1 BGS 1835

Università di Pavia — Dipartimento Scienze della Terra e dell'Ambiente 2

NPA Satellite Mapping 3

CGG GeoConsulting

A multidisciplinary approach based on PSI- derived ground motion, hydrogeological and lithological data to estimate the Chalk aquifer properties in the London Basin

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N° abstract 2249

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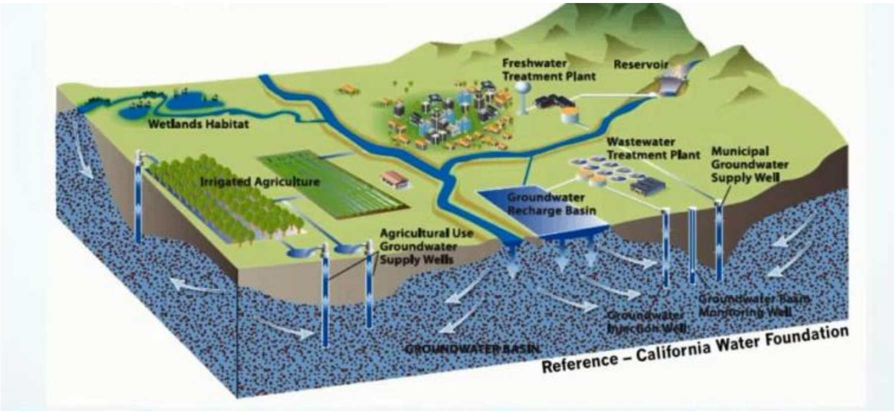
Background

Aim: To characterize aquifer properties (Storage) in-situ over wide areas and to understand local variability.

The high costs of borehole campaigns result in investigations on limited spatial and temporal scales.

Can remote sensing techniques be used to characterize aquifer storage at large-scales



http://cart.grac.org/SGM-Act

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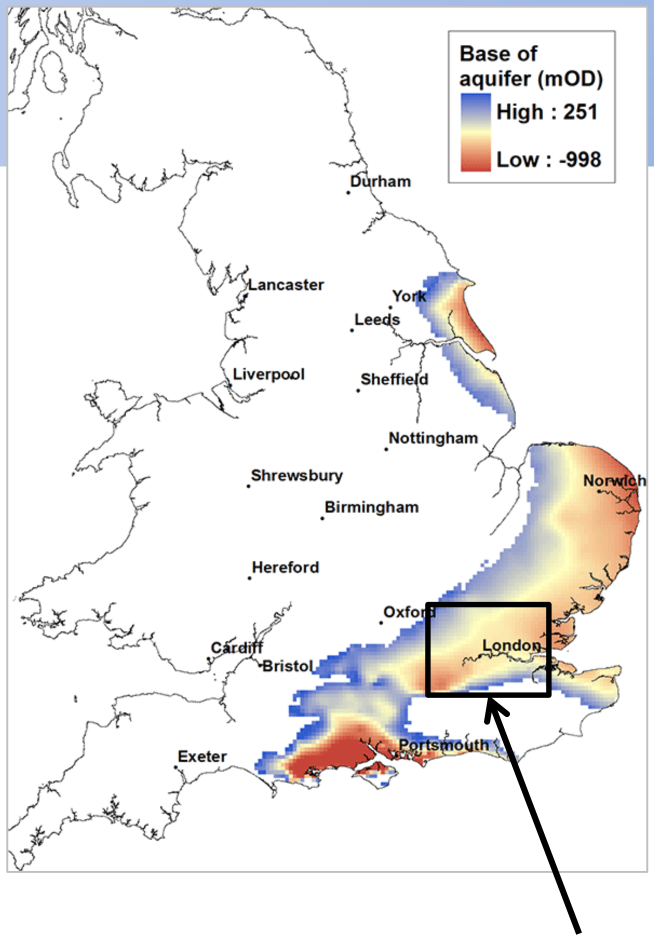
Research Objectives

Is there a relationship between groundwater level change and ground level change for the chalk aquifer? Can this relationship be quantified?



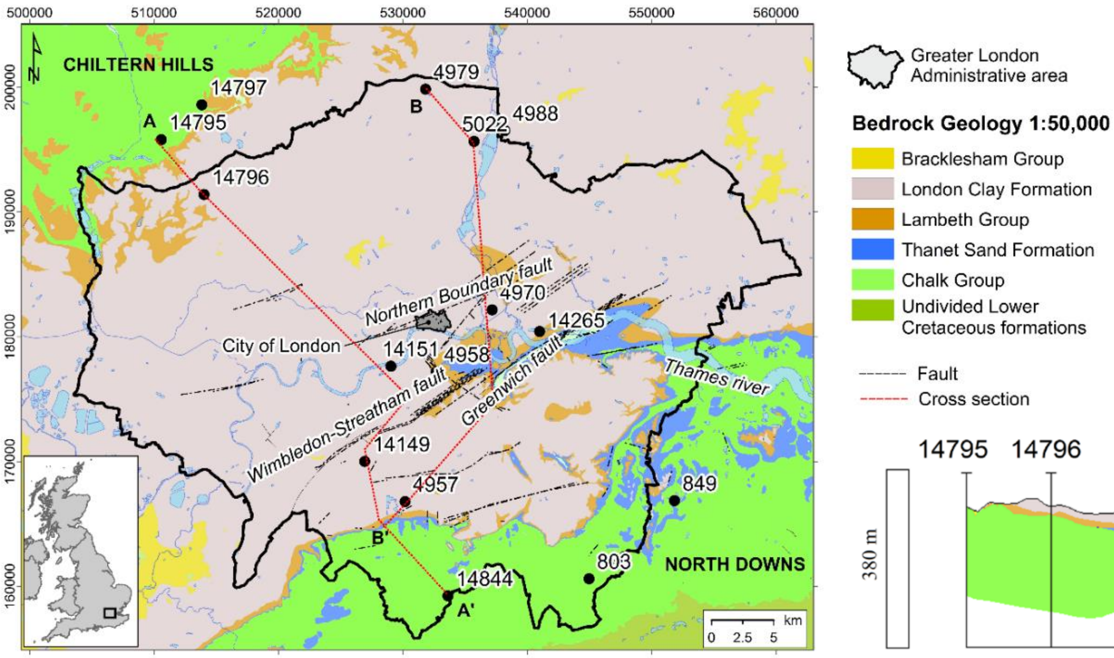
1) Estimation of the storage coefficient of the chalk aquifer under different aquifer conditions (unconfined, semi-confined, confined);

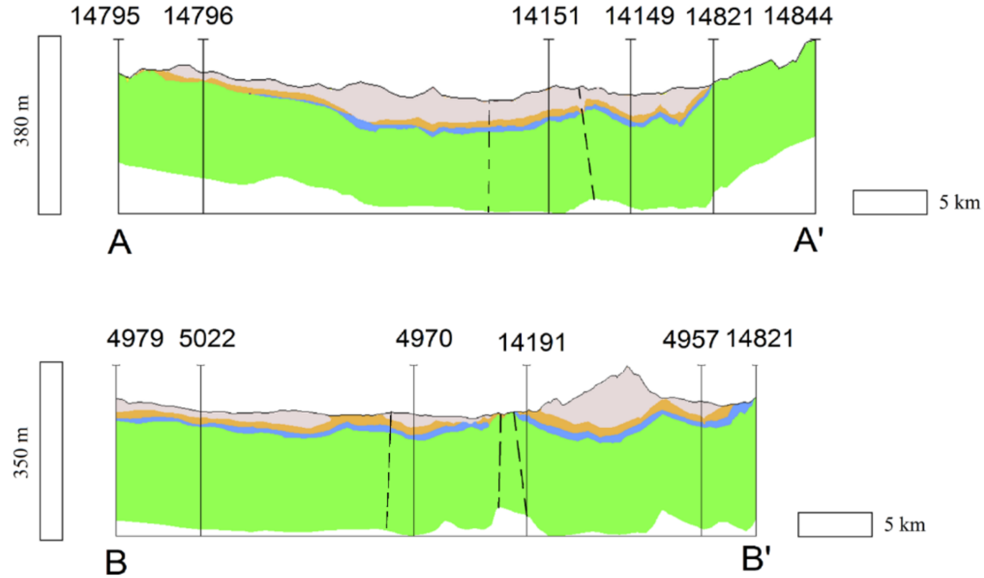
2) Characterisation of the aquifer properties over wide areas;

3) Modelling of the ground motion response to hydraulic head changes.

1. Study area

1.1. Geology of London





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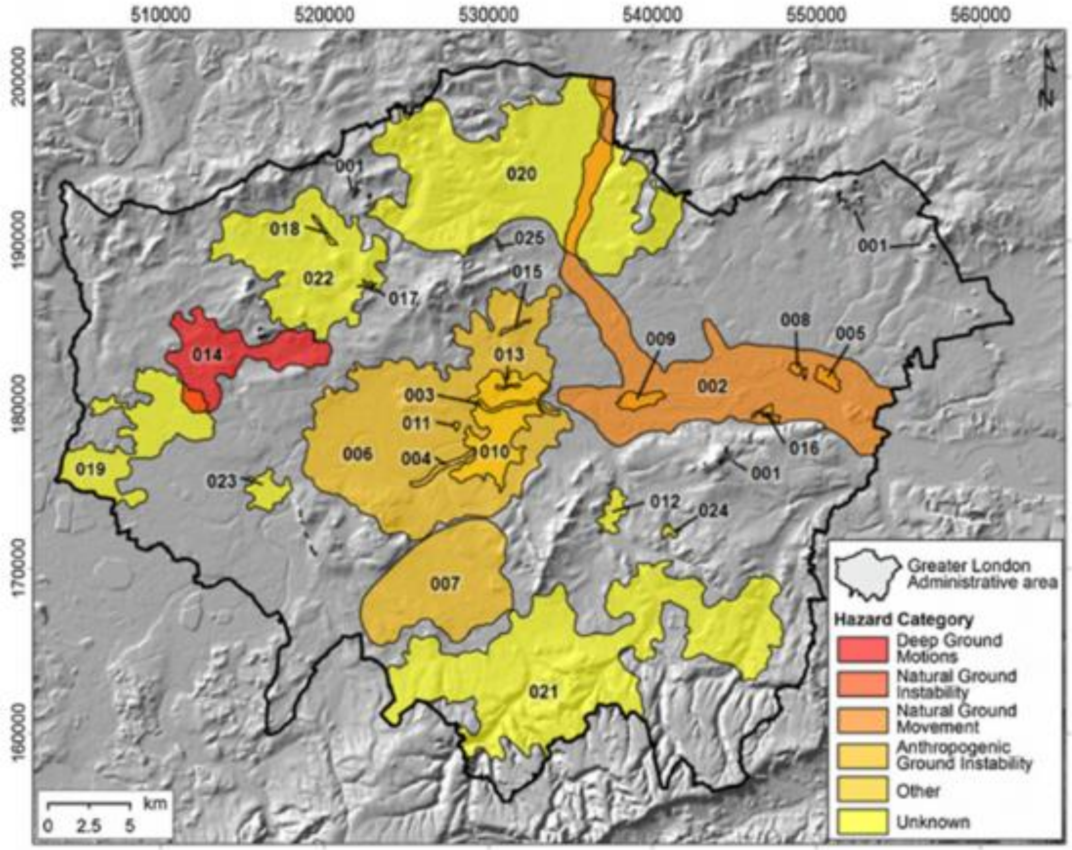
1. Study area

1.2. Geohazards



Cigna et al.. 2015

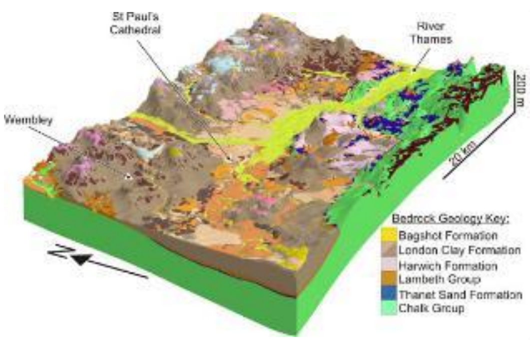
Figure 3

PanGeo Ground Stability Layer of Greater London: observed geohazards classified by Hazard Category and overlapped onto shaded relief of NEXTMap® DTM at 50 m resolution. *Labels* indicate the last three digits of the INSPIRE polygon IDs. Refer to Table 2 for detailed information and PSI ground motion statistics for each observed geohazard. British National Grid; Projection: Transverse Mercator; Datum: OSGB 1936. NEXTMap® Britain © 2003, Intermap Technologies Inc., All rights reserved

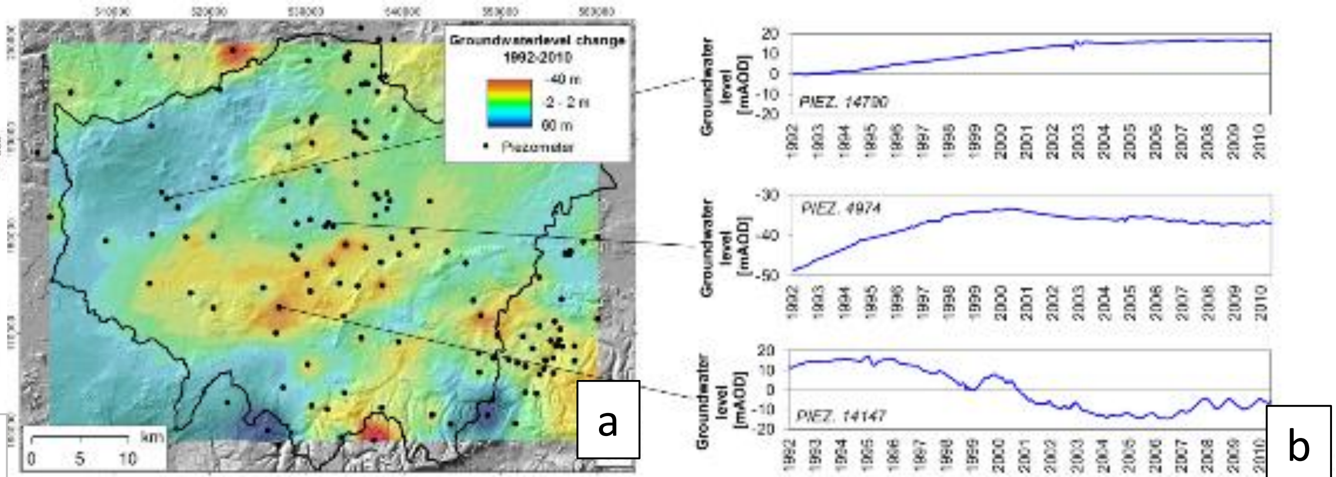
2. Input data

2.1. Geological model and hydrogeological data

- In the **1950**s a combination of aquifer depletion, improvements in surface water quality and water storage led to a decline in groundwater abstraction and a recovery of groundwater levels
- An action plan was developed by London Underground, Thames Water and the Environment Agency (EA), i.e. the GARDIT (General Aquifer Research Development and Investigation Team) strategy.
- Since **1999** there has been an increase in the licensed volume of abstraction of at least 3×10^6 l/d in central London (EA 2015).



BGS 3D geology model



Groundwater level change 1999-2010

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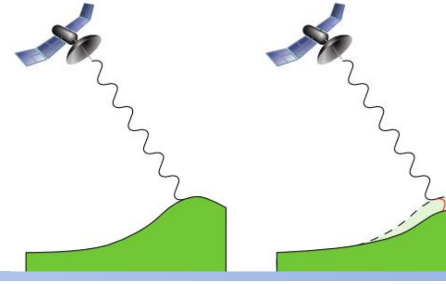
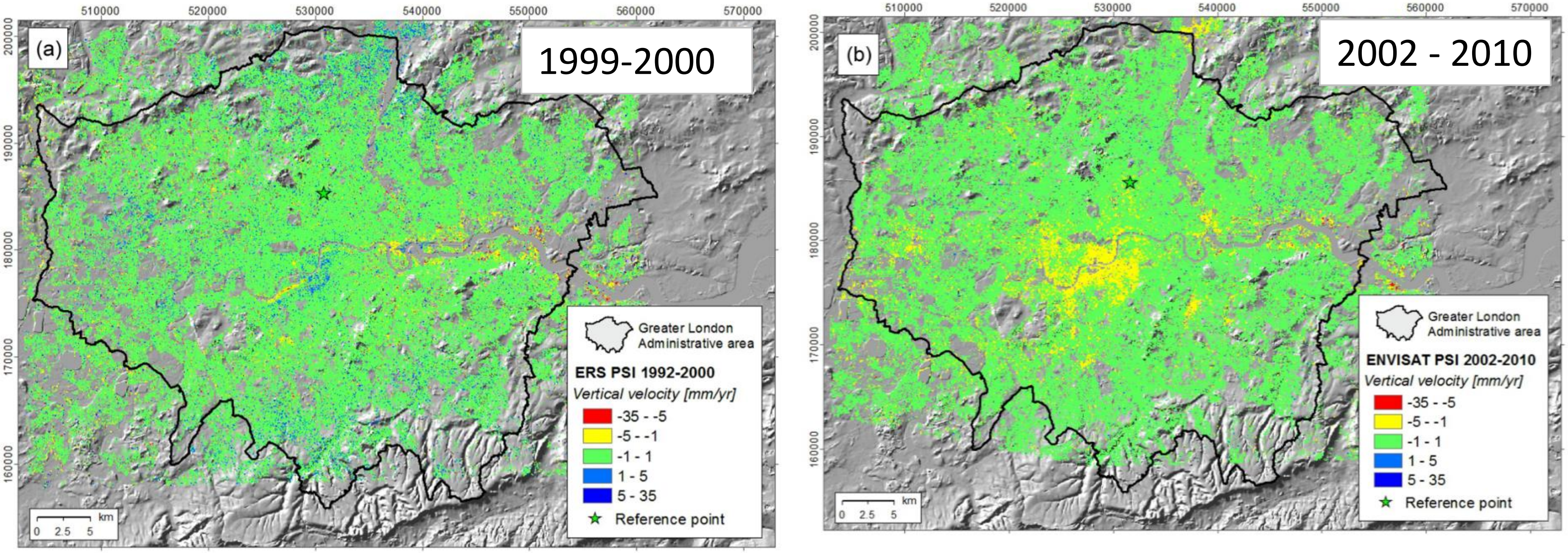
2. Input data



2.2. InSAR: PSI (Persistent scatterer interferometry)

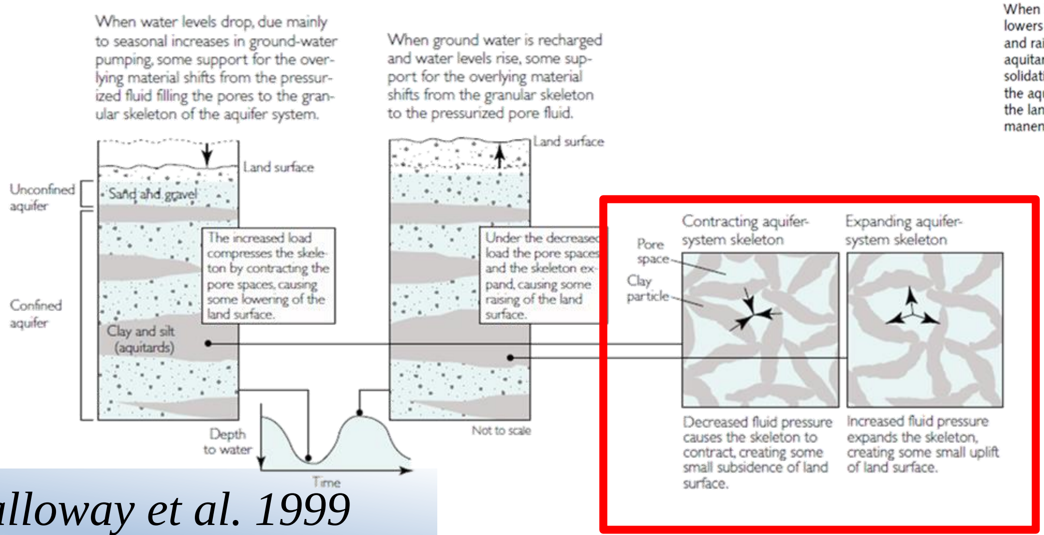


Vertical motion velocities

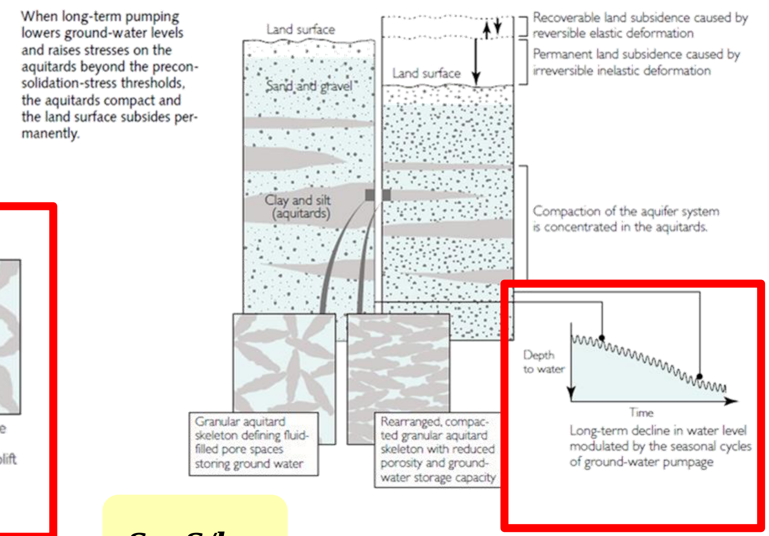
Vertical motion velocities estimated for the London Basin with PSI analysis in (a) 1992-2000 and (b) 2002-2010, overlapped onto shaded relief of NEXTMap® DTM at 50 m resolution. British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936. ERS-1/2 and ENVISAT PSI data © CGG NPA Satellite Mapping. NEXTMap® Britain © 2003, Intermap Technologies Inc., All rights reserved.

3. Methodology

Estimation of the aquifer storage coefficient and compressibility



Galloway et al. 1999



$$S = S'k + Sk + Sw = Sk^* + Sw$$ (Galloway et al. 1998)

Where $S'k$ and Sk are respectively the aquitard and the aquifer skeletal storage, while Sw is the water storativity. Sk^* is the aquifer-system skeletal storage.

Aquifer storage

$$S = \Delta d / \Delta h$$ (Hoffmann et al. 2001)

Where Δd is the vertical displacement as estimated by the satellite data, and Δh is the hydraulic head change.

$$Ss = S/b$$

Aquifer compressibility

$$\alpha = \alpha f + \alpha m = Ss/\rho w g$$ (Price 1987)

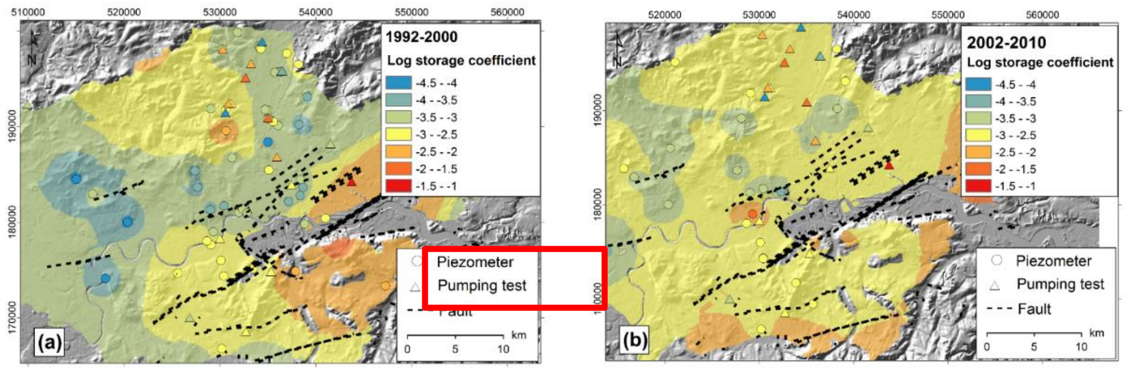
Where αf is the compressibility of the aquifer due to the presence of fractures, αm is the compressibility of the aquifer skeleton unfractured. Ss is the specific storage, b the thickness of the saturated aquifer, ρw the water density, g the gravity acceleration.

4. Results and discussion

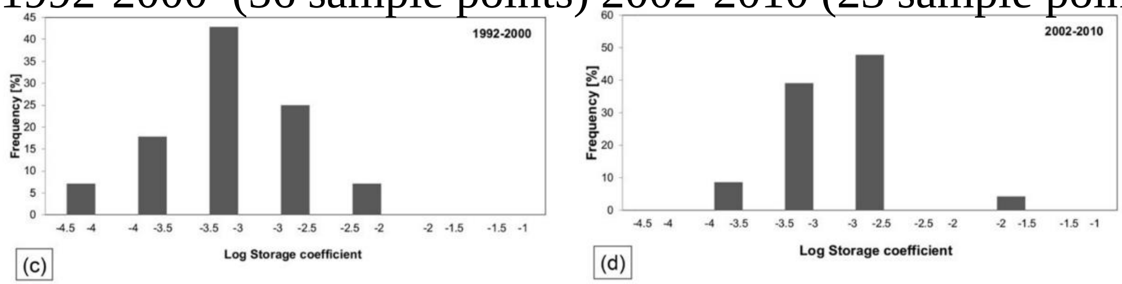
4.1. Aquifer storage coefficient derived from PSI data

$S = \Delta d / \Delta h$

- confined and semiconfined



1992-2000 (56 sample points) 2002-2010 (23 sample points)



Mean S = 1.18×10^{-3}
Range S = 4.5×10^{-5} - 7.3×10^{-3}

Mean S = 1.68×10^{-3}
Range S = 1.3×10^{-4} - 1×10^{-2}

- The ground response to groundwater level variations is not uniform across the London Basin.
- Spatio-temporal variations of the storage coefficient are related to lithology, structural control in the bedrock aquifer and the nature of the confining geology.

Pump test results:
9×10^{-5} - 5.2×10^{-2}

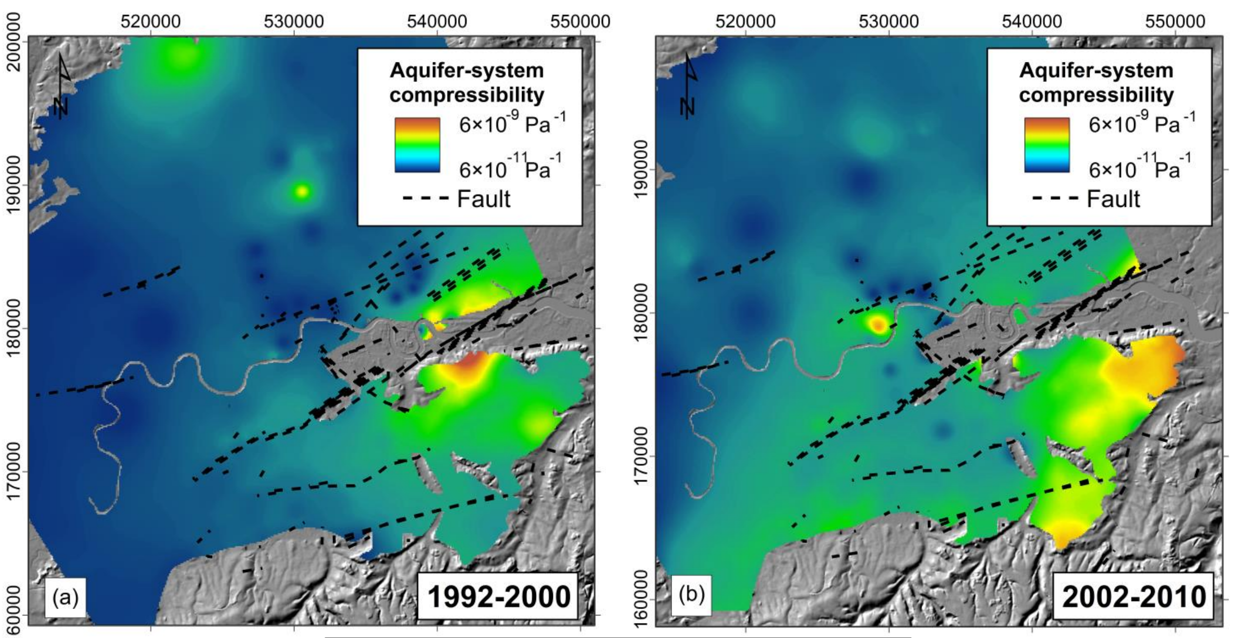
Maps of the **aquifer storage coefficient** in (a) 1992-2000 and (b) 2002-2010 (Distribution of aquifer storage coefficient data in 1992-2000 (c) and 2002-2010 (d) within the London Basin.

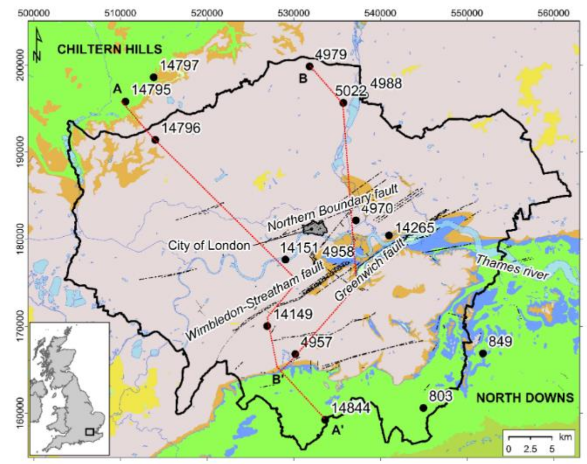
4. Results and discussion

4.2. Aquifer compressibility derived from PSI data

α=αf+ αm=Ss/ρwg

- confined and semiconfined





Bedrock geology

Compressibility: $10^{-11} – 10^{-9}$

Maps of the **aquifer compressibility** in the periods (a) 1992-2000 and (b) 2002-2010 (BGS ©NERC. All Rights Reserved. 2016), overlapped onto shaded relief of NEXTMap® DTM at 50 m resolution. British National Grid. Projection: Transverse Mercator. Datum: OSGB 1936. NEXTMap® Britain © 2003, Intermap Technologies Inc., All rights reserved.

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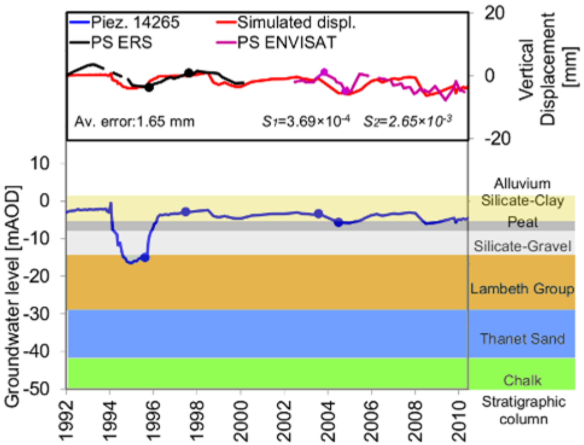
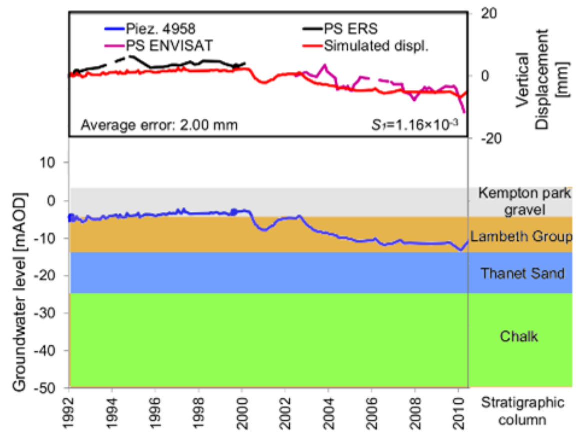
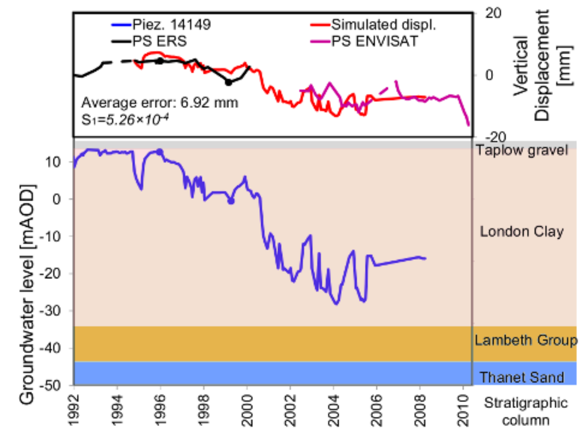
4. Results and discussion

$\Delta d = S \times \Delta h$

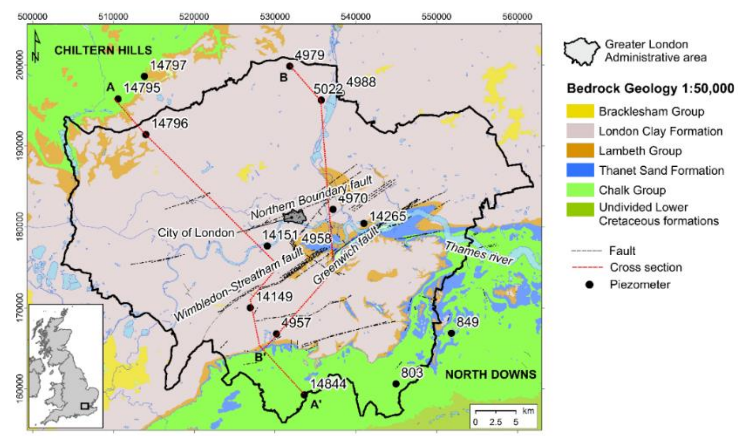
4.3. Modelling ground motion caused by groundwater level change







In areas where the chalk is confined by the Lambeth Group, a greater storage coefficient (1×10^{-3}) is observed than where confined by the London Clay (3×10^{-4} – 7×10^{-4}) was observed.



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5. Conclusions

- PSI analysis and data are capable of supporting the characterisation of aquifer properties of fractured aquifers over wide regions of interest

- The combined analysis of hydrological information with displacement maps and time-series retrieved from multi-sensor and multi-temporal SAR images has allowed the derivation of the relationship between groundwater level changes and surface displacements

- The application of satellite data provides new opportunities to address future approaches for monitoring groundwater level variations over wide urban areas such as the London Basin

Future developments

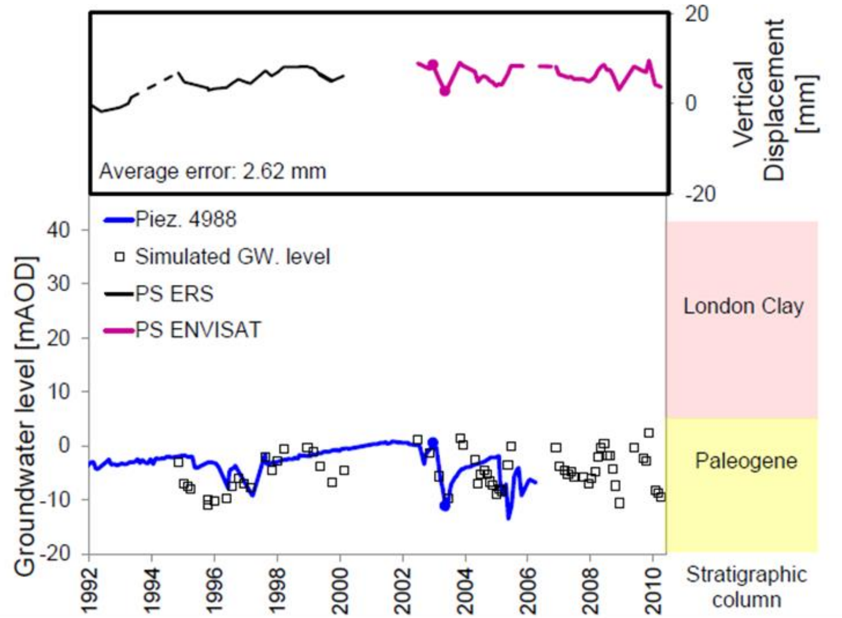
Future investigations will be performed, in order to:

- investigate areas affected by different hydrogeological characteristics;
- apply the methodology using new SAR sensors, or constellation of sensors, including COSMO-SkyMed and Sentinel-1 with reduced revisiting time and higher spatial resolution.

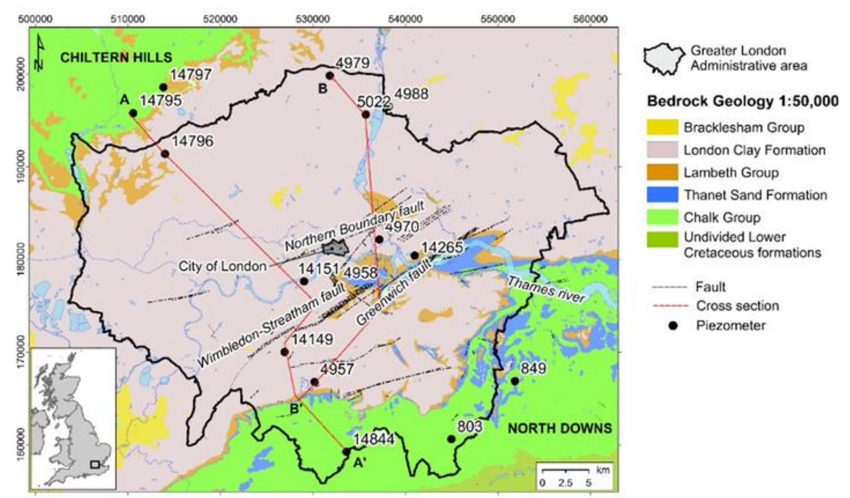
Thank you for your attention

4. Results and discussion

4.4. Modelling groundwater level change



$$\Delta h = \Delta d / S$$



The simulated groundwater (GW) level is reported. Groundwater level data © Environment Agency copyright and/or database rights 2015. All rights reserved.