THE SUBSIDENCE PREDICTION METHOD UPDATE: A NEW UNIFYING INFLUENCE FUNCTION FOR SHAPE DEVIATIONS AND ASYMMETRY

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Abstract

This study is devoted to the problem of accurately predicting subsidence caused by human activities in regions with tectonic activity. Unlike traditional models that rely on symmetrical patterns, this research delves into the irregular and complex shapes of subsidence troughs in tectonic zones. By integrating the effects of horizontal stress into empirical techniques, the research significantly enhances the precision of subsidence predictions. The innovative model developed effectively accounts for asymmetry and shape irregularities, achieving a 30% enhancement in prediction accuracy (estimated by MSE comparing) when tested on a real-world salt cavern subsidence case in north Germany.

WORKFLOW

Input data

- Measured subsidence by leveling (731) with an interval of 5 years
- Cavern data (91): location volume and types (oil, gas, brine)

Parameter estimation

The basin hopping method based on Quasi-Newton local parameter estimator

Result evaluation

- Statistical values
- Residual distribution
- Complexity/effectivity analysis

RESULTS

New empirical solution

$$S(r,\varphi) = \frac{\Delta V}{\int_0^{2\pi}\int_0^{\infty} exp\left(-\pi \frac{r^\delta}{R(\varphi)^\delta}\right)^2 r\, dr\, d\varphi} \cdot exp\left(-\pi \left(\frac{r}{R(\varphi)}\right)^\delta\right)$$

ΔV – convergence Volume,
$R(\varphi)$ - a function of the asymmetry
δ – a shape parameter that defines the position of the inflexion point
r – horizontal distance between the cavern centre to the point on surface, φ – azimut of r

Implementation options **Implementation options**

If $(R(\varphi) = const)$ & $(\delta = 2)$, *then:*

$$S(r) = \frac{\Delta V}{R^2} \cdot exp\left(-\pi\left(\frac{r}{R}\right)^2\right)$$

A cassical solution
original solution of
Sroka & Shober (1990)

If $(R(\varphi) = const)$ & $(\delta \neq 2)$, *then:*

$$S(r) = \frac{\Delta V\,(2.31 \cdot e^{-\delta} + 0.69)}{R^2} \cdot exp\left(-\pi\left(\frac{r}{R}\right)^\delta\right)$$

A shape-adopted solution
corrected solution of
Eickermeier (2005)

If $(R(\varphi) = function)$ & $(\delta = 2)$, *then:*

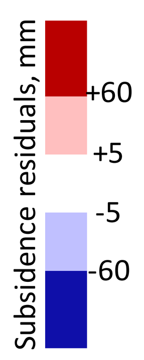
$$S(r,\varphi) = \frac{\Delta V}{\int_0^{2\pi}\int_0^{\infty} exp\left(-\pi \frac{r^2}{R(\varphi)^2}\right) r\, dr\, d\varphi} \cdot exp\left(-\pi\left(\frac{r}{R(\varphi)}\right)^2\right)$$

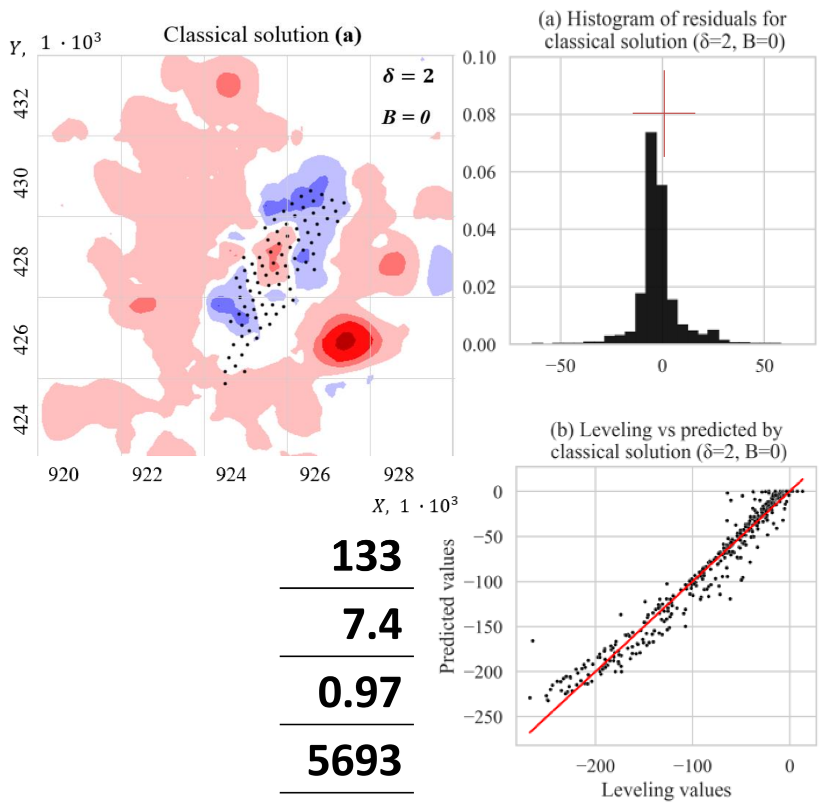
An asymmetrical solution
corrected solution of
Quasnitza (1988)

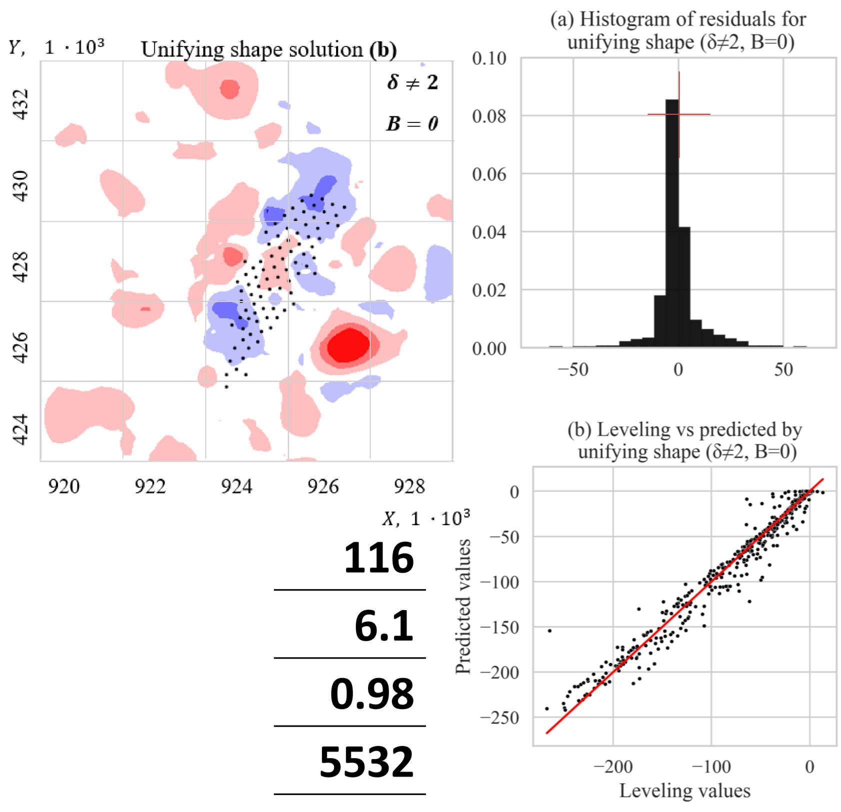
If $(R(\varphi) = function)$ & $(\delta \neq 2)$, *then:*

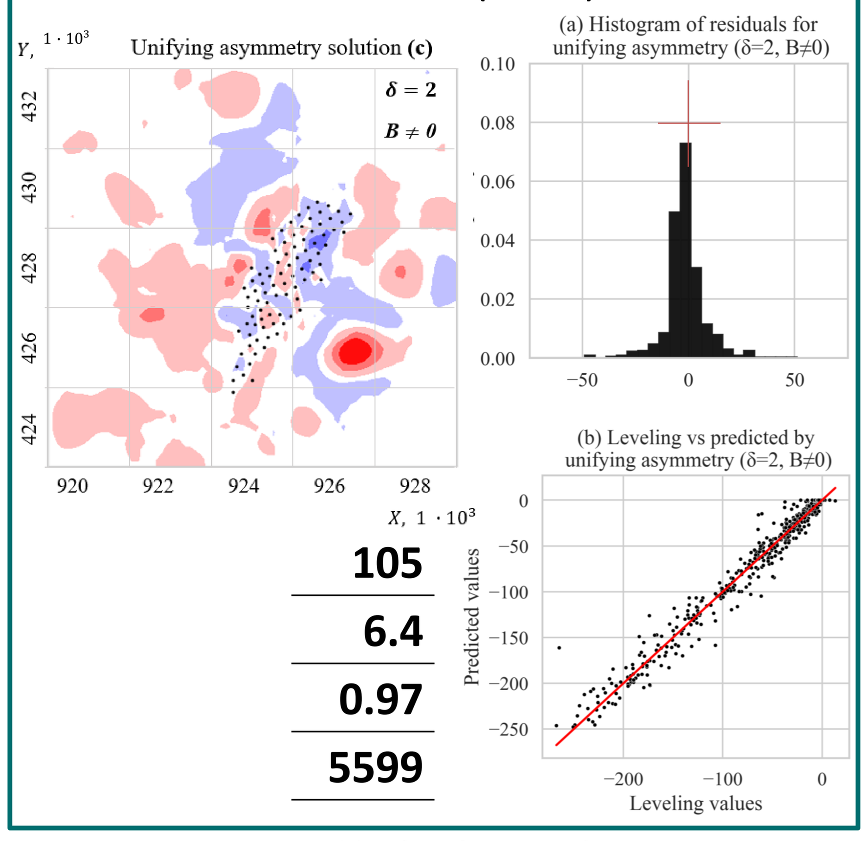
$$S(r) = \frac{\Delta V}{\int_0^{2\pi}\int_0^{\infty} exp\left(-\pi \frac{r^\delta}{R(\varphi)^\delta}\right) r\, dr\, d\varphi} \cdot exp\left(-\pi\left(\frac{r}{R(\varphi)}\right)^\delta\right)$$

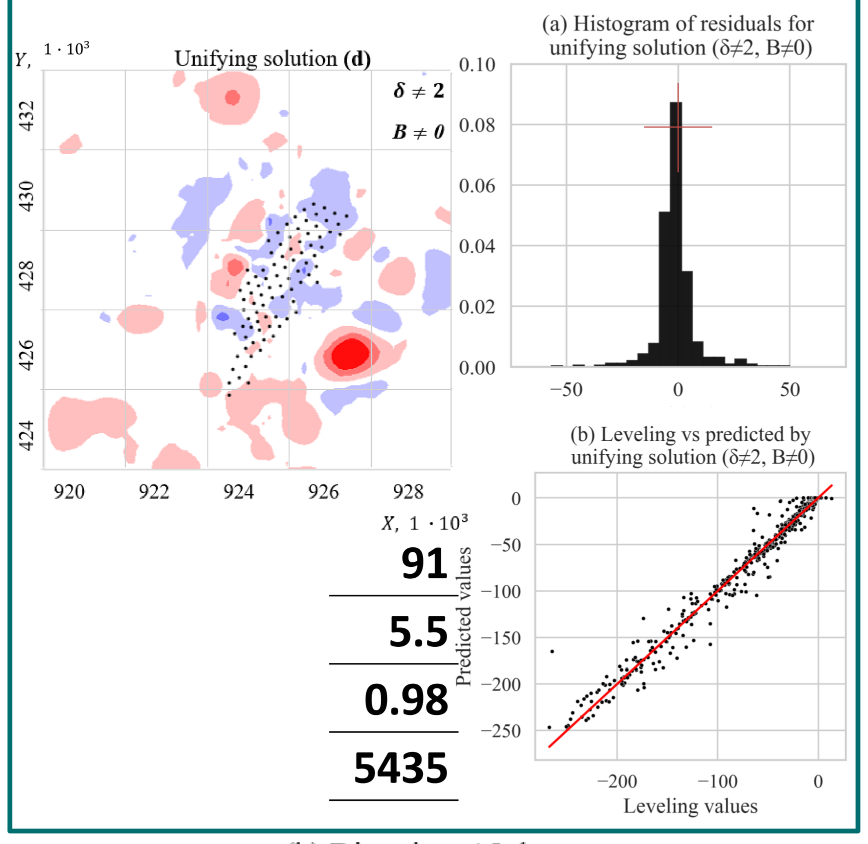
A new unified solution
asymmetry and shape-addopted
Solution



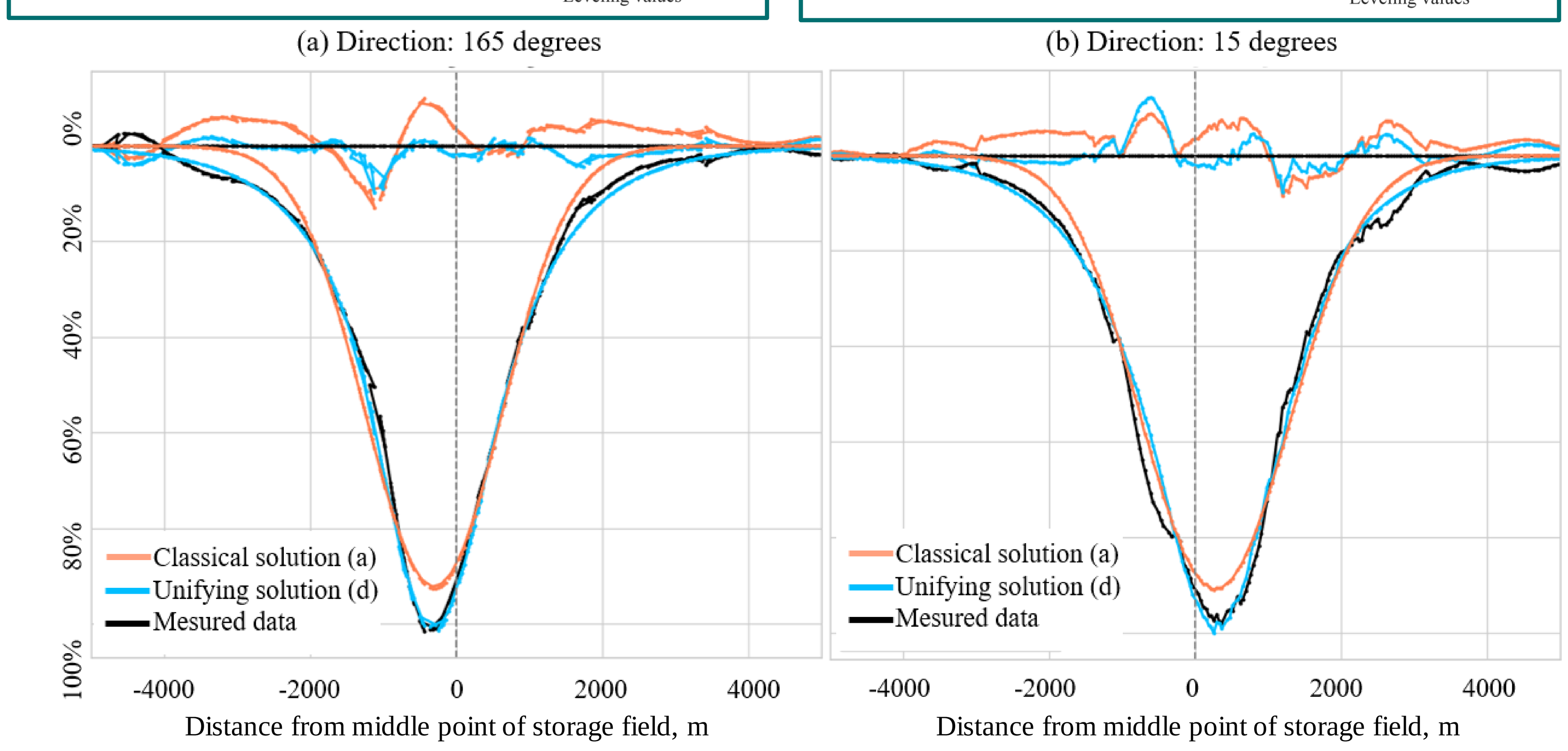








	Classical	Shape-adopted	Asymmetrical	Unified
MSE	133	116	105	91
MAE	7.4	6.1	6.4	5.5
R2	0.97	0.98	0.97	0.98
BIC	5693	5532	5599	5435



CONCLUSIONS

- The empirical method of subsidence prediction is based on the theory of stochastic media, which relies on a common probability space. However, deformation is influenced by stress conditions and the distribution of rock mass properties. Thus, the rock mass cannot always be represented as a common probability space for the subsidence process.
- Implementation of flexibility in the empirical solution of subsidence prediction (in particular in sense asymmetry and shape) increases the quality of subsidence prediction, without a significant increase in complicity. (MSE -30%, BIC -5%)
- In the case of the tectonic stress field, the classical subsidence prediction balances between covering the perepherie area of subsidence and central. According to the larger area of the periphery, the solution underestimates maximum subsidence.

REFERENCES

Babaryka & Benndorf (2023)
Babaryka & Benndorf (2022)
Eickemeier (2005)
Sroka & Schober (1990)
Quasnitza (1988)

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