2}{2 i_m^2}} \quad \text{where} \quad \mathrm{x_m} = \alpha + \mathrm{x},\ \mathrm{V_{Lm}} = \beta \mathrm{V_L},\ \mathrm{i_m} = \gamma \mathrm{i}$$



5. Maximum bending and diagonal strains from actual deflection ratio Δ/L





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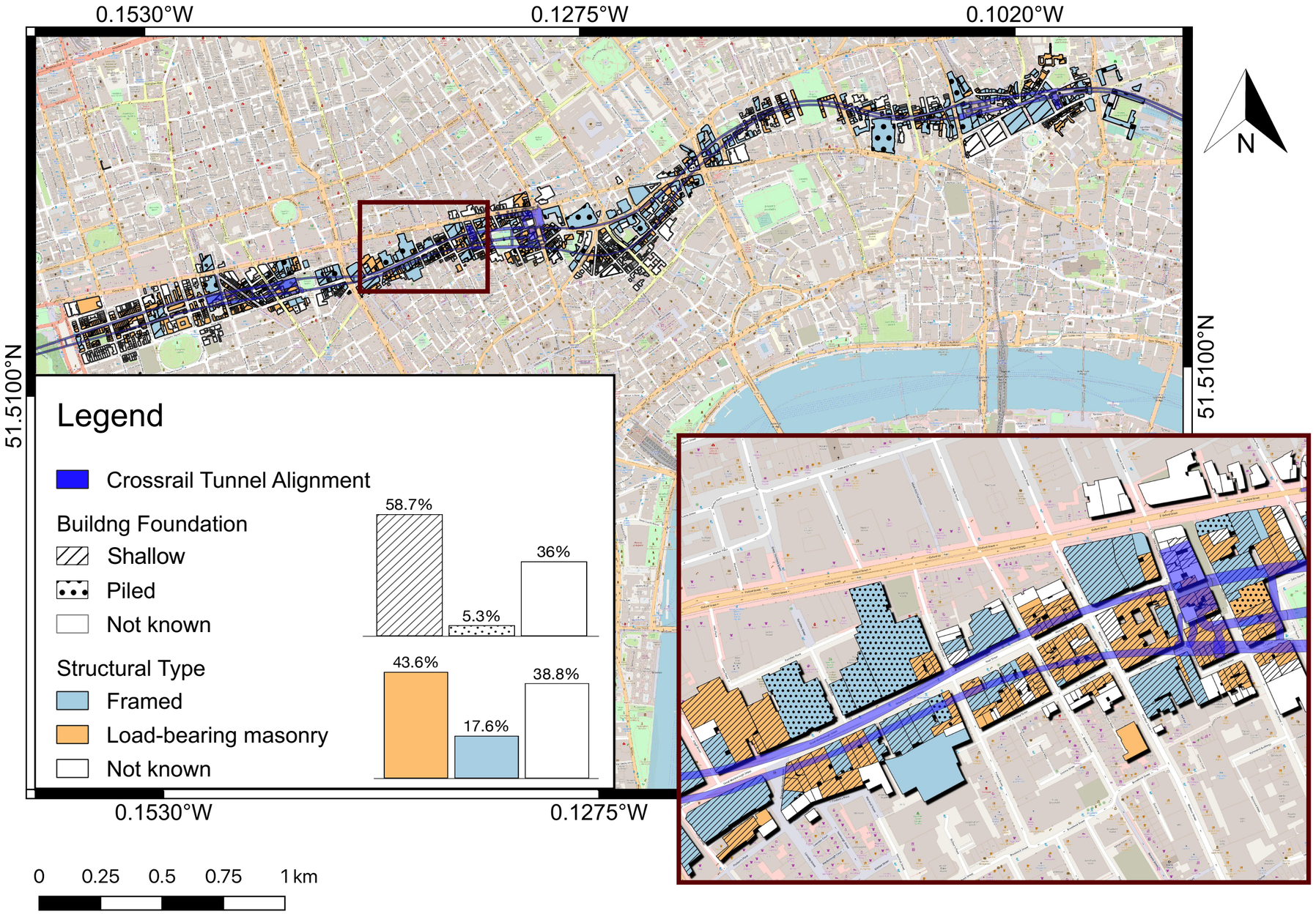

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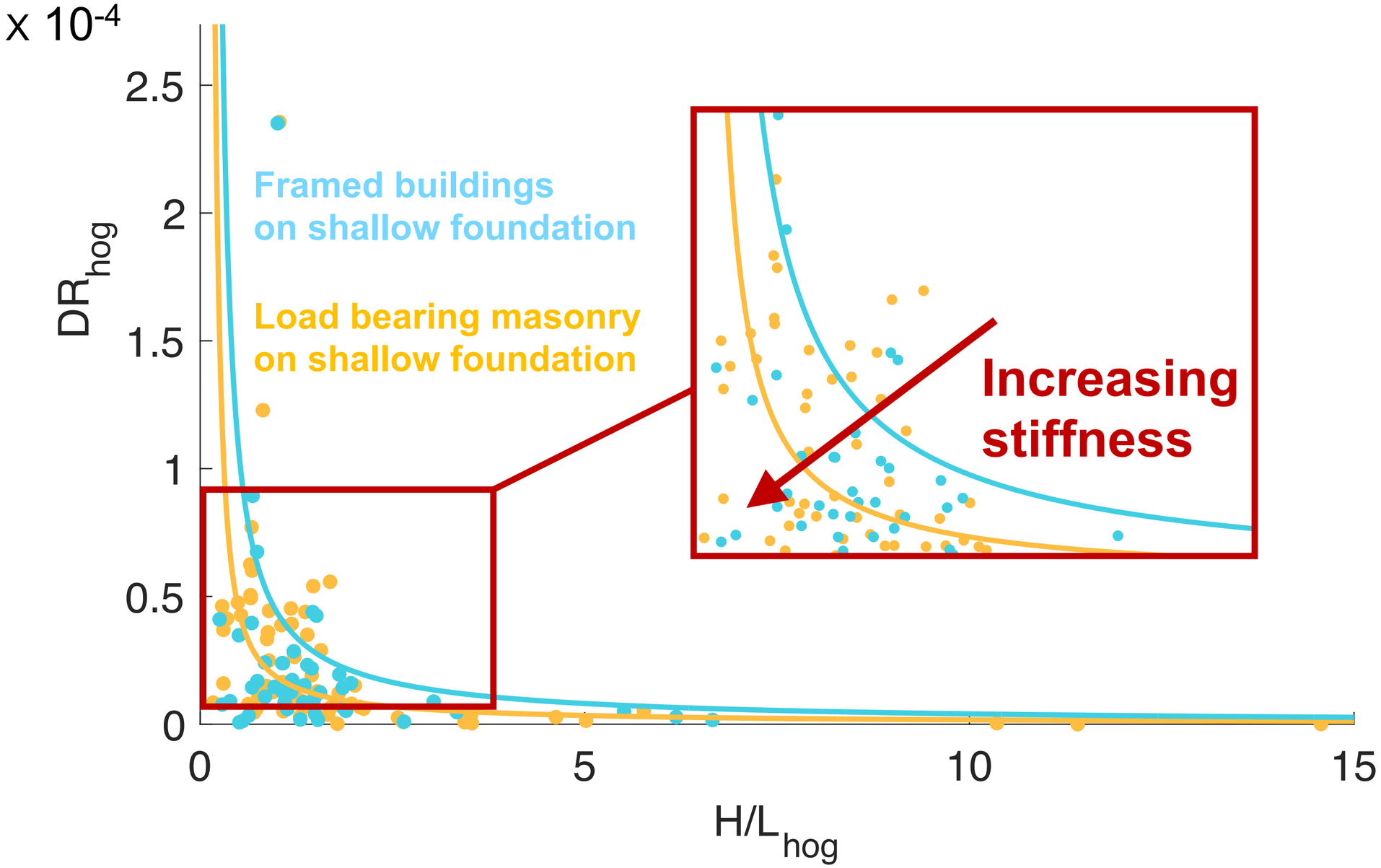

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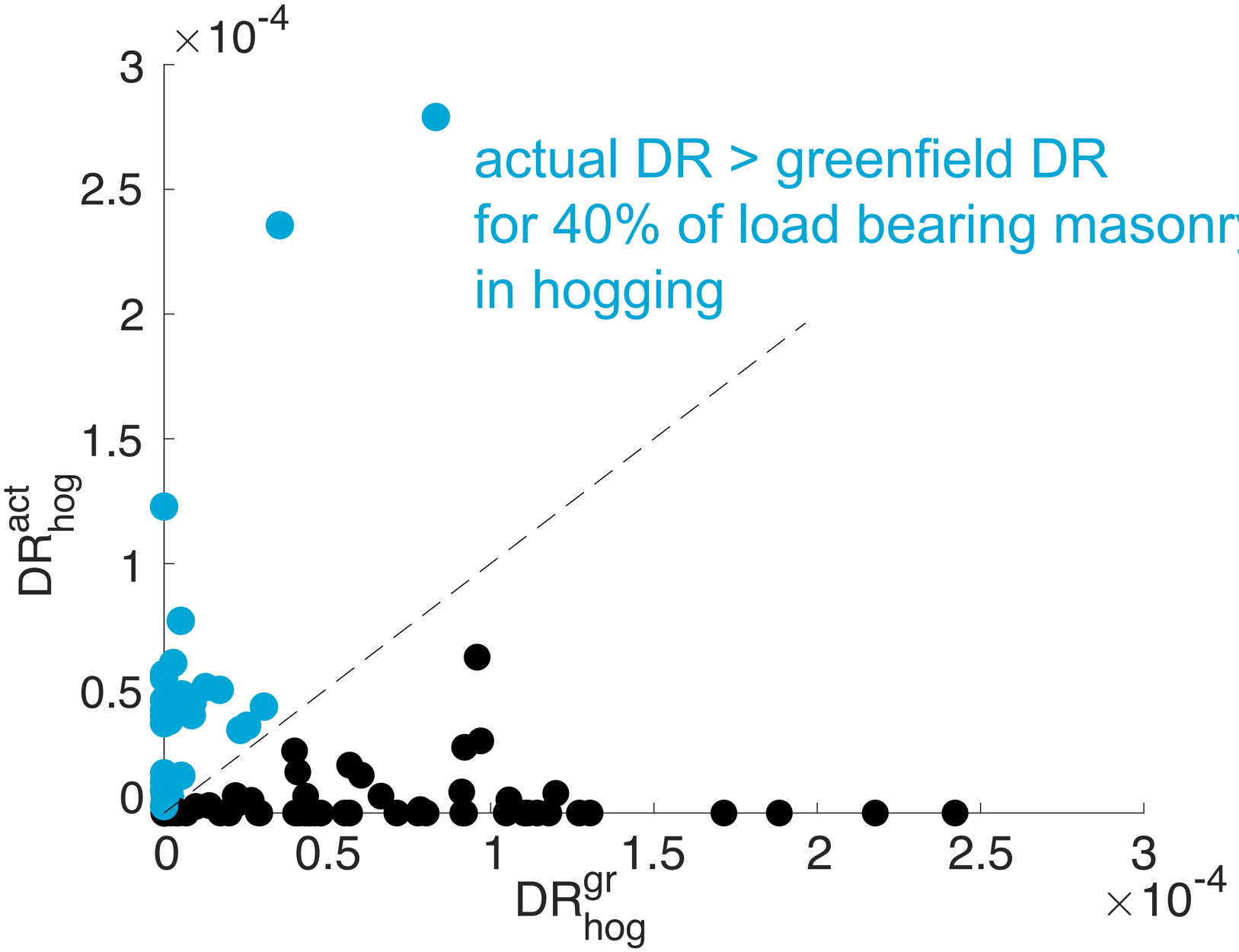

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Conclusions

- New automated integration of InSAR monitoring and damage assessment procedures
- Large amount of high-quality building measurements at city scale
- Possibility to investigate the structural response to tunnelling for different classes of buildings

Thanks!

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