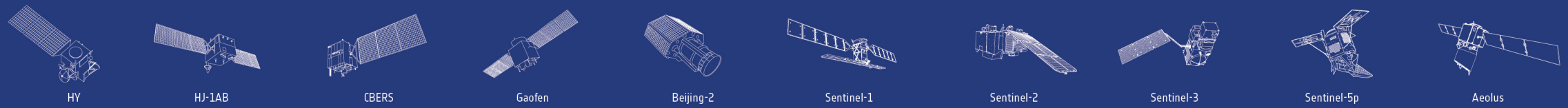

2023 DRAGON 5 SYMPOSIUM

3rd YEAR RESULTS REPORTING

11-15 SEPTEMBER 2023

[PROJECT ID. 58897]

[EO SERVICES FOR SMART CITIES]

58897 EO Services 4 Smart Cities

Effects of ecological water replenishment on formation stability and urban security along Yongding River in Beijing, China

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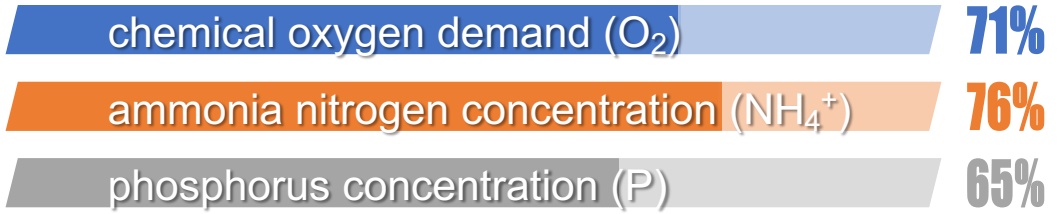
Contents

Introduction

- As the important water resource conservation area and ecological barrier, Yongding River is known as the ecological arteries of the coordinated development of Beijing-Tianjin-Hebei Region.
- Long-term overexploitation of groundwater has led to a decline in groundwater level of the plain area in Beijing, which has caused a series of problems.

  such as a large-scale and uneven land subsidence, interruption of river, water pollution, groundwater quality decline, etc.
- In order to restore the ecological function of Yongding River, the ecological water replenishment (Beijing section) has been performed since 2003.
- The uncertainty of ecological water replenishment (EWR) of Yongding River on the groundwater system and land surface stability of the coast has been an important scientific issue.

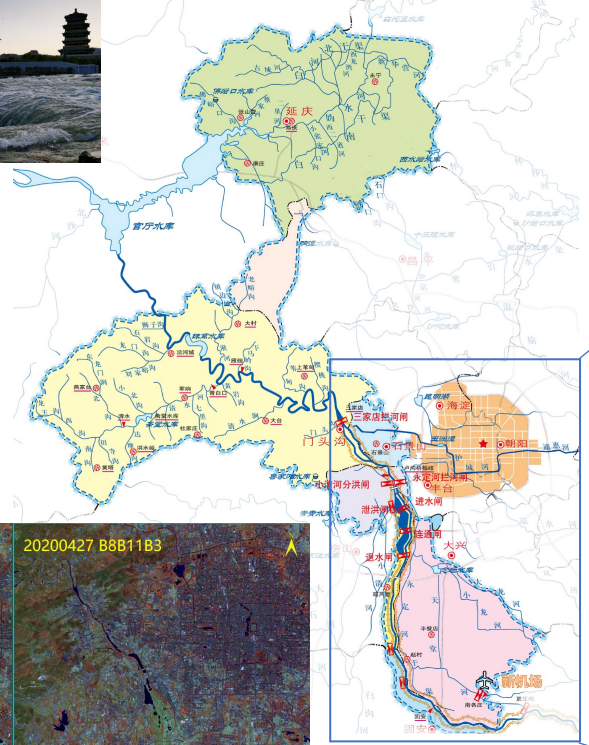
Cumulative water replenishment	Groundwater level recovery	Main pollutants decreases
$21.5 * 10^9$ m³ 2017~2022.5	> 9 m 2015~2021	

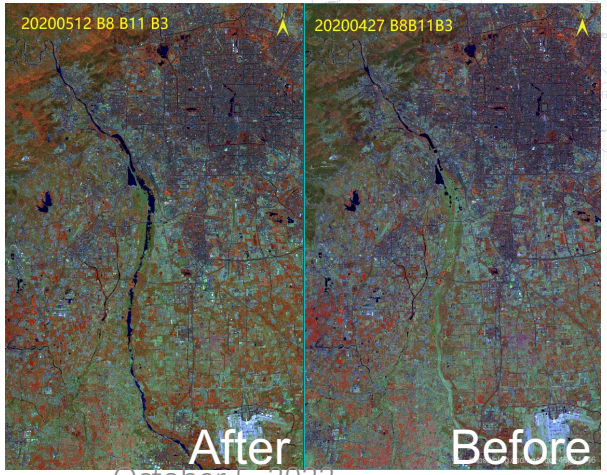


Introduction

Schematic diagram of Yongding River Basin in Beijing

永定河流域北京境内示意图





October 5, 2023
Sentinel-2A

Introduction

In this study, the evolution of groundwater flow field and the corresponding response of land subsidence along Yongding River (Beijing section) were analyzed by performing spatio-temporal analysis, time series decomposition, based on the data sets covering traditional hydrogeological data, groundwater observation data, and satellite-based images. Taking building stability, underground subway lines safety as examples, the impacts of ecological water replenishment on urban security of Yongding River were evaluated.

Objectives

TO analyze the impact of EWR in Yongding River (Beijing section) on the surrounding groundwater flow fields and surface deformation. 1

TO evaluate the impact of hydration on the safety of urban safety, and provide a scientific reference for avoiding the potential negative impact of EWR. 2

Study area

Fig. a

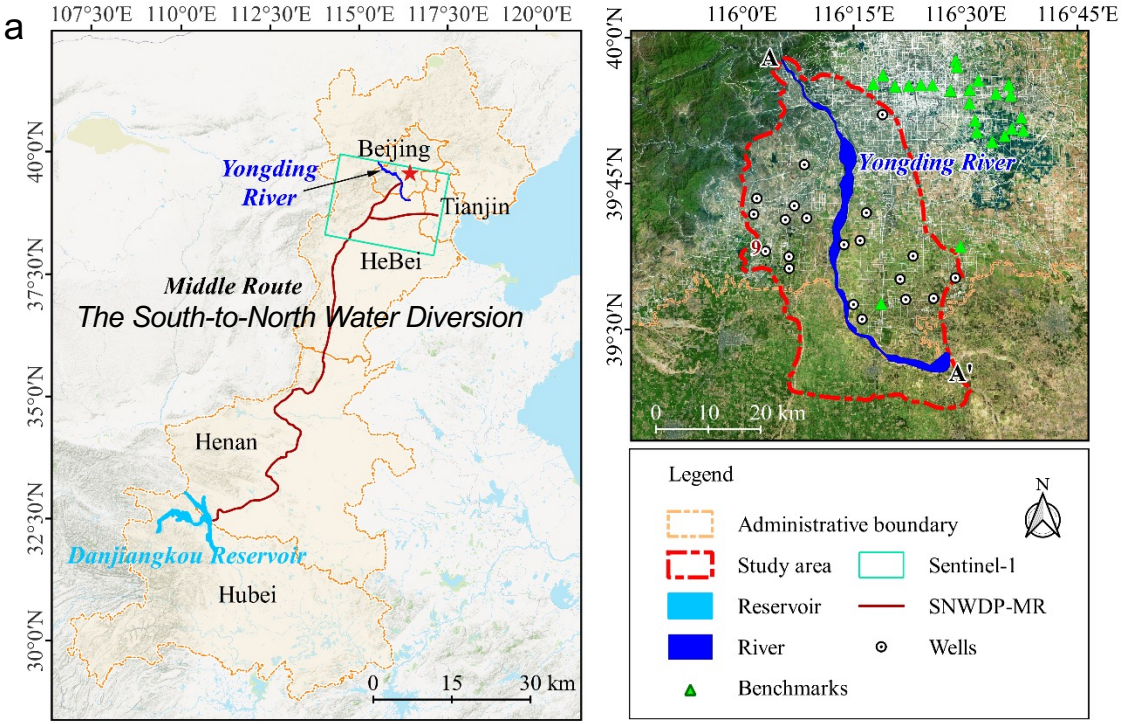
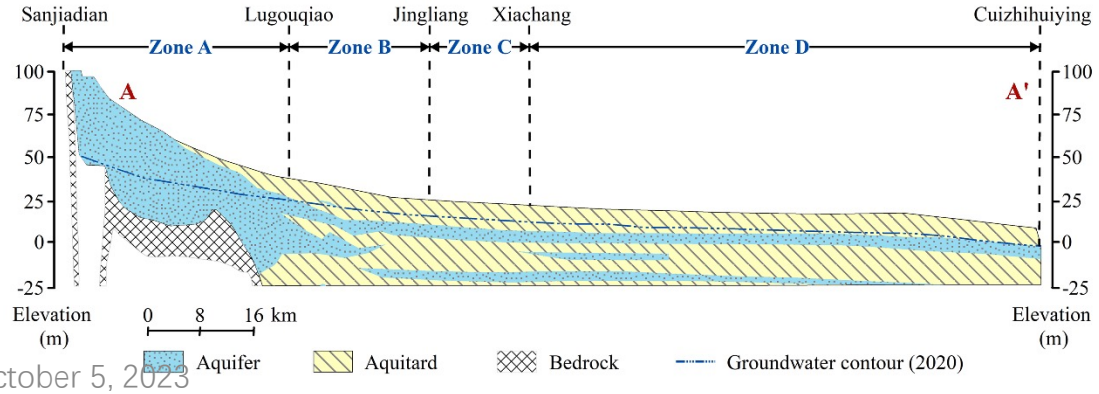


Fig. b



The lithological distribution along the Beijing section of Yongding river

Fig. c

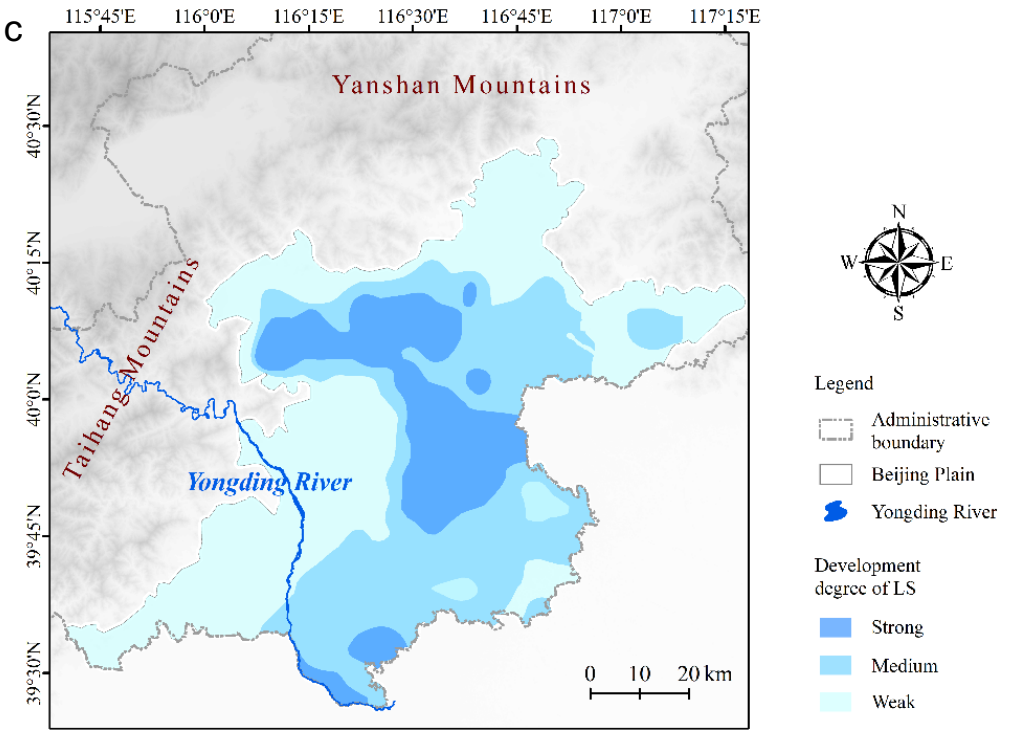
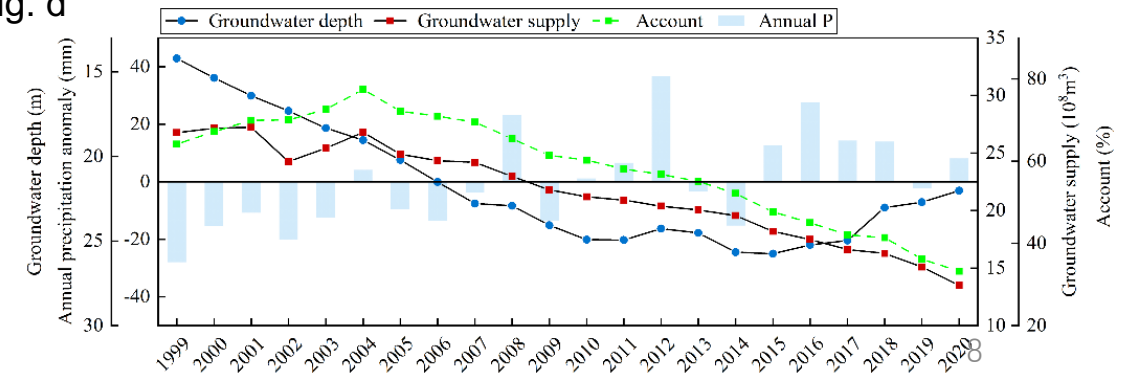
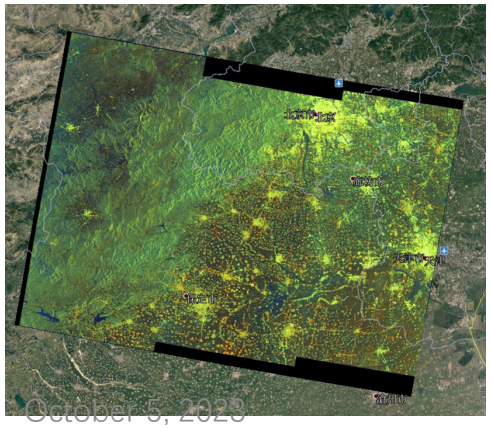


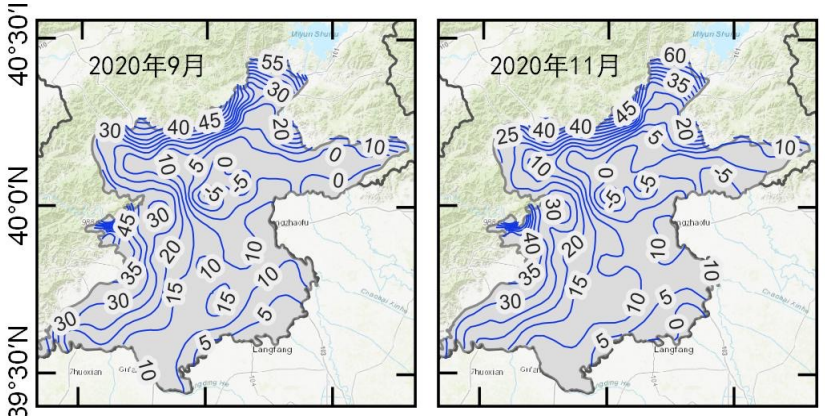
Fig. d

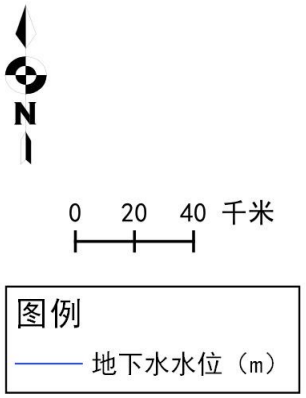


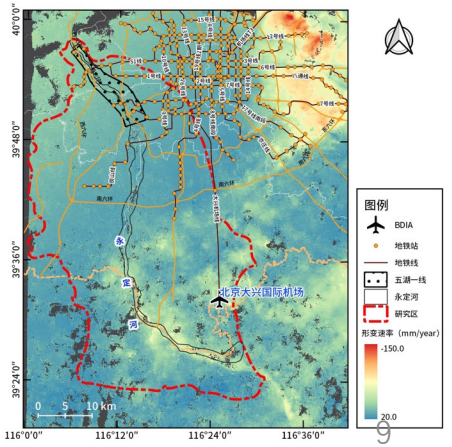
Data

- 60 Sentinel-1A/B interferometric wide (IW) single look complex (SLC) images
- Precise orbit data of the Sentinel-1A/B satellite, accordingly
- 1-arcsecond Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM) V2
- ERA-5 dataset from European Centre for Medium-Range Weather Forecasts (ECMWF)
- Groundwater tables, wells, leveling, …
- Basic geographical information data, subway lines, buildings, rivers, poi, etc.



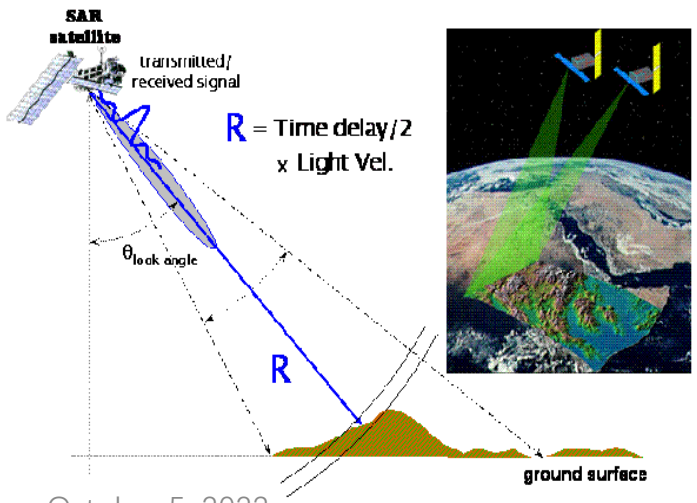






Land subsidence observation—InSAR

- Differential SAR Interferometry (DInSAR) uses two or more satellite radar images acquired over the same area to map topography and detect surface changes (motion).
- The SBAS (small baseline subset) method has become a reliable method for monitoring slow ground displacement and has been widely used, because of its ability to monitor large-scale deformation with millimeter accuracy.



$$\phi = \phi_{flat} + \phi_{elevation} + \phi_{displacement} + \phi_{atmosphere} + \phi_{noise}$$

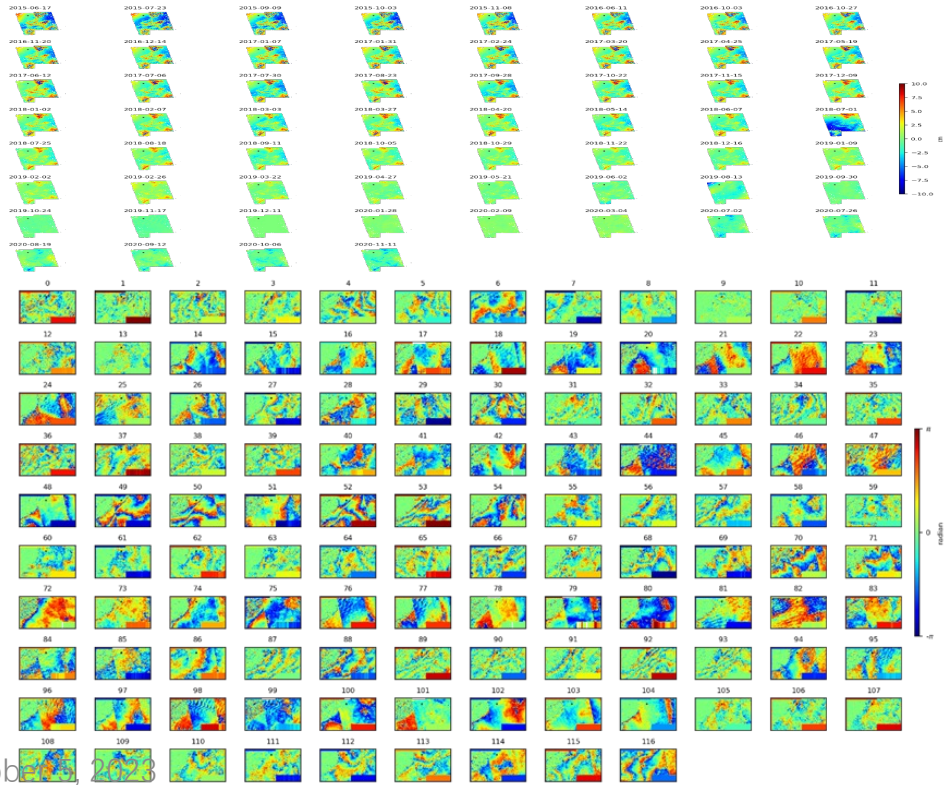
Geometrical and/or temporal decorrelation

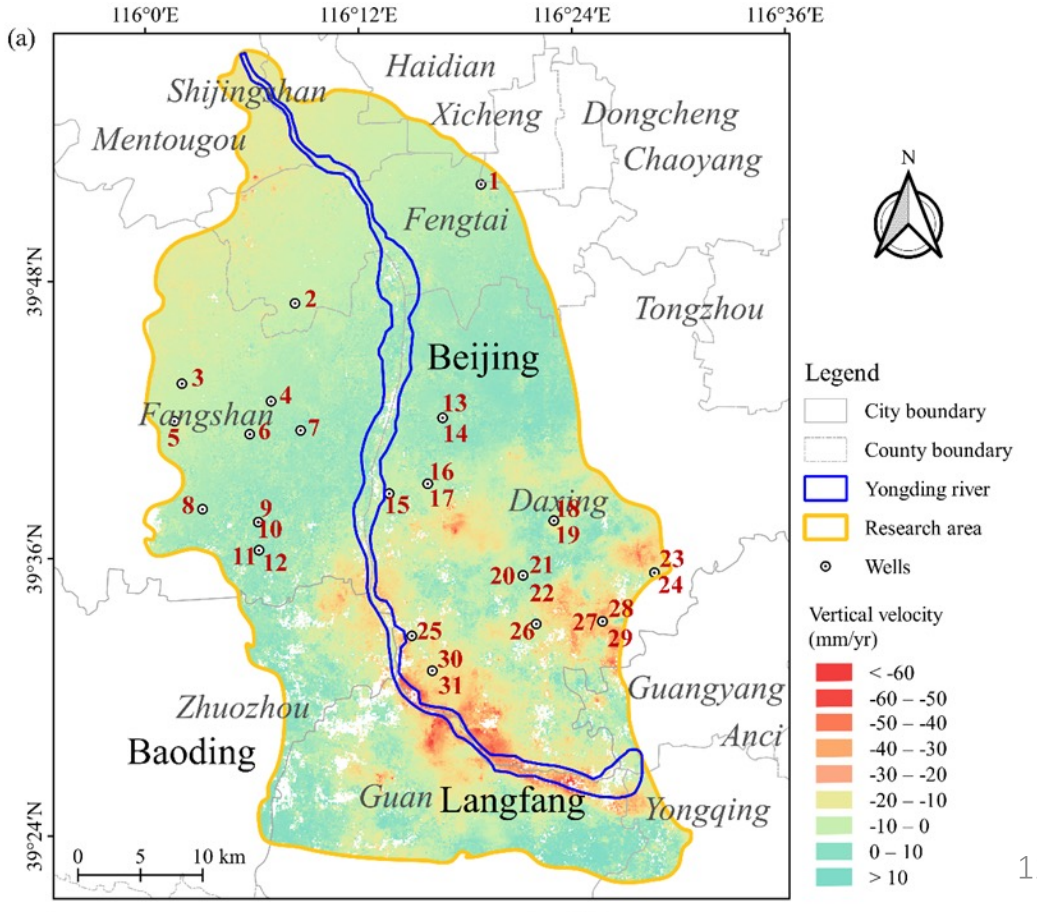
$$\frac{4\pi}{\lambda}\frac{B_n}{R}\frac{r}{\tan\theta} \qquad \frac{4\pi}{\lambda}\cdot\frac{B_n}{R_0}\cdot\frac{\Delta q}{\sin\theta} \qquad \frac{4\pi}{\lambda}d \qquad \Delta\psi$$

Summary of the SAR interferometric phase contributions

Land subsidence observation

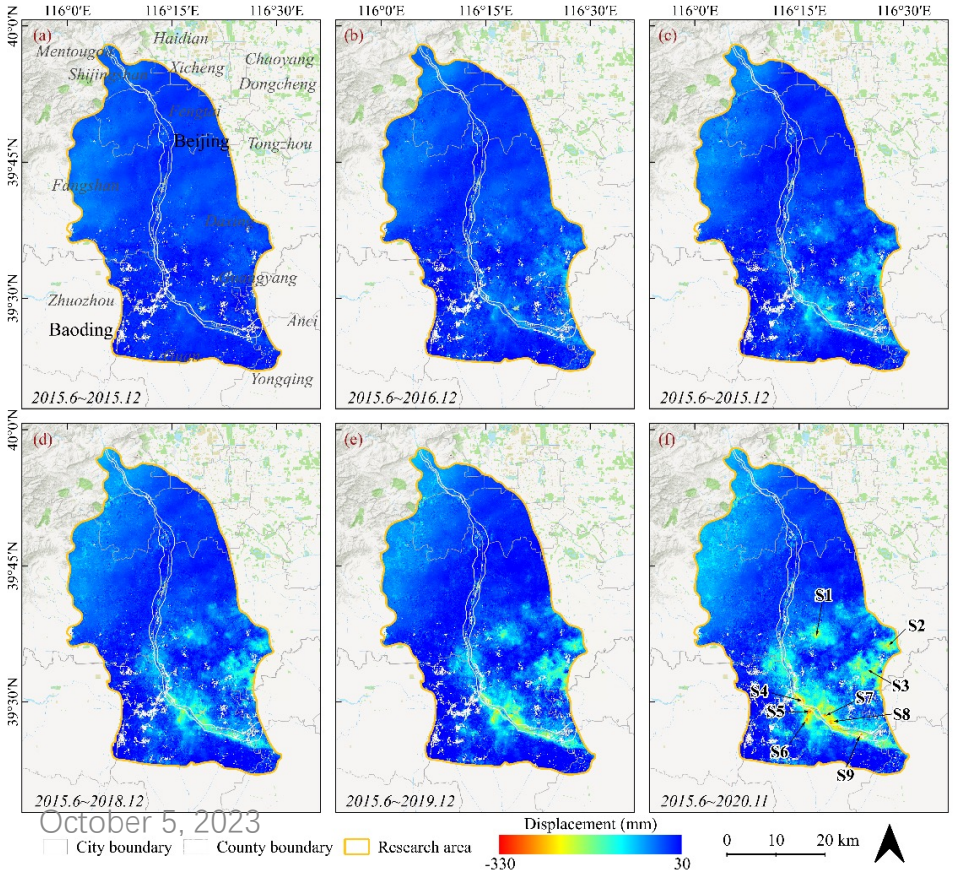
- 117 interferograms was generated.
- Displacement rate ranges from -62.3 mm/yr to 22.4 mm/yr with a mean standard variance of 3.11 mm/yr during the observation period.

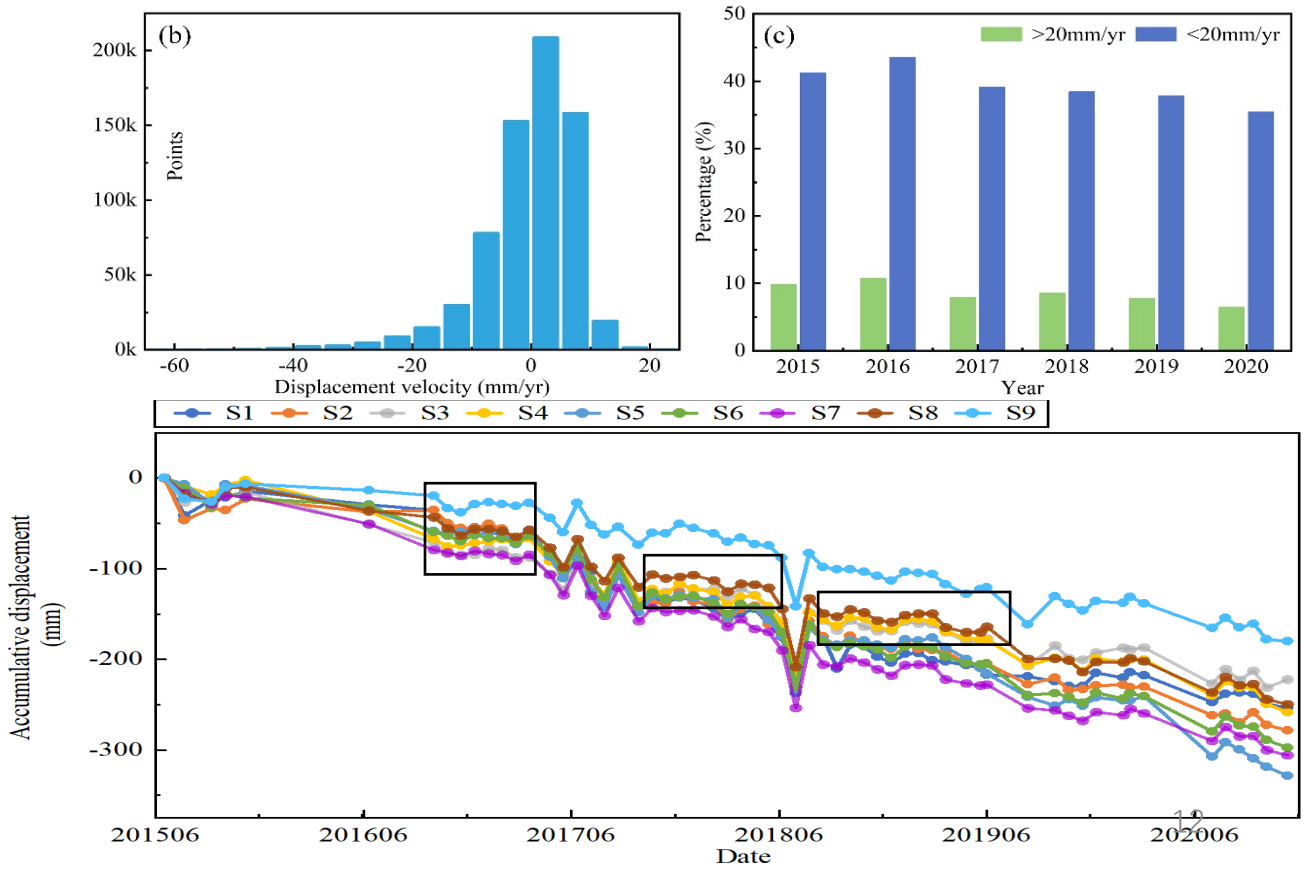




Land subsidence observation

- Ground displacement gradually increased and unevenly distributed.
- Sinking bowls were formed in the north of Langfang and the south of Daxing, which tended to be connected together.



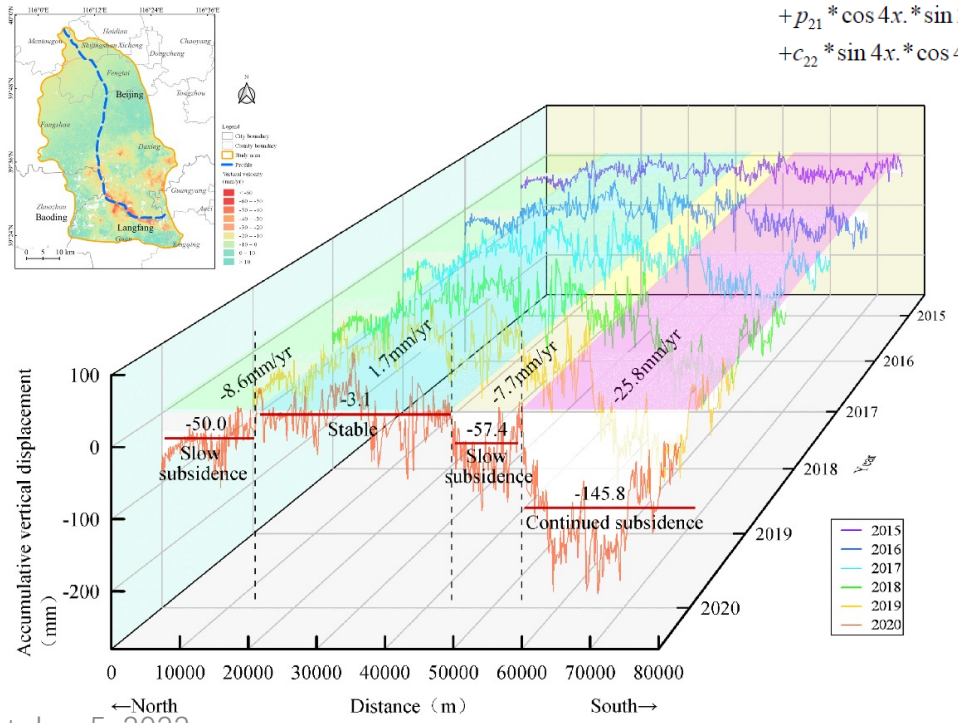


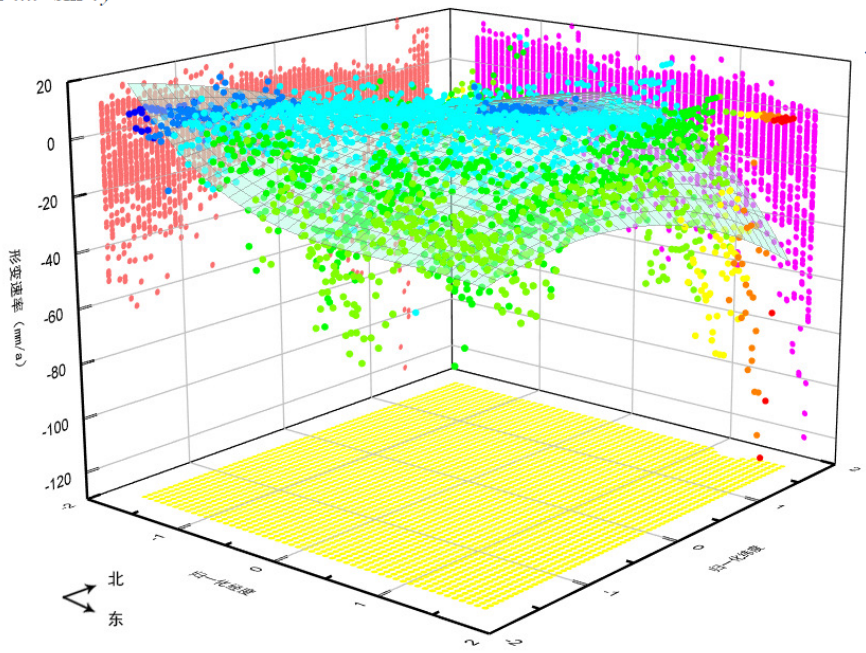
Land subsidence observation

- The distribution of land subsidence along the river can be divided into four sections.
- Trend analysis: high in the southwest, low in the southeast and northeast, and gentle in the middle along the north-south direction.

$$
\begin{aligned}
f(x,y) = {} & e_{00} + e_{01} * \cos 2y + p_{01} * \sin 2y + e_{02} * \cos 4y + p_{02} * \sin 4y \\
& + e_{10} * \cos 2x + c_{10} * \sin 2x + e_{11} * \cos 2x. * \cos 2y + c_{11} * \sin 2x. * \cos 2y \\
& + p_{11} * \cos 2x. * \sin 2y + w_{11} * \sin 2x. * \sin 2y + e_{12} * \cos 2x. * \cos 4y \\
& + c_{12} * \sin 2x. * \cos 4y + p_{12} * cso2x. * \sin 4y + w_{12} * \sin 2x. * \sin 4y \\
& + e_{20} * \sin 4x + c_{20} * \sin 4x + e_{21} * \sin 4x. * \cos 2y + c_{21} * \sin 4x. * \cos 2y \\
& + p_{21} * \cos 4x. * \sin 2y + w_{21} * \sin 4x. * \sin 2y + e_{22} * \cos 4x. * \cos 4y \\
& + c_{22} * \sin 4x. * \cos 4y + p_{22} * \cos 4x. * \sin 4y + w_{22} * \sin 4x. * \sin 4y
\end{aligned}
$$

Fourier series fitting



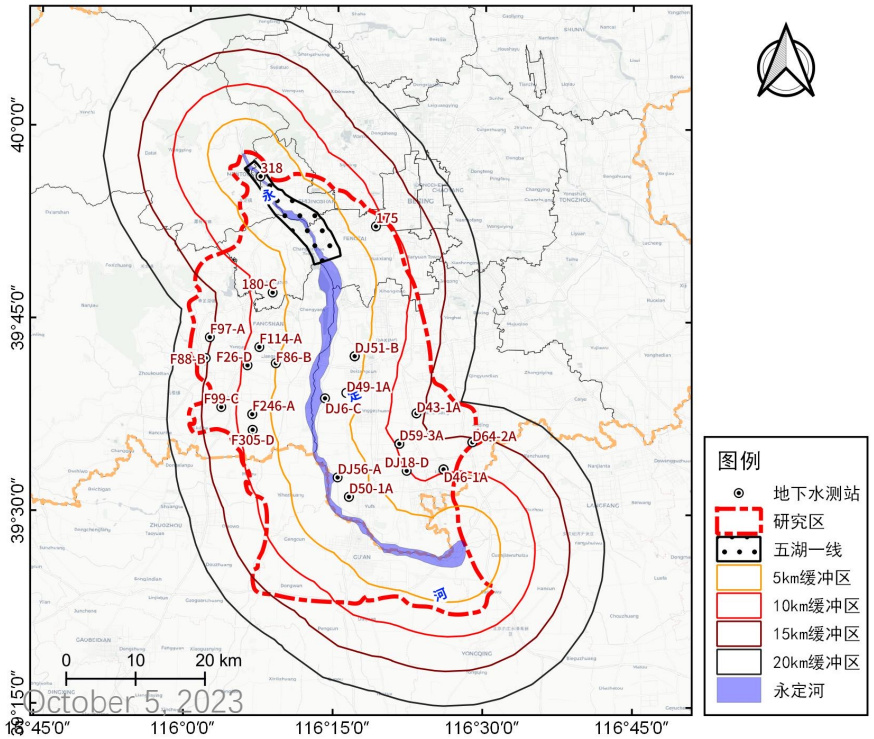


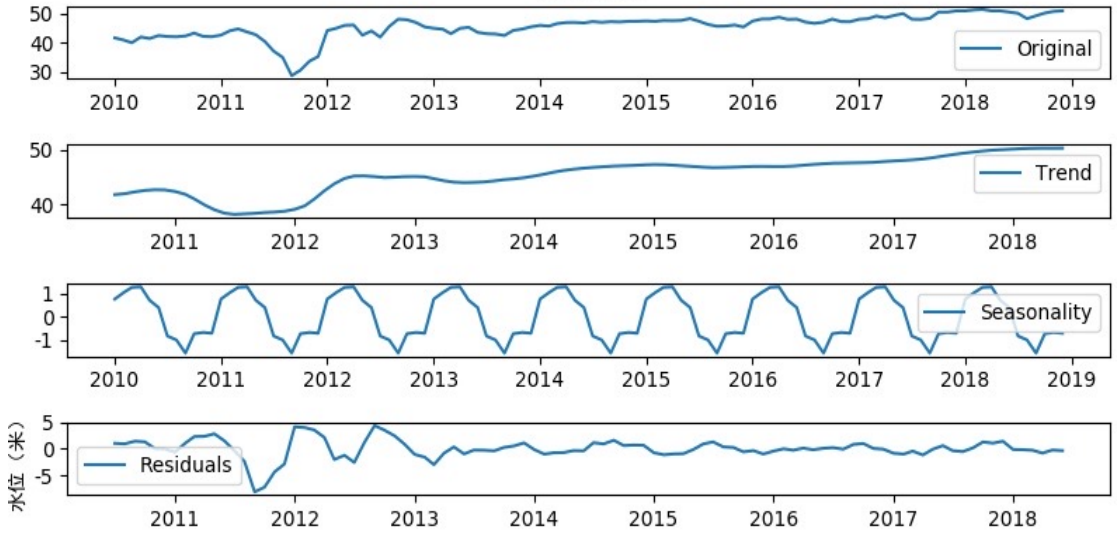
surface polynomial fitting results of land subsidence field

Groundwater observation

- Buffer zones of 5km, 10km, 15km and 20km were established.
- wells are divided into four categories according to the distance away from the river.
- Using seasonal-trend decomposition based on loess (STL) to explore temporal patterns of land subsidence and groundwater changes in study area.

$$Y_v = T_v + S_v + R_v \quad v = 1, \cdots, N$$



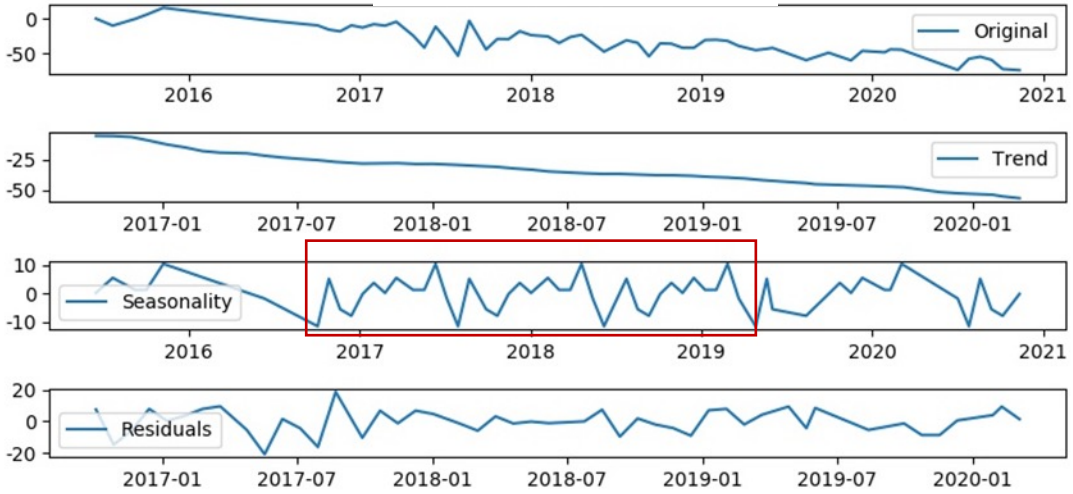


STL is a filtering procedure for decomposing a time-series into additive components of variation (trend, seasonality and the remainder) by the application of loess smoothing models.

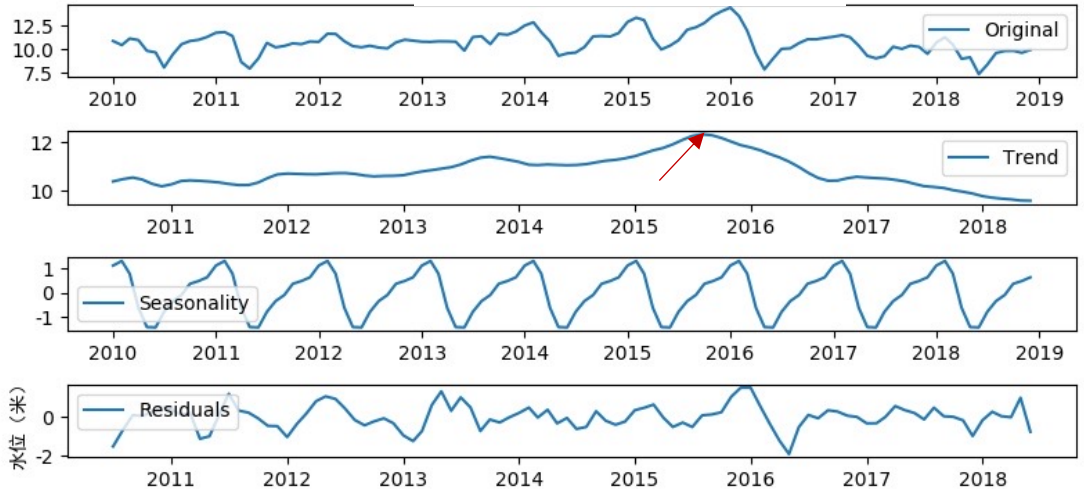
Land subsidence vs Groundwater level

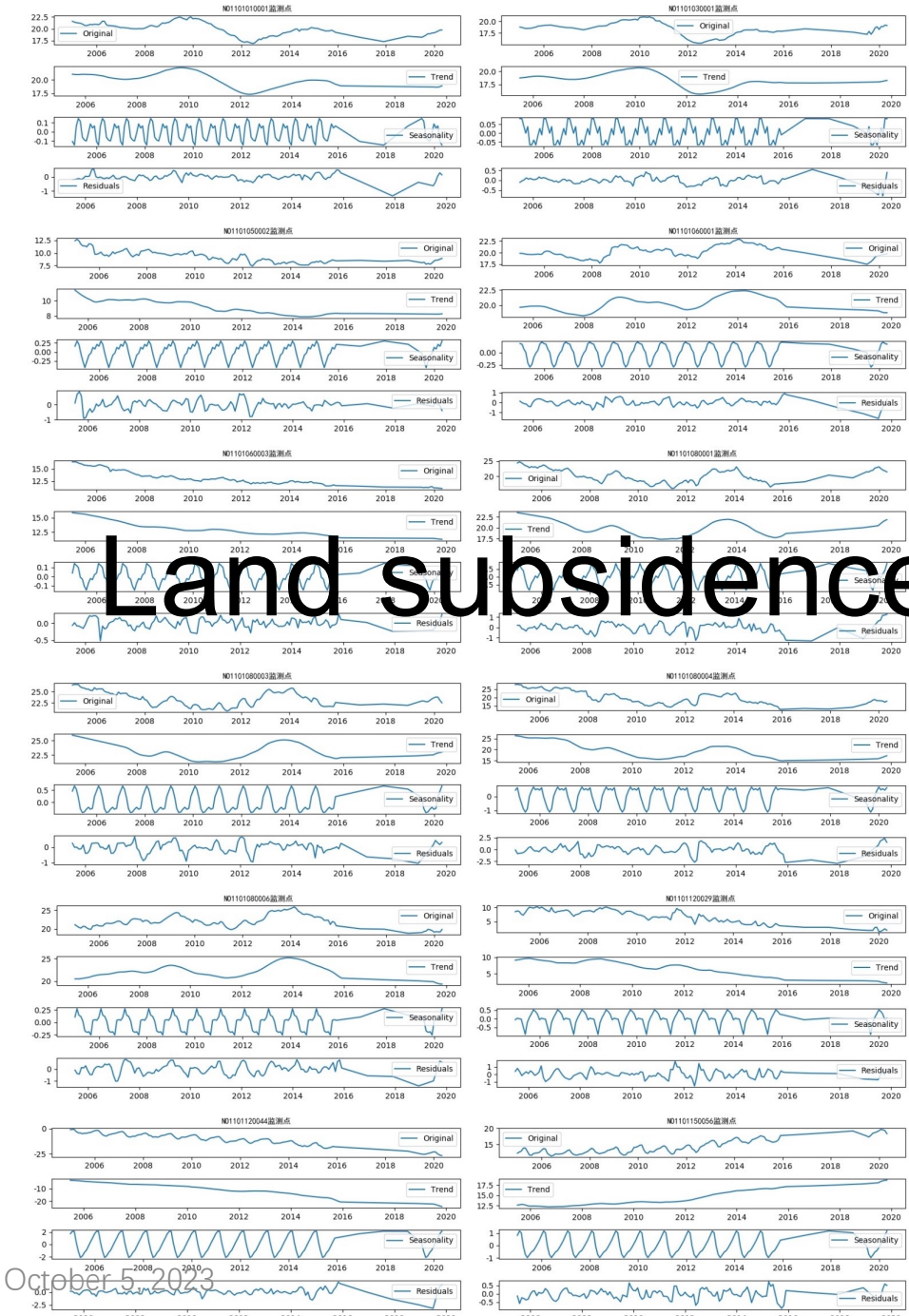
- The land surface at the monitoring site was slowly downward.
- There was a periodic changes of about 11 ~ 12 months.
- The groundwater level rise first and then decreased. The inflection point appears in July to August 2015.
- There was also a seasonal change of about 12 months.

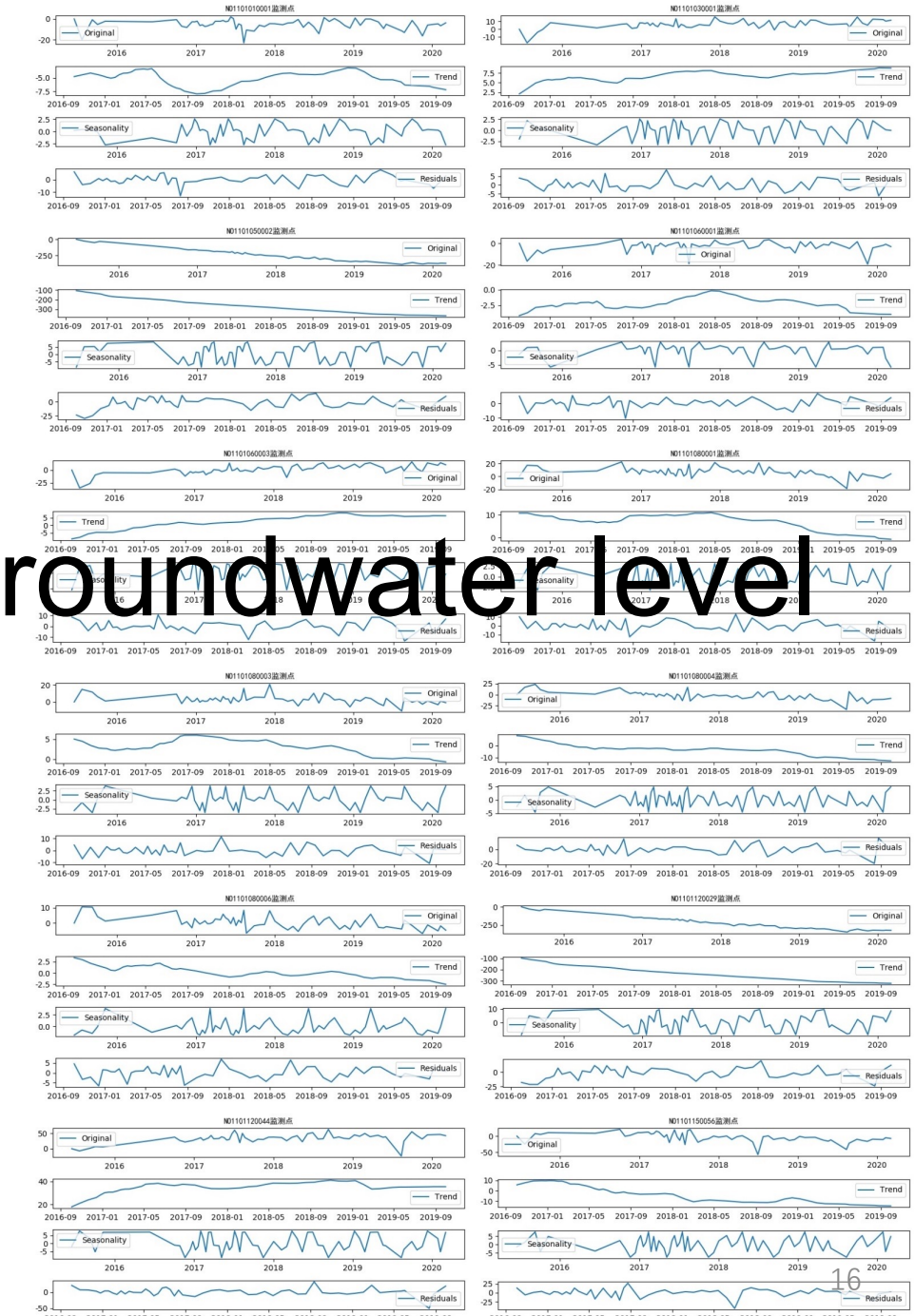
Land subsidence



Groundwater level



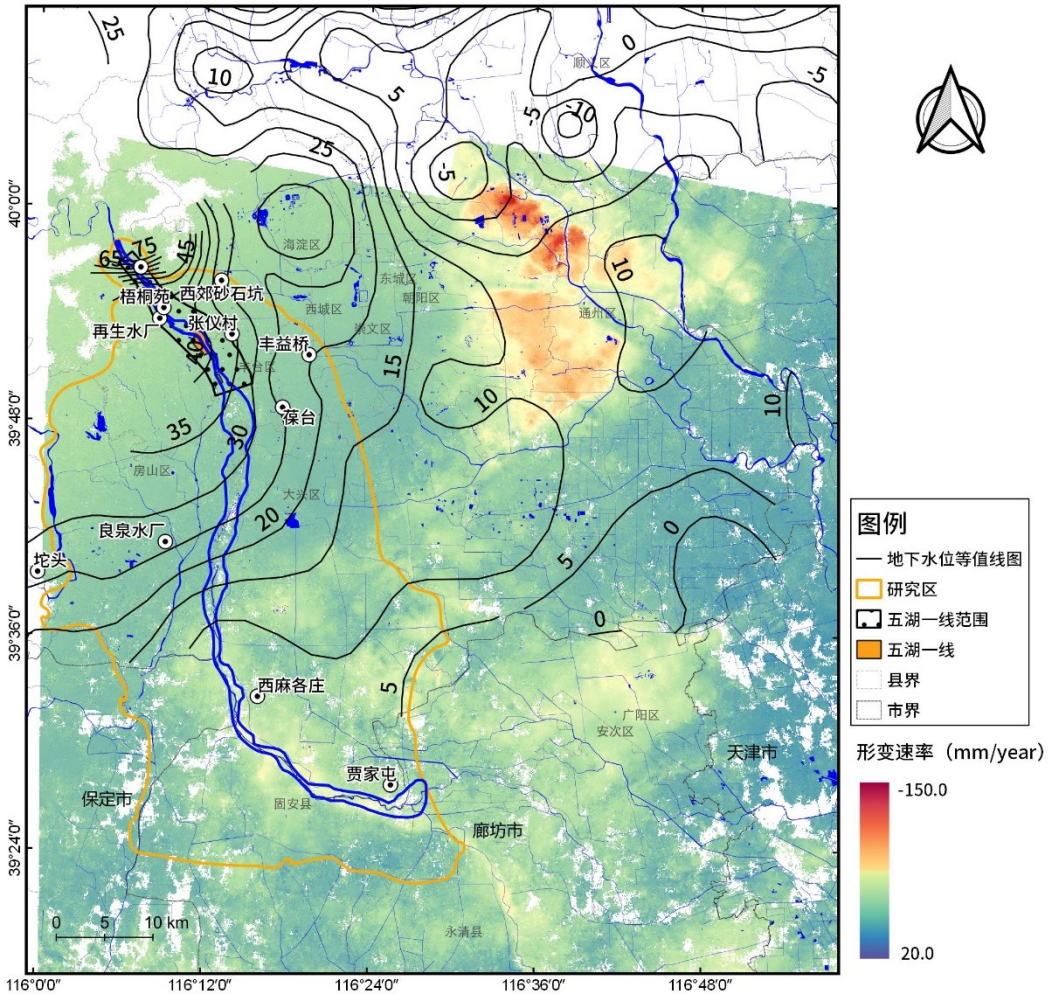




Land subsidence vs Groundwater level

Land subsidence vs Groundwater level

- In the land subsidence area, the average annual land subsidence rate has a high consistency with the spatial distribution of groundwater level isolines in the same period.
- Especially in Jinzhan of Chaoyang District, Taihu Liyuan of Tongzhou District and other areas, the center of groundwater funnel almost completely coincides with the center of land subsidence.



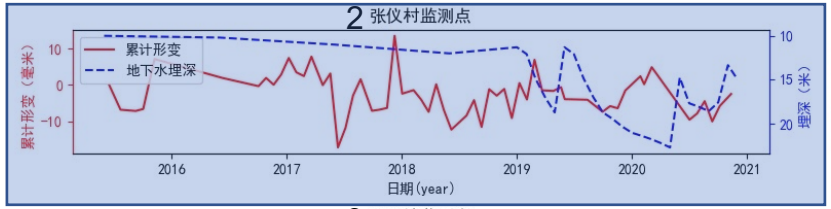
Land subsidence vs Groundwater level

- The land surface responds to the change of water table with elastic deformation at well #1,#2,#5,#8.

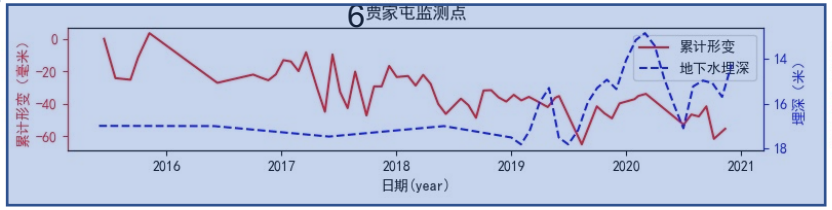
  When the water table drops, the pore water pressure decreases and the surface sinks, vice versa.

- For well #1,#2,#6,#7 the groundwater depth rise significantly from 2019 to 2020, which was consistent with the ecological water replenishment.

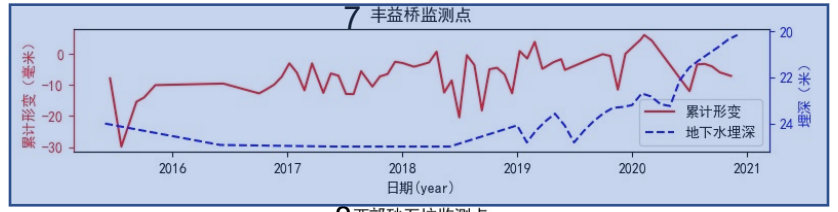
Distance from the river: ~5km;



5~10km;



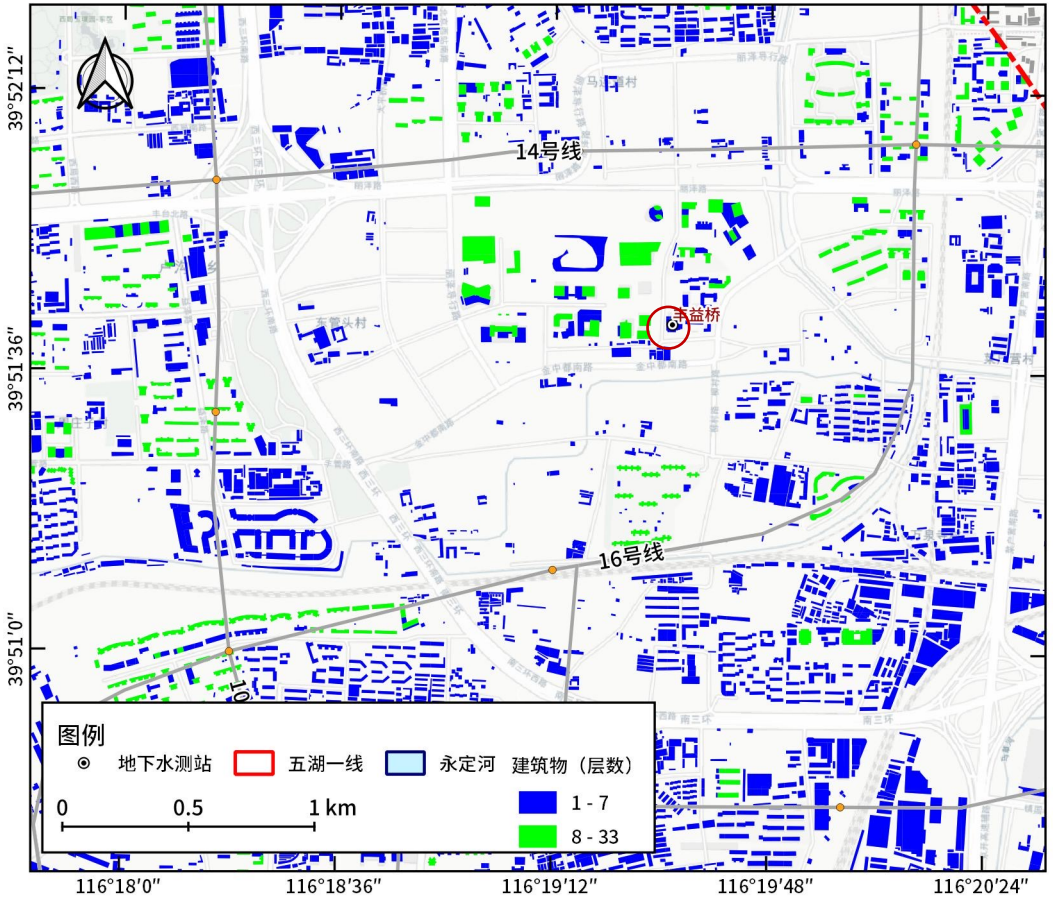
>10 km



Influence on building stability

Fengyiqiao: 8 km from Yonding River

High density buildings, with 8~33 storeys;
the foundation should be 0.5 ~ 6.7 m.



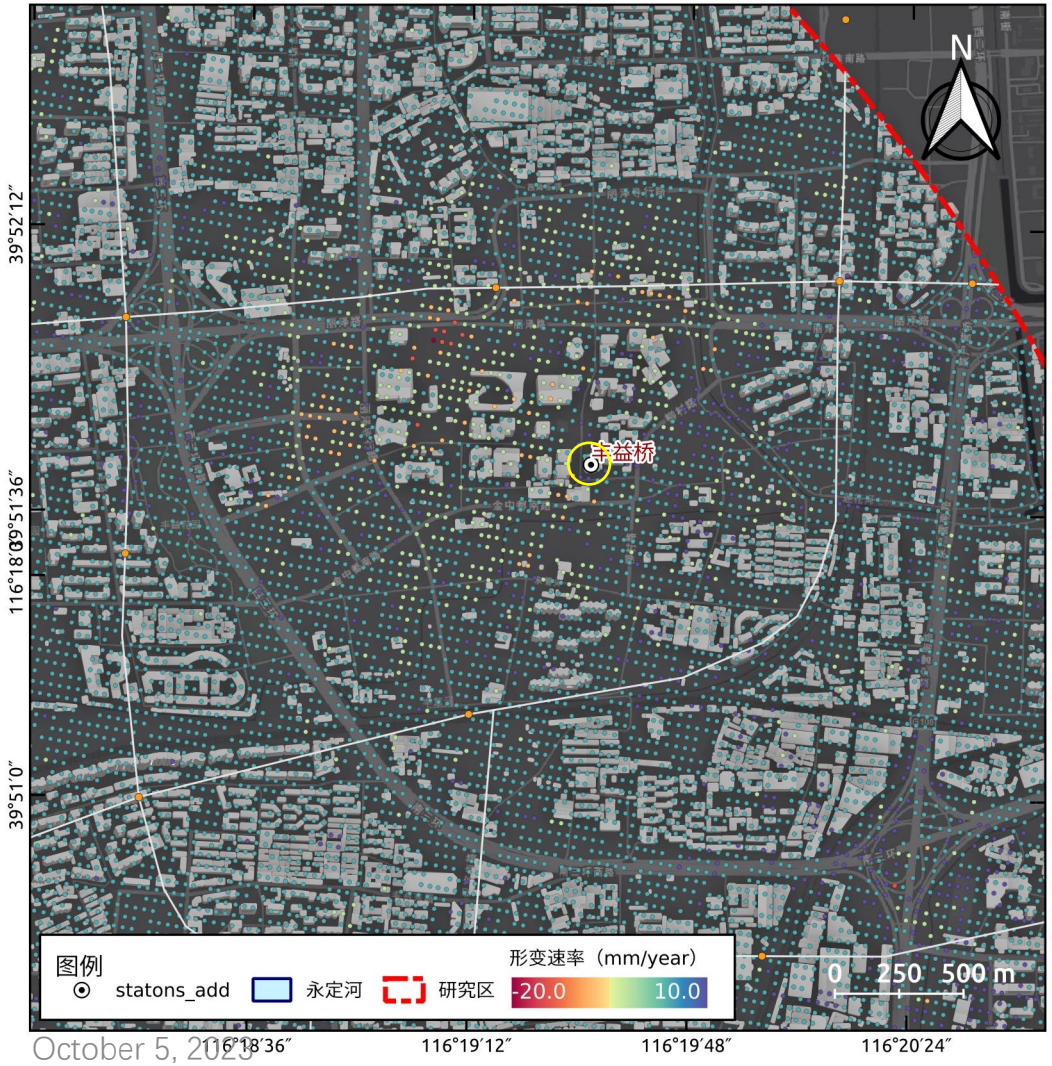
In theory, if the water table here keep rising at 2.5 m/year, in 5.4 years, around May 2026, The foundation of the building will be soaked and eroded by groundwater.

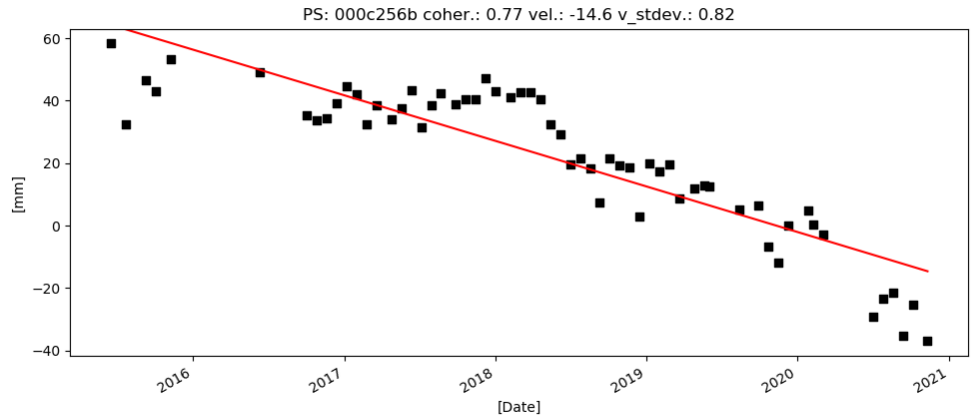
The time (in years) it takes for the water level to rise back to the critical level

Well pos.	0.5m/year	1m/year	1.5m/year	2m/year	2.5m/year	2020.12埋深
丰益桥	26.9	13.5	9.0	6.7	5.4	20.15
葆台	15.2	7.6	5.1	3.8	3.0	14.31
贾家屯	15.1	7.5	5.0	3.8	3.0	14.24
西麻各庄	27.9	14.0	9.3	7.0	5.6	20.67

Influence on building stability

Fengyiqiao: 8 km from Yonding River

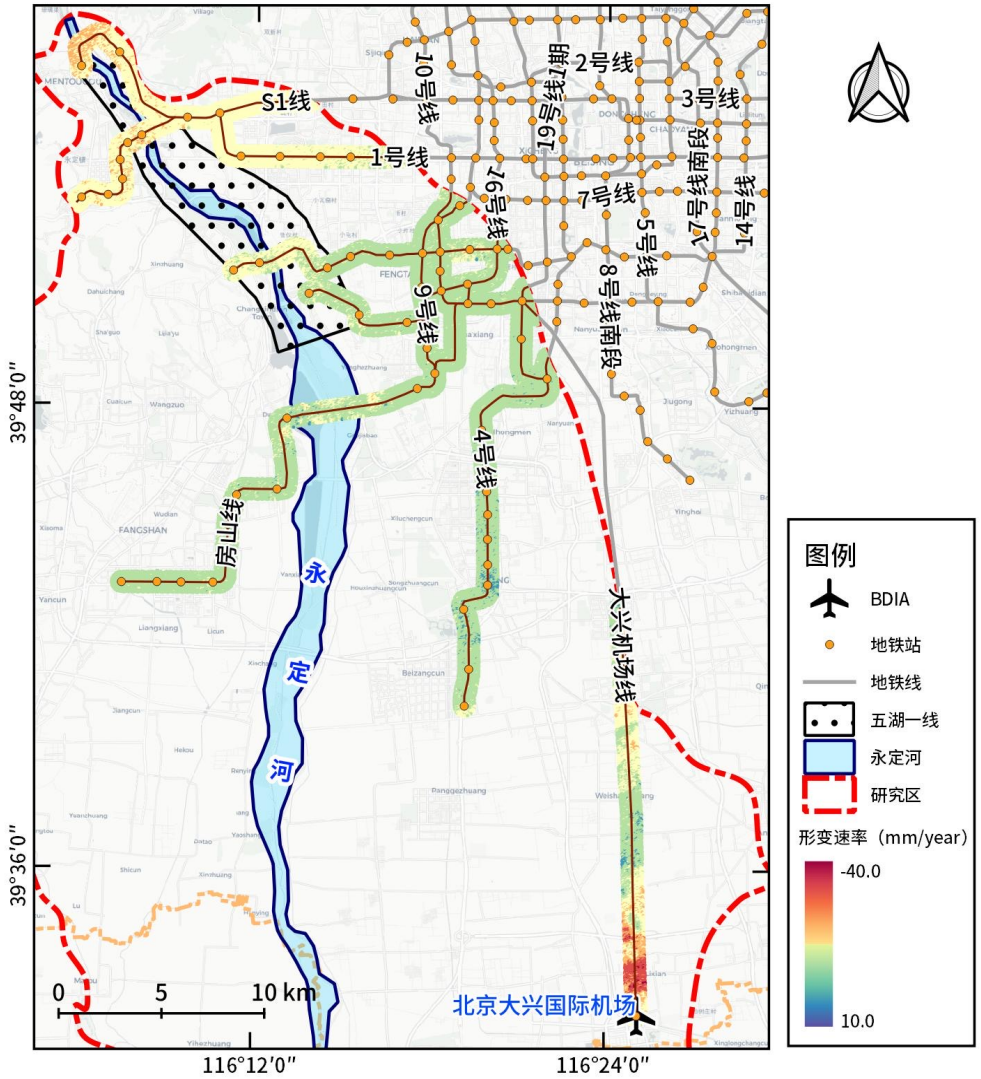


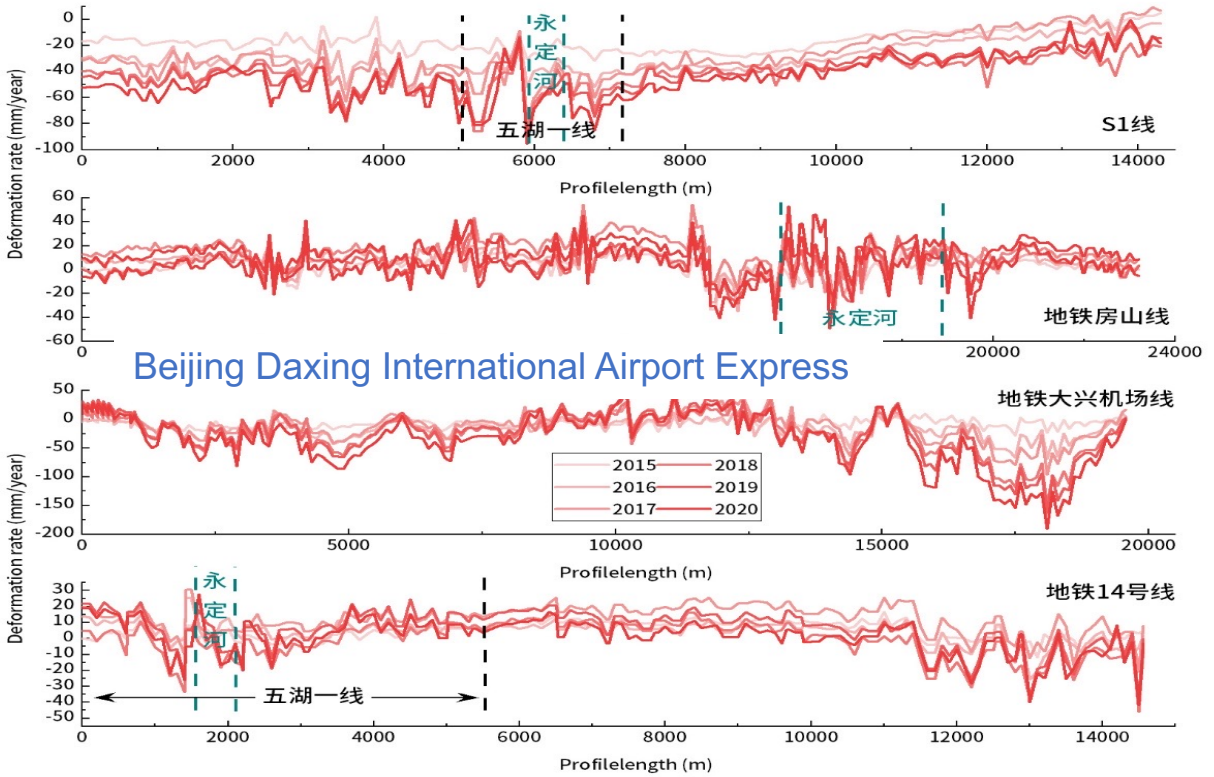


Assuming that the subsidence rate is a constant, the threshold (200 mm) will be reached in the near future (Feb. 2029) if the aquifer at that location continues to be compacted.

However, It should be noted that, as the government in Beijing and the Beijing-tianjin-hebei region has increased their efforts to prevent and control land subsidence, and the rate of land subsidence in the Beijing Plain has slowed down.

Influence on subway lines





The deformation rate along BDIAE exceeds -50 mm/year, with a cumulative settlement close to 200 mm.
Although engineering measures have been taken during the construction of subway, the evolution of groundwater and subsidence in this area still needs to be paid close attention to.

Conclusion

At present, ecological water replenishment of Yondding River has no obvious impact on the formation deformation, but the rising groundwater level and differential land subsidence in some regions will pose a great risk to the safety of coastal areas in the future.

In addition, the Beijing section of the Yongding River crosses multiple subway lines, and the affected area is close to the Beijing Daxing International Airport. Local groundwater level rising may cause underground facilities damage, and uneven land subsidence may cause surface & underground structure break, as well as the stability of electronic equipment, which affecting the safe operation of airports and rail transit. Therefore, the urban security risk that it may bring, need to pay close attention to.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Thanks!