Monitoring land subsidence over large area with time series InSAR technique

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Motivatio

Subsidence in China

- **20 provinces were affected,**

  four subsidence zones,

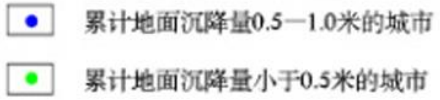
  total area around 930,000 sq. km with > 20

  Out of them, 50 cities suffer severe ground

- Main reasons: over-exploitation of groundwater and other ground

  as and co

- over 10-b



Different methods of measuring subsidence

METHOD	Component displacement	Resolution[1] (millimeters)	Spatial density[2] (samples/survey)	Spatial scale (elements)
Spirit level	vertical	0.1–1	10–100	line-network
Geodimeter	horizontal	1	10–100	line-network
Borehole extensometer	vertical	0.01–0.1	1–3	point
Horizontal extensometer:				
Tape	horizontal	0.3	1–10	line-array
Invar wire	horizontal	0.0001	1	line
Quartz tube	horizontal	0.00001	1	line
GPS	vertical horizontal	20 5	10–100	network
InSAR	range	5–10	100,000–10,000,000	map pixel[3]

Cost

expensive

economic

--USGS Facesheet-051-00, “Measuring land subsidence from space”, 2000

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Research and development on InSAR subsidence monitoring

- Our team led by Prof. Yonghong Zhang has focused on SAR Interferometry (InSAR) for more than 10 years.

- An improved time series InSAR technique, namely “Multiple-master Coherent Target Small-Baseline InSAR” (MCTSB-InSAR), has been developed, which is more advantageous than PS-InSAR and SBAS-InSAR alone.

- On the basis of MCTSB-InSAR, GDEMSI software was developed

GDEMSI ——
Ground DEformation Monitoring System with InSAR

Key features of GDEMSI

- GUI –based
- Supporting parallel computing
- Supporting fully automatic running
- Excellent Balance between encapsulation and flexibility
- A series of innovative algorithms embedded

Applications

- MCTSB-InSAR and GDEMSI have been used in many application projects, and mapped ground deformation over area more than 300,000 km2, including:
  - Beijing-Tianjin-Hebei region (1992-2016, 96,000km2)
  - Jiangsu province (2007-2015, 107,000 km2)
  - Zhejiang plain region (30,000km2)
  - Taiyuan, Shanxi
  - Urumqi, Xinjiang
  - Baotou, Inner-mongolia
  - Luanchuan, Henan
  - Nanpiao, Liaoning
  - Gongying, Shandong
  - Shenzhen, Guangdong
  - Jixi, Heilongjiang
  - Wenchuan, Sichuan

(The background is provided by Google Earth)

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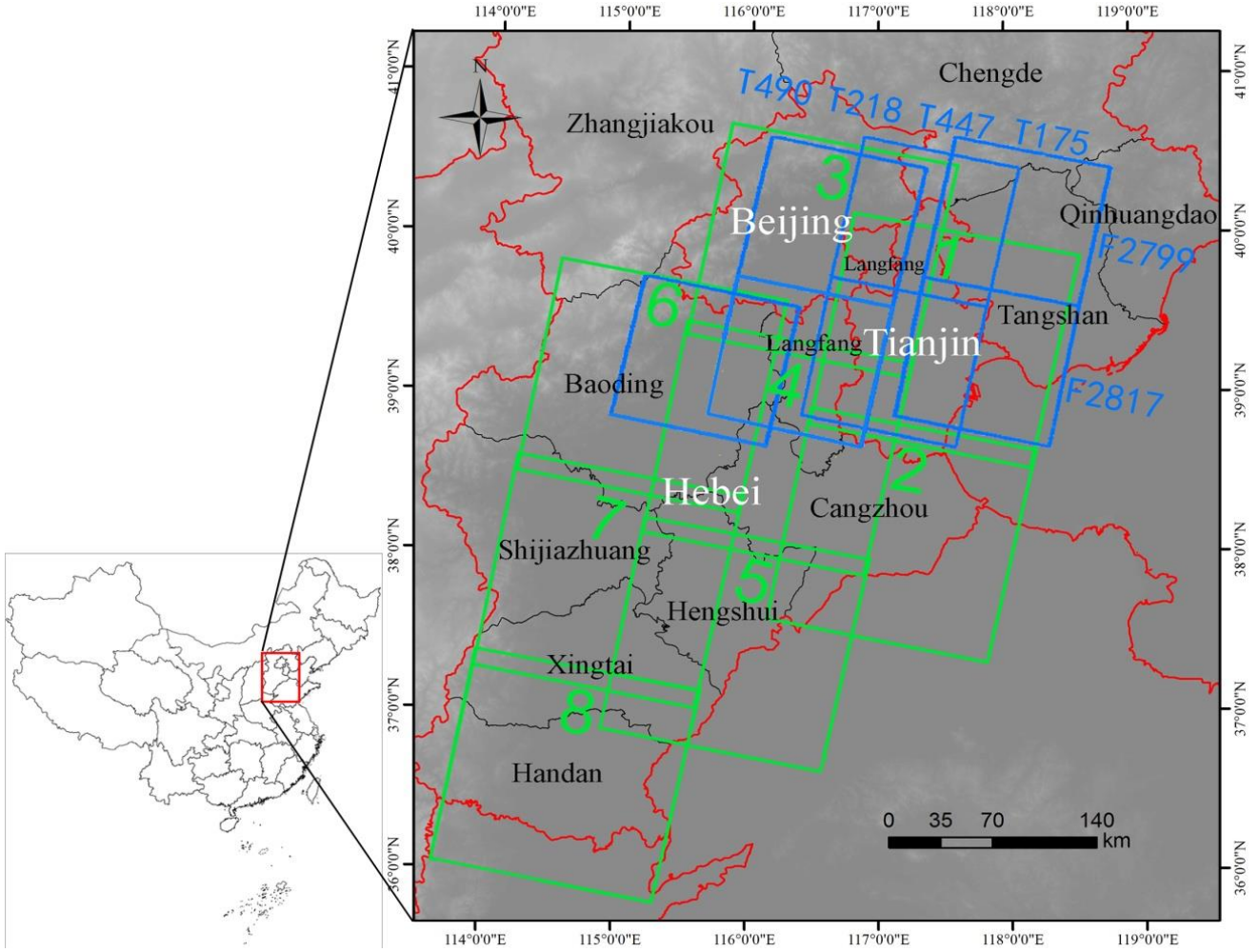
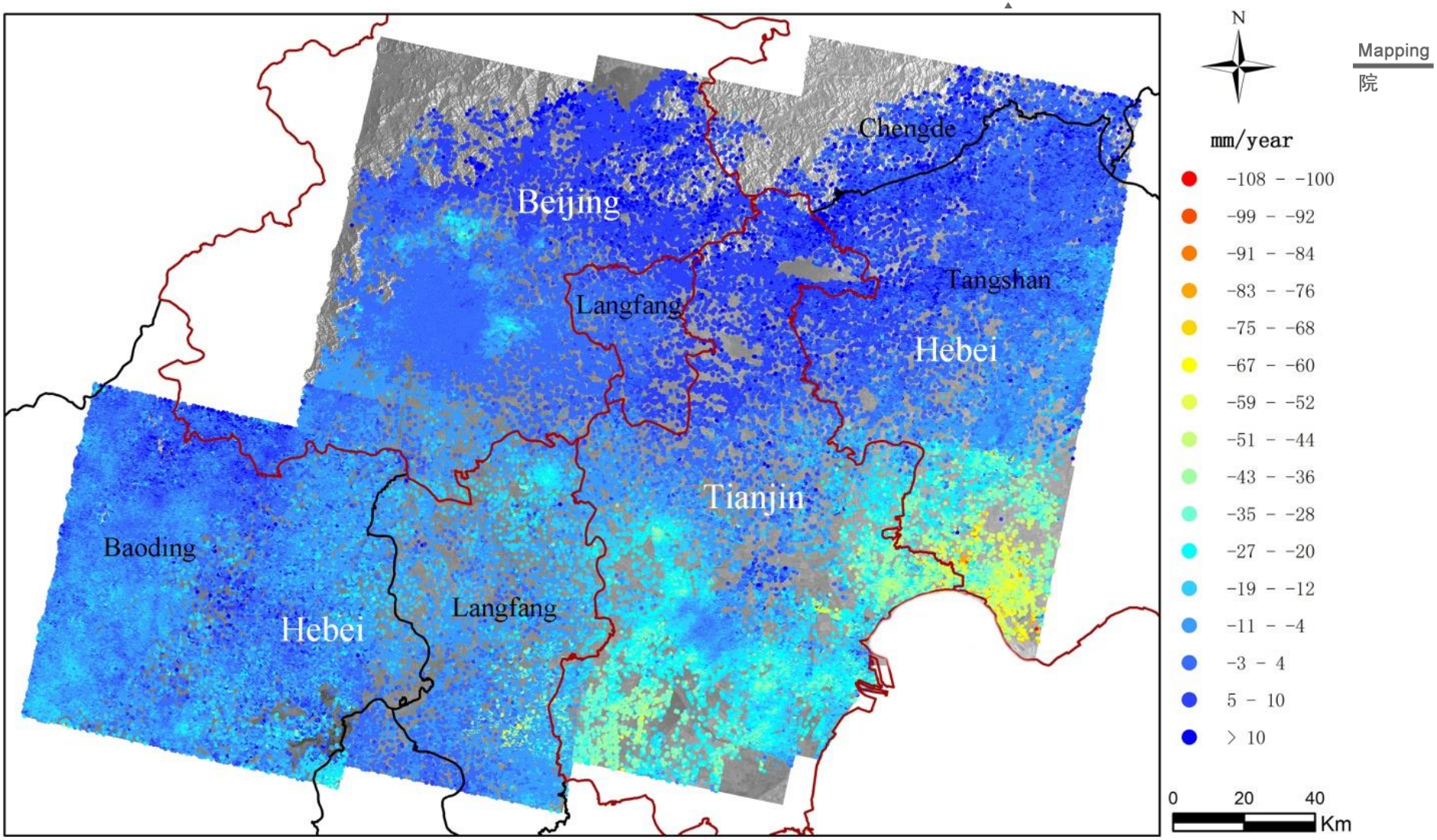
Ground subsidence monitoring in the Beijing-Tianjin-Hebei region from 1992 to 2016



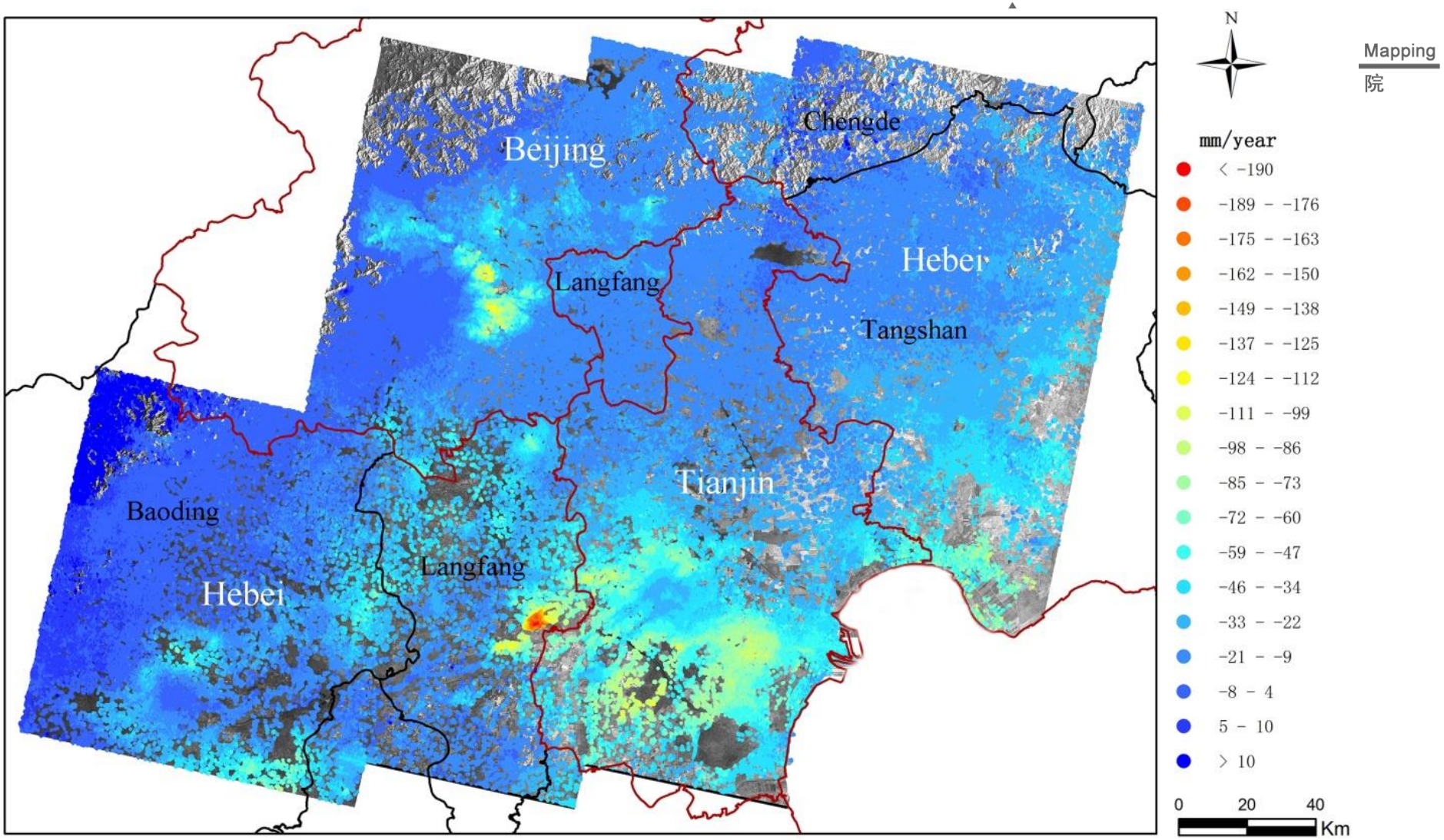
Location of the monitoring area and coverage of SAR data.

A **blue** rectangle stands for the coverage of one **ERS/ENVISAT** SAR scene,

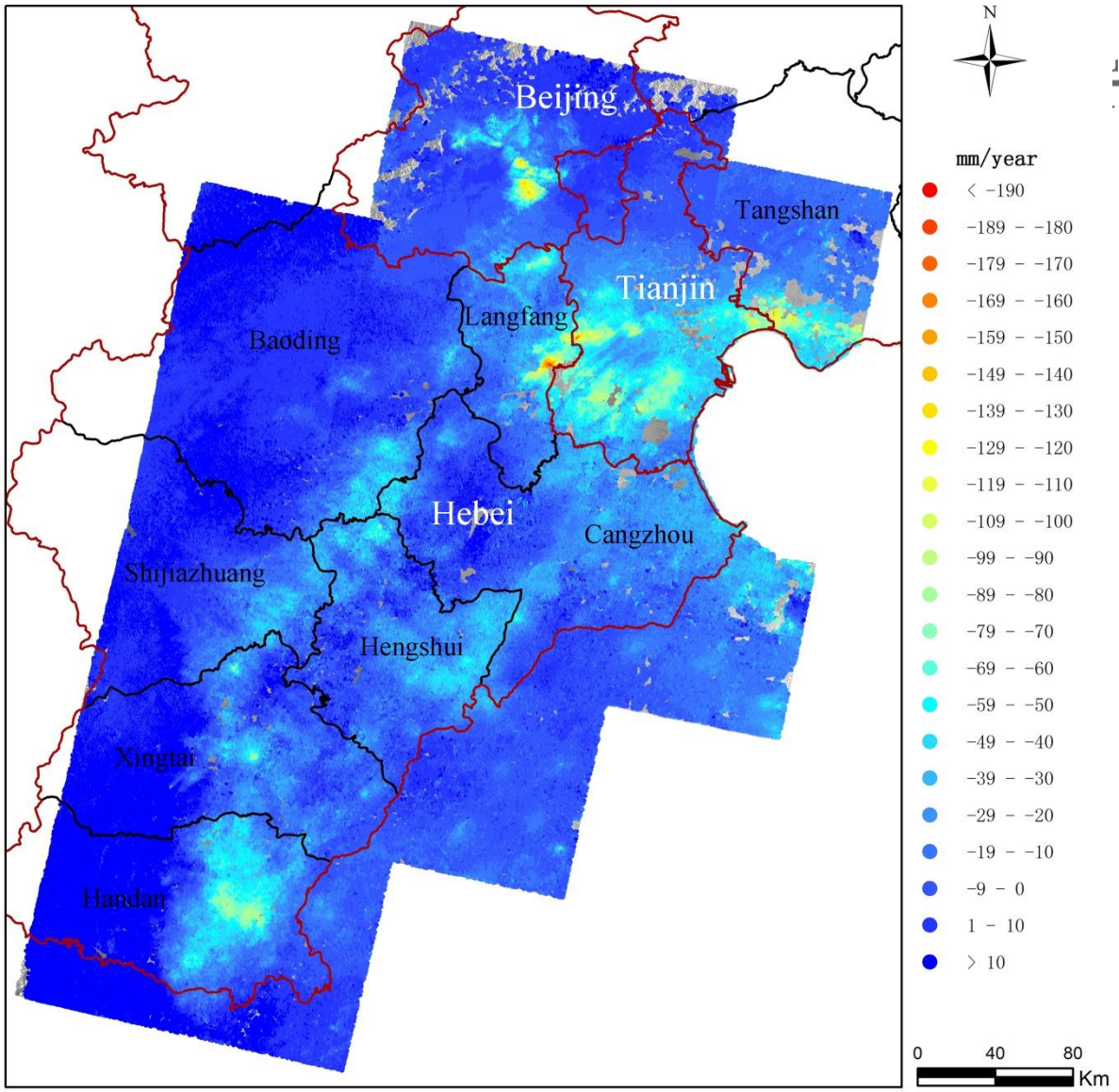
and a **green** rectangle for one **RADARSAT-2** SAR image.



Average subsidence rate over the Beijing-Tianjin-Hebei region **from 1992 to 2000** observed by time series ERS-1/2 SAR images

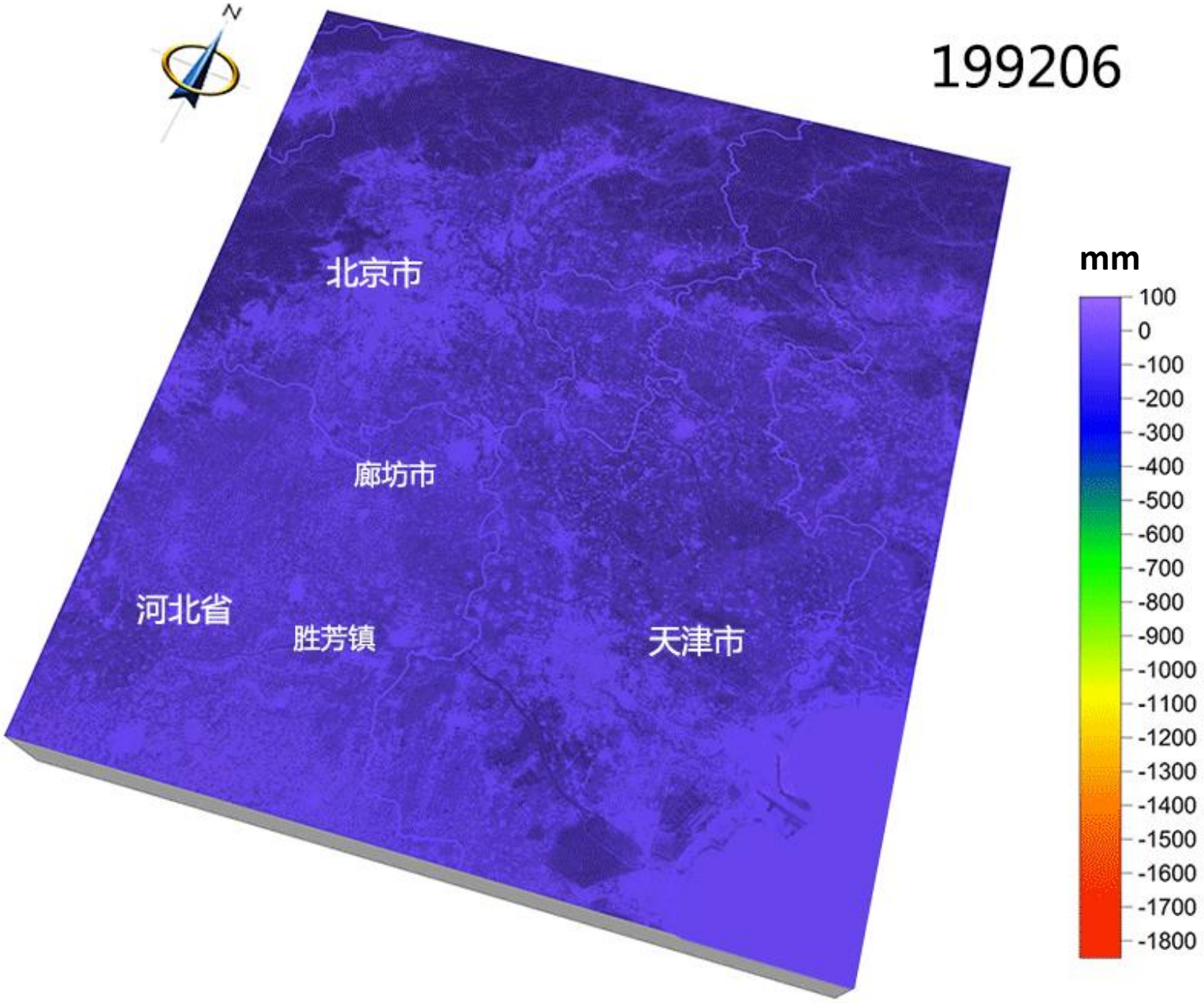


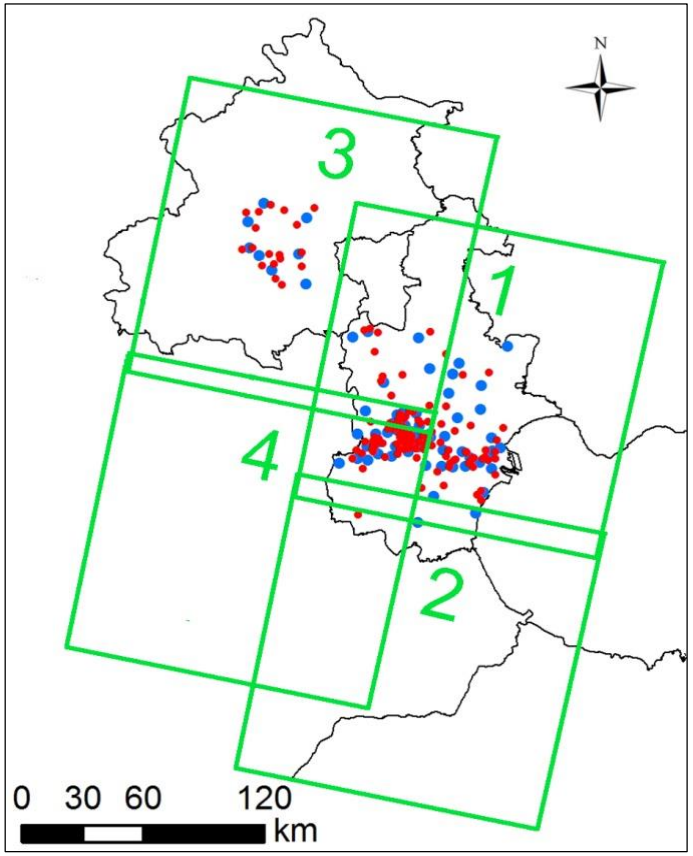
Average subsidence rate over the Beijing-Tianjin-Hebei region **from 2003 to 2010** observed by time series ENVISAT ASAR images.



Average subsidence rate over Beijing-Tianjin-Hebei region **from 2012 to 2016** observed by time series RADARSAT-2 images

Evolution of ground subsidence over Beijing-Tianjin-Hebei region from 1992 to 2016





Locations of the leveling points used for accuracy evaluation

Table 1. Statistics of accuracy evaluation of InSAR-derived subsidence rate in three periods (mm/year)

Time spans	Number of used leveling points	Maximum difference	Minimum difference	Standard deviation of difference
1992-2000	123	14	-12	8.7
2003-2010	166	11	-14	4.7
2012-2016	141	11	-16	5.4

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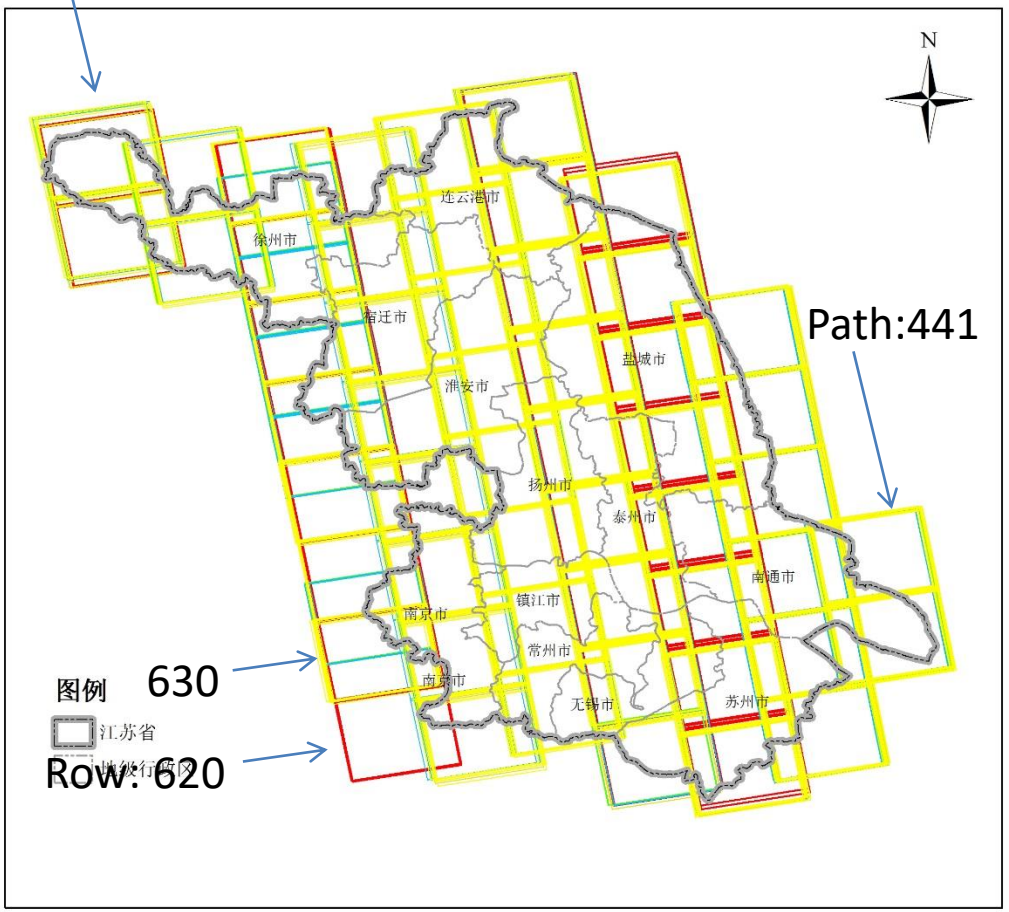
Ground subsidence monitoring over Jiangsu province with MCTSB-InSAR

- Jiangsu is one of the most prosperous provinces in China.
- Located at the Yangze river delta region, Jiangsu has suffered very serious ground subsidence since 1990s with the economy starting to boom.
- Jiangsu provincial government funded the project of monitoring ground subsidence over its full territory with InSAR.
- The project has been implemented to obtain ground subsidence for two terms: 2007-2011, and 2012-2015.

Term 1: 2007-2011

- Data source: ALOS PALSAR
- 53 frames to form a full coverage
- Totally 958 PALSAR scenes

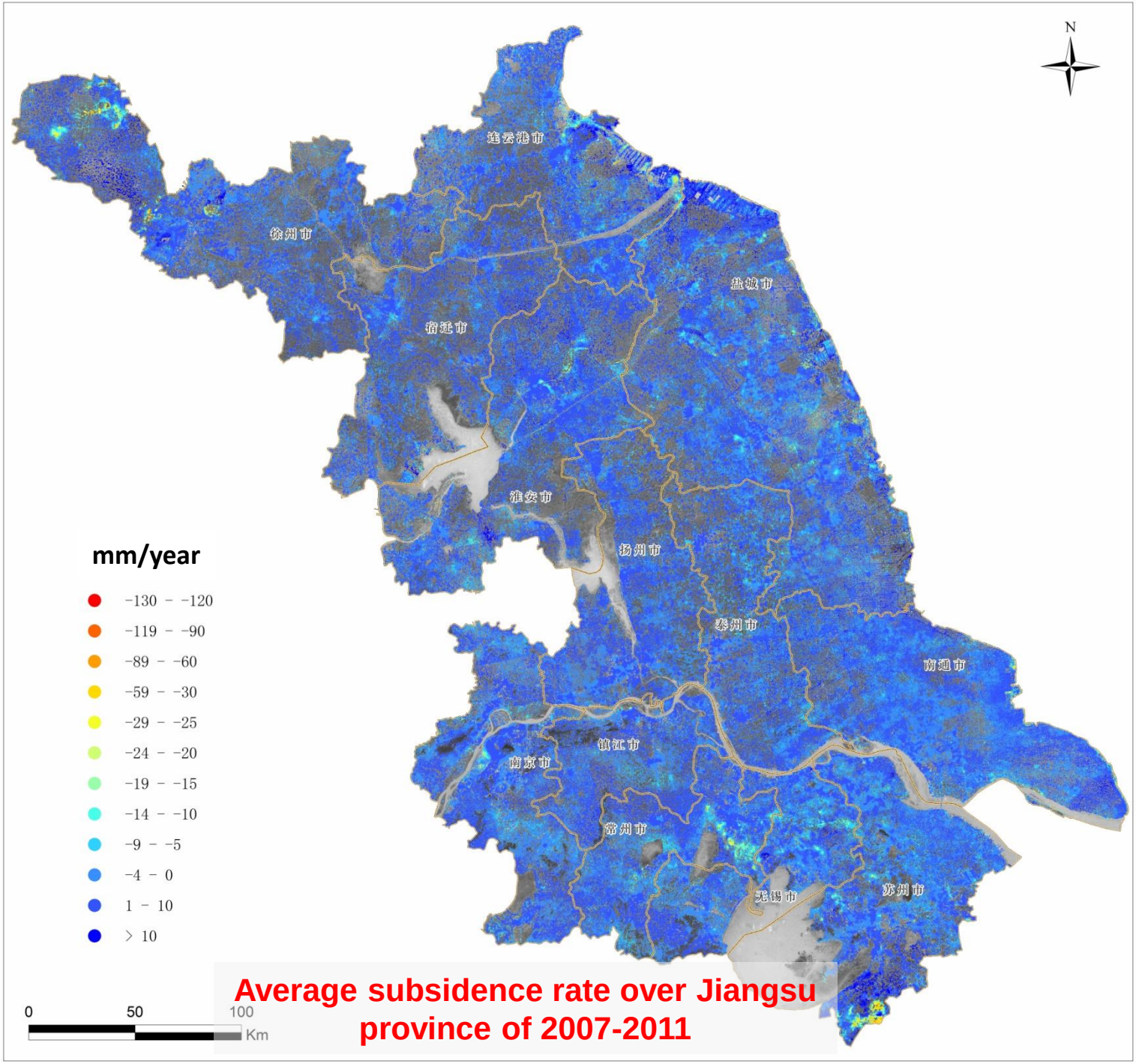
	449	448	447	446	445	444	443	442	441
690						18			
680	17	18	15	17	20	21	19		
670	17	18	15	17	20	20	19		
660			15	17	21	21	21	19	
650			15	17	21	21	20	19	
640			15	17	19	21	19	19	
630			15	17	21	21	19	19	19
620			15	16	21	21	21	19	19
610			2	16	19	10	21	19	



Resolution: 30m

Around 7 M coherent targets

Maximum subsidence rate: 138 mm per year.

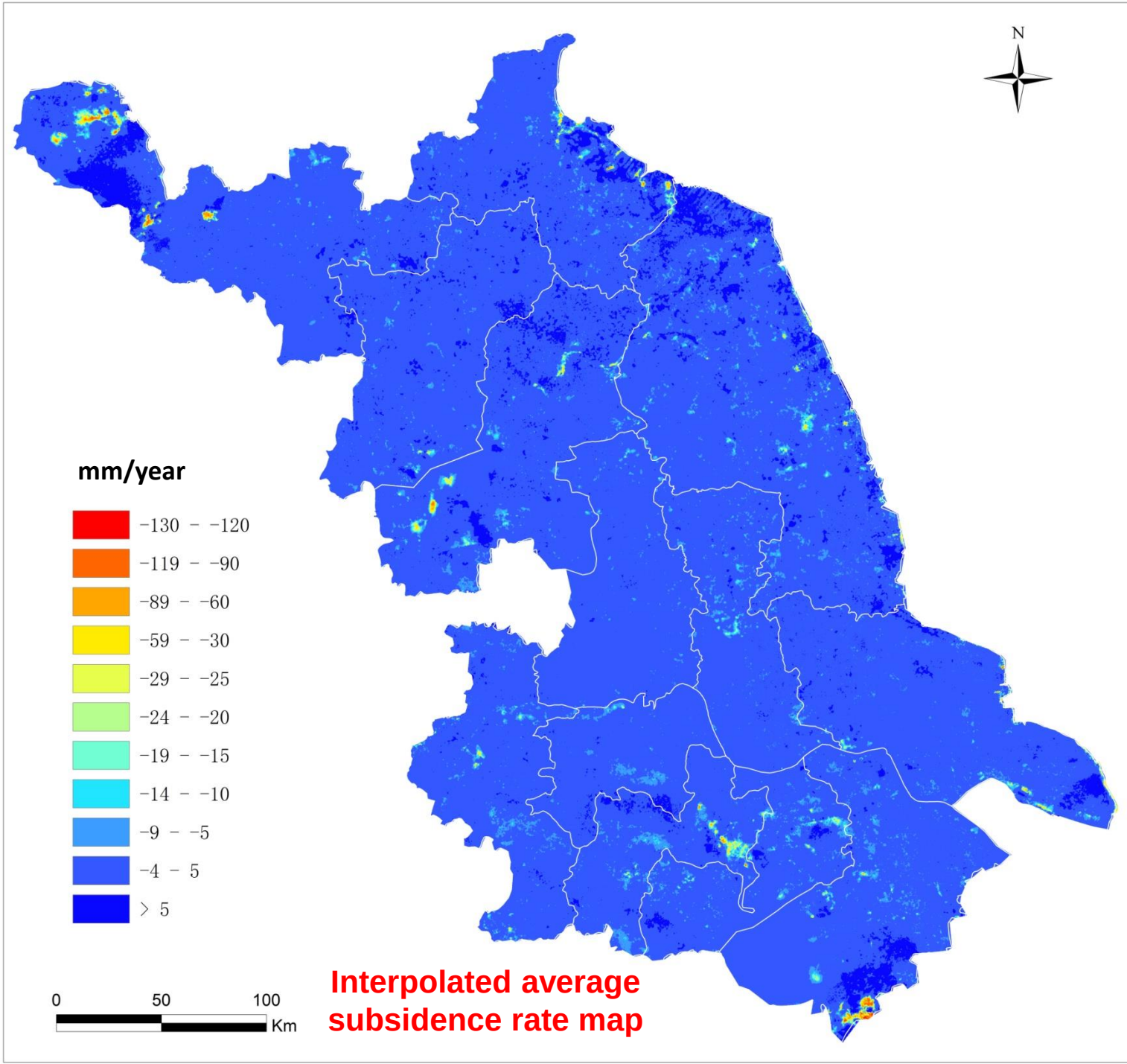


Average subsidence rate over Jiangsu province of 2007-2011

Subsidence zones are clearly presented.

It represents a first ever subsidence map at a resolution of 30 m covering the full province.

It served as a base to investigate the driving forces of subsidence, and to make decisions on how to mitigate subsidence

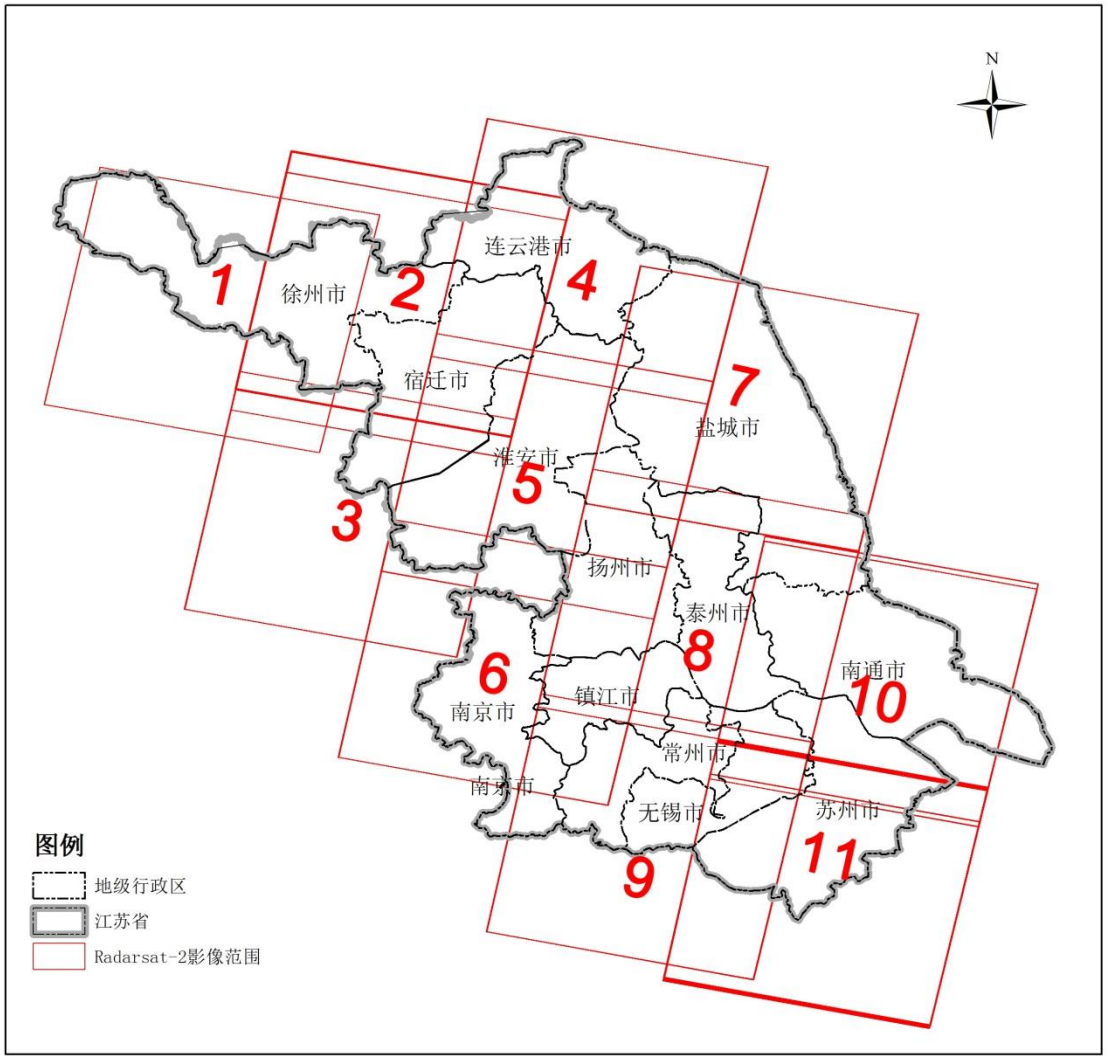


Interpolated average subsidence rate map

Term 2: 2012-2015

- Data source: RADARSAT-2
- 11 frames to form a full coverage
- Totally 259 scenes

Frame	Stack size	Acquisition time span
1	24	20120211-20150806
2	24	20120125-20160104
3	11	20120125-20121226
4	25	20120201-20151218
5	25	20120201-20151007
6	25	20120201-20151007
7	25	20120208-20151201
8	25	20120208-20160118
9	25	20120208-20160118
10	25	20120310-20151208
11	25	20120310-20160101

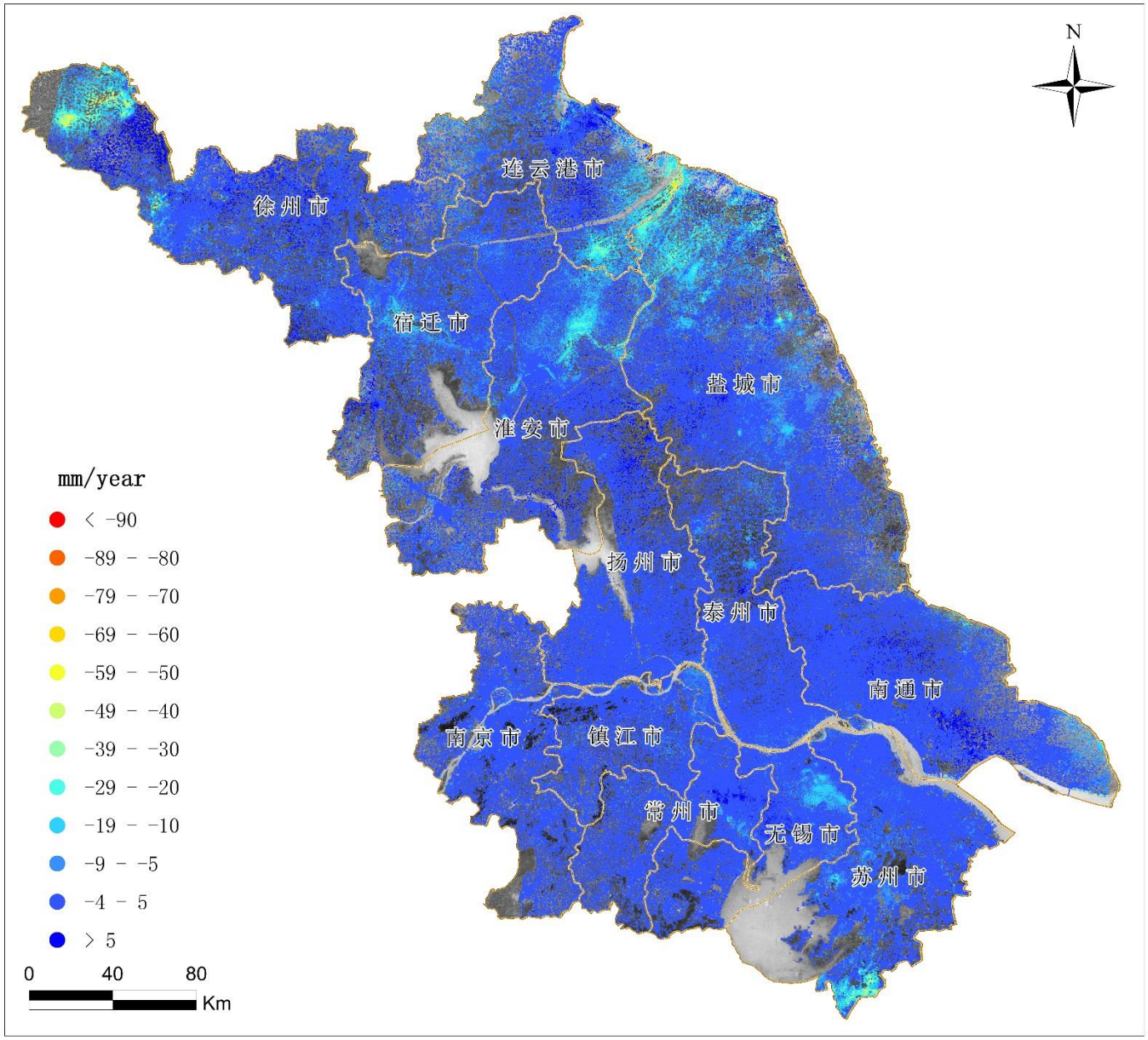


Resolution: 25m

Around 5 M coherent targets are selected

Density of targets: 50 per km2

Maximum subsidence rate: 98 mm per year.

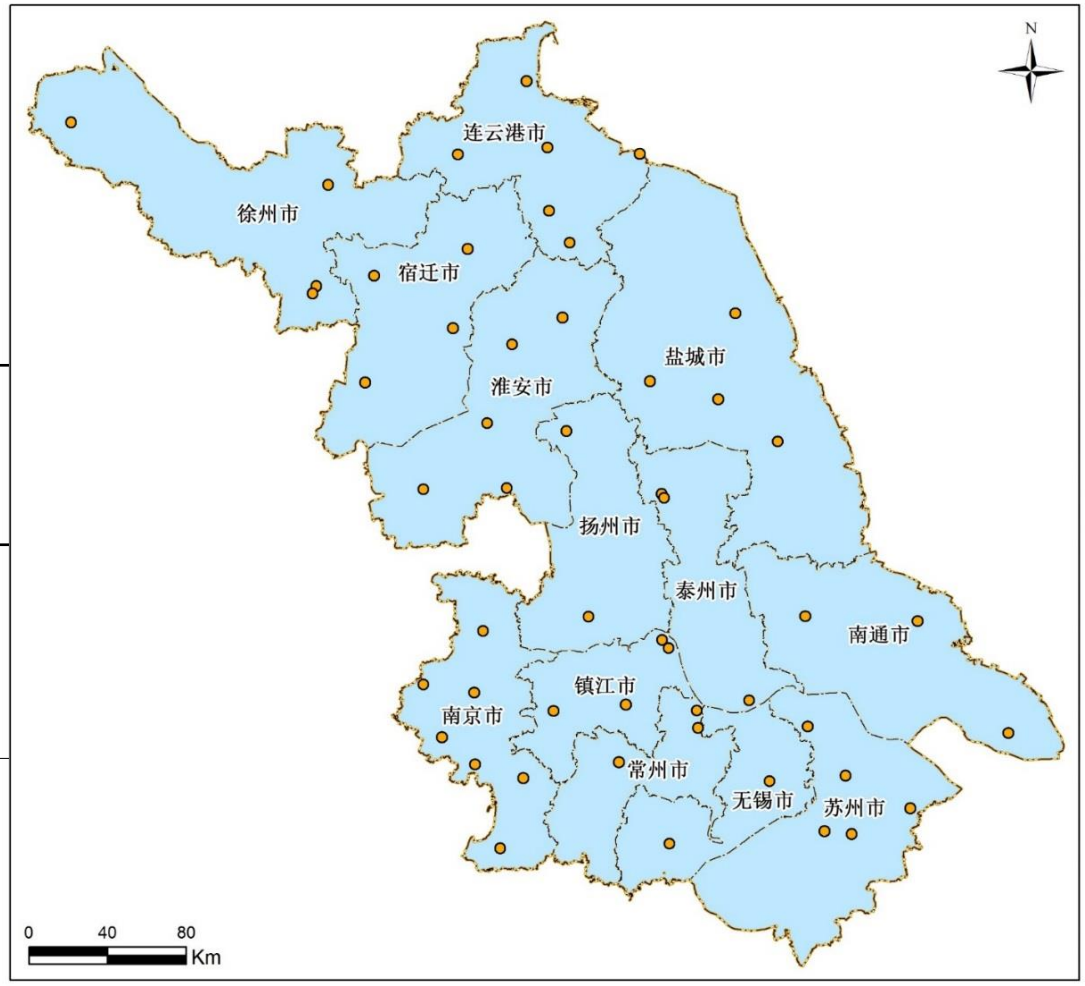


Average subsidence rate over Jiangsu province of 2012-2015

Accuracy validation

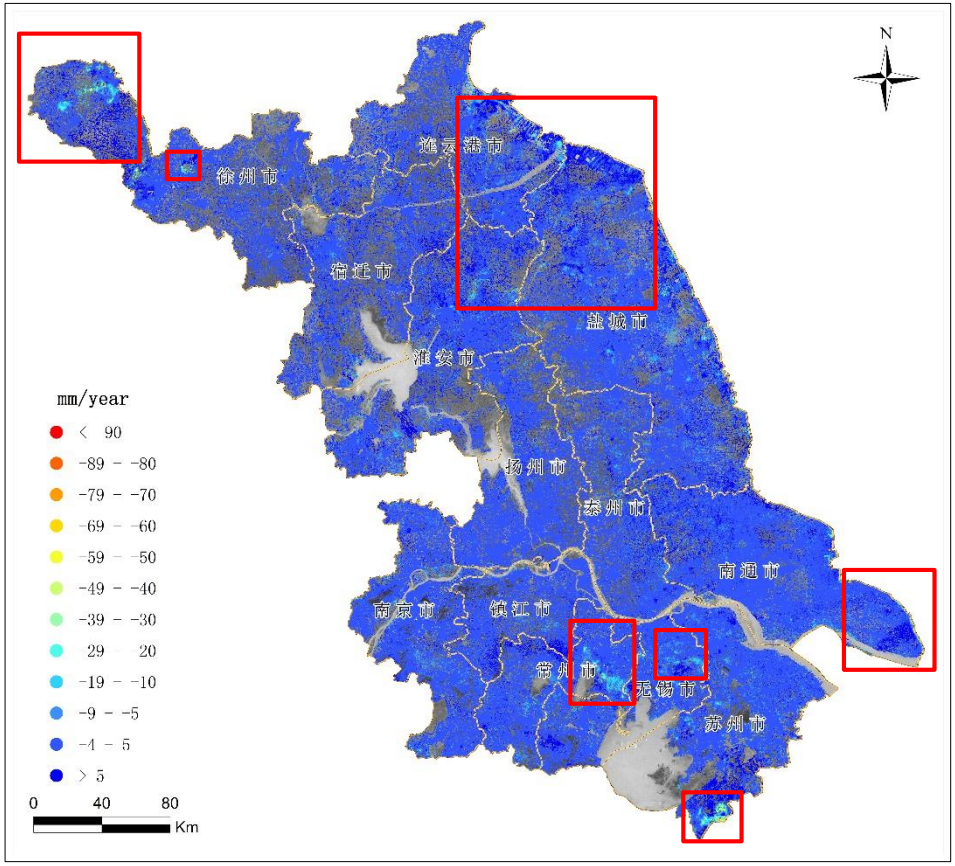
Table 2. Statistics of accuracy evaluation of InSAR-derived subsidence rate in two periods (mm/year)

Time spans	Number of used CORS data	Standard deviation of difference
2008-2011	57	3.8
2012-2015	44	4.3

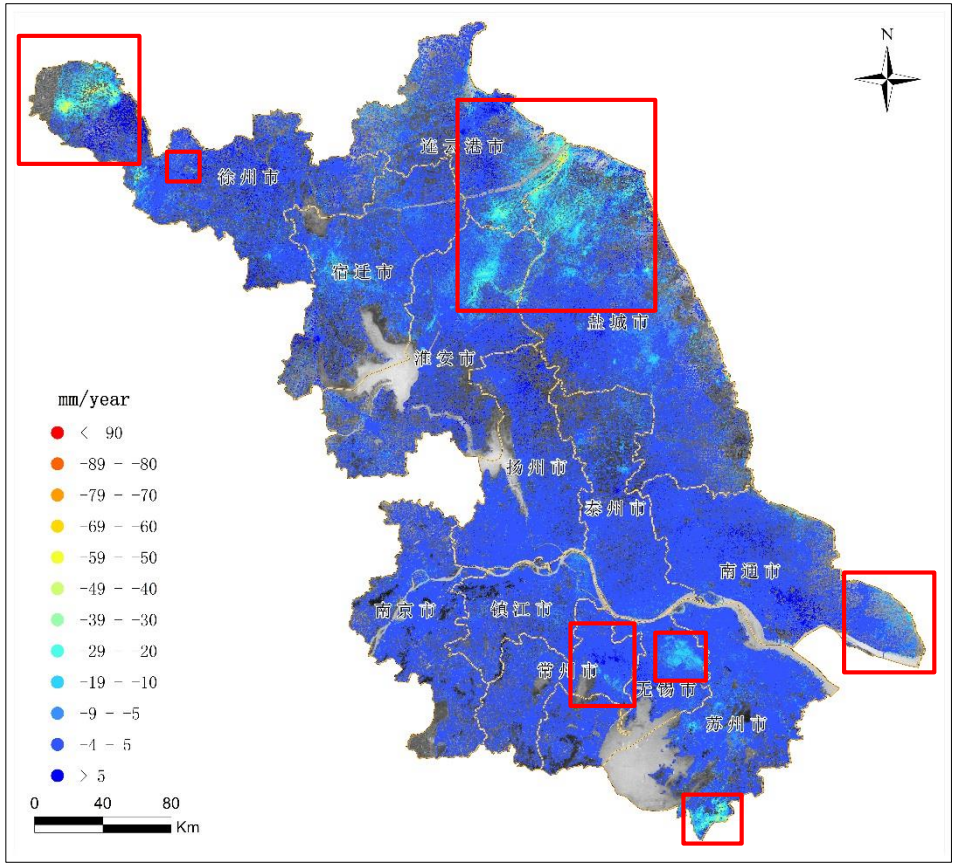


Locations of the CORS data used for accuracy evaluation

Comparison of subsidence rate between 2012-2015 and 2007-2011



Average subsidence rate in 2007-2011



Average subsidence rate in 2012-2015

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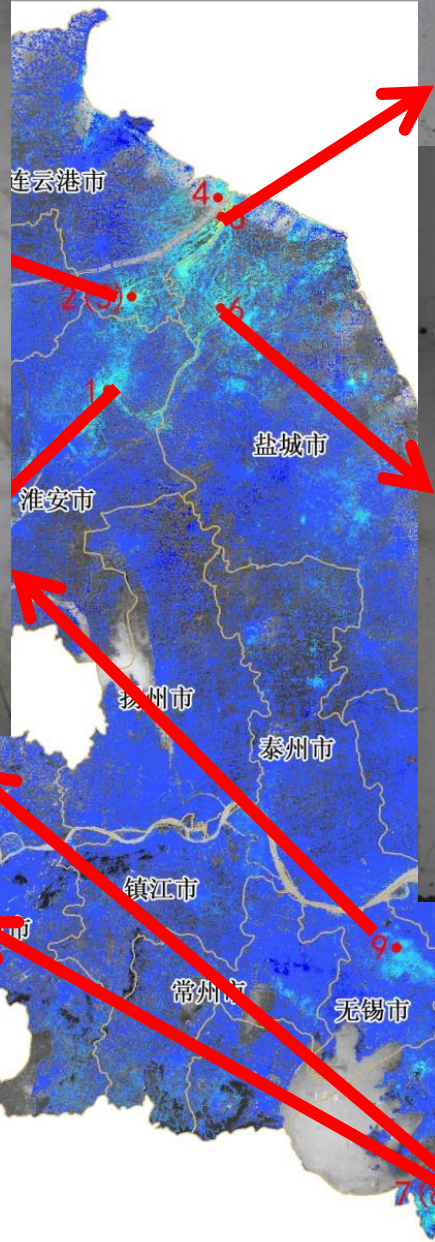

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Infrastructure health monitoring in detail in Hangzhou with high resolution SAR data

Data source: COSMO-SkyMed

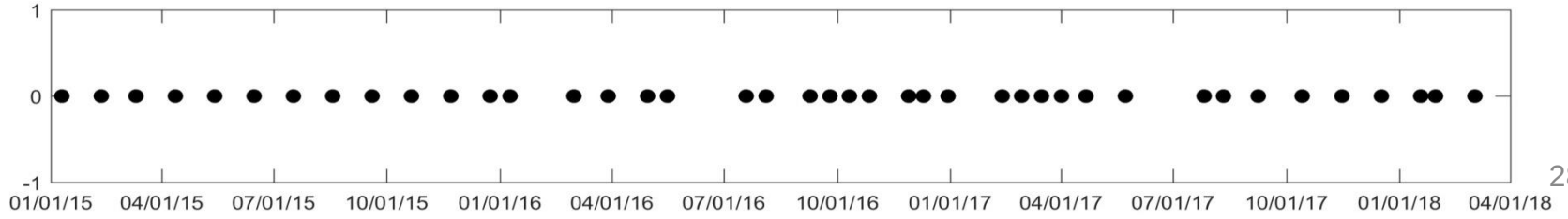
Image resolution: 3m

Number of SAR images: 41

Acquisition date:

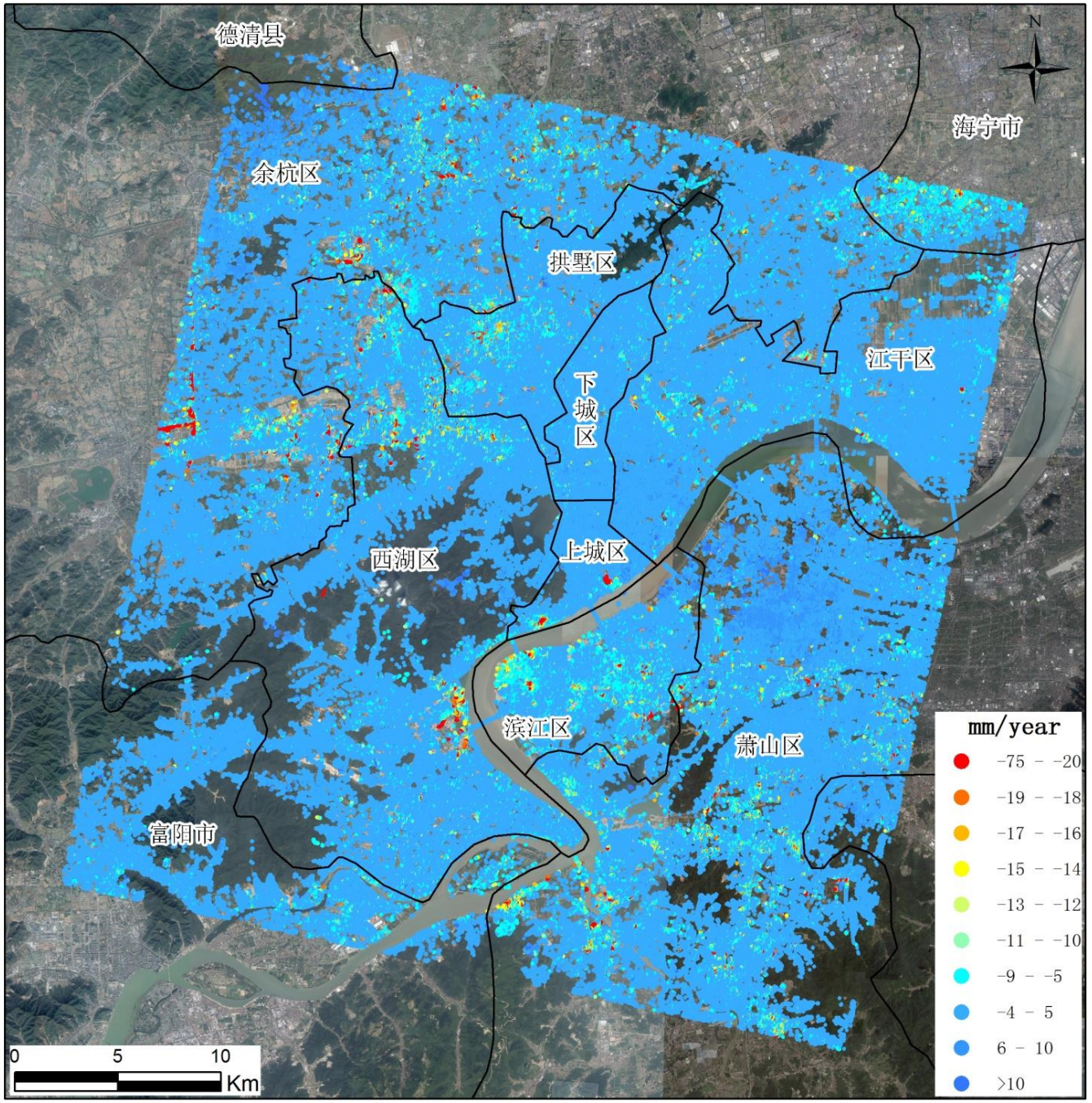
20150110-20180303

NO.	Acquisition date (yymmdd)	NO.	Acquisition date (yymmdd)
1	20150110	22	20161011
2	20150211	23	20161027
3	20150311	24	20161128
4	20150412	25	20161210
5	20150514	26	20161230
6	20150615	27	20170212
7	20150717	28	20170228
8	20150818	29	20170316
9	20150919	30	20170401
10	20151021	31	20170421
11	20151122	32	20170523
12	20151224	33	20170726
13	20160109	34	20170811
14	20160301	35	20170908
15	20160329	36	20171014
16	20160430	37	20171115
17	20160516	38	20171217
18	20160719	39	20180118
19	20160804	40	20180130
20	20160909	41	20180303
21	20160925		



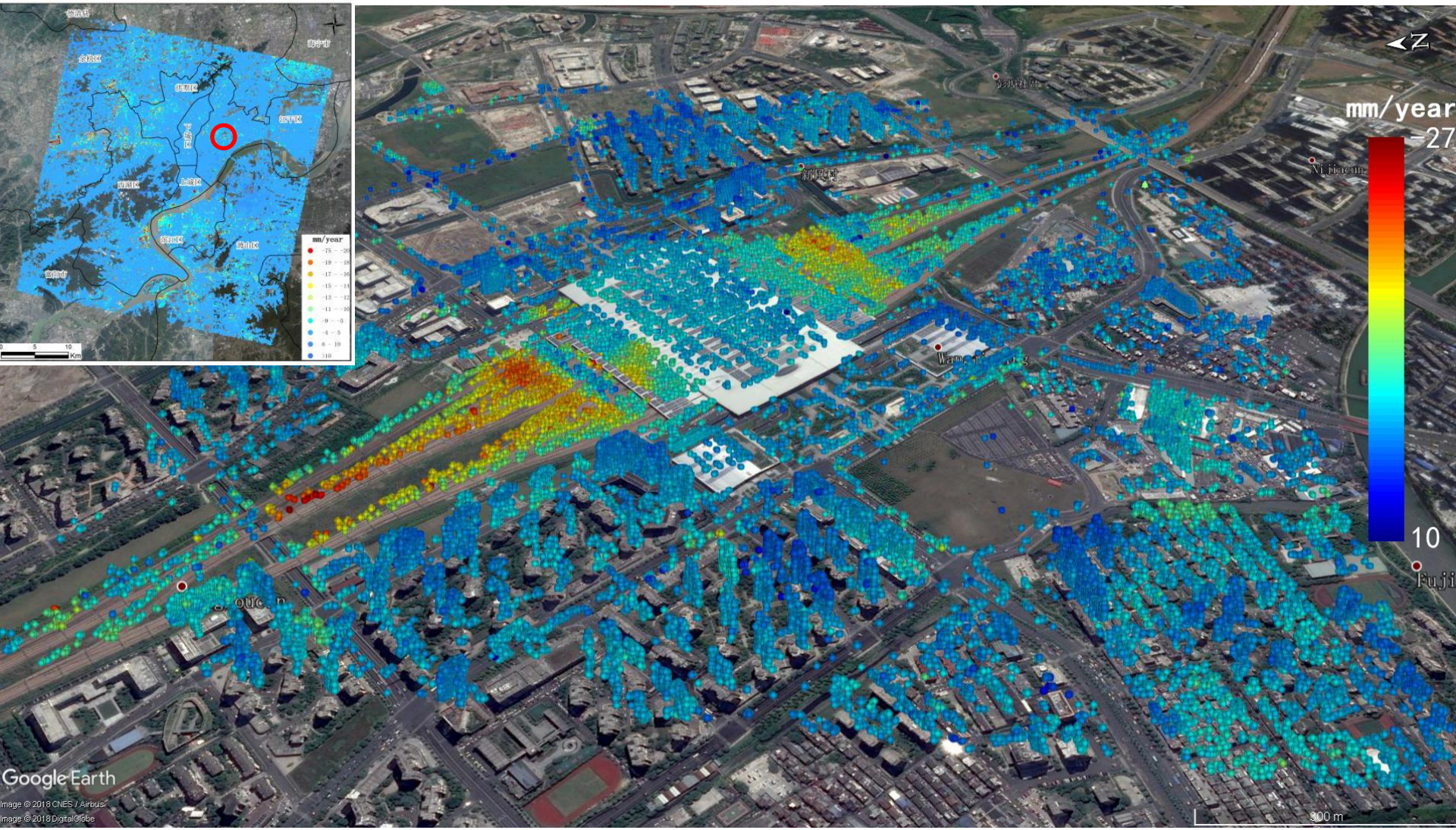
15,687,256 point targets are selected

Density of targets: **9800** per km2

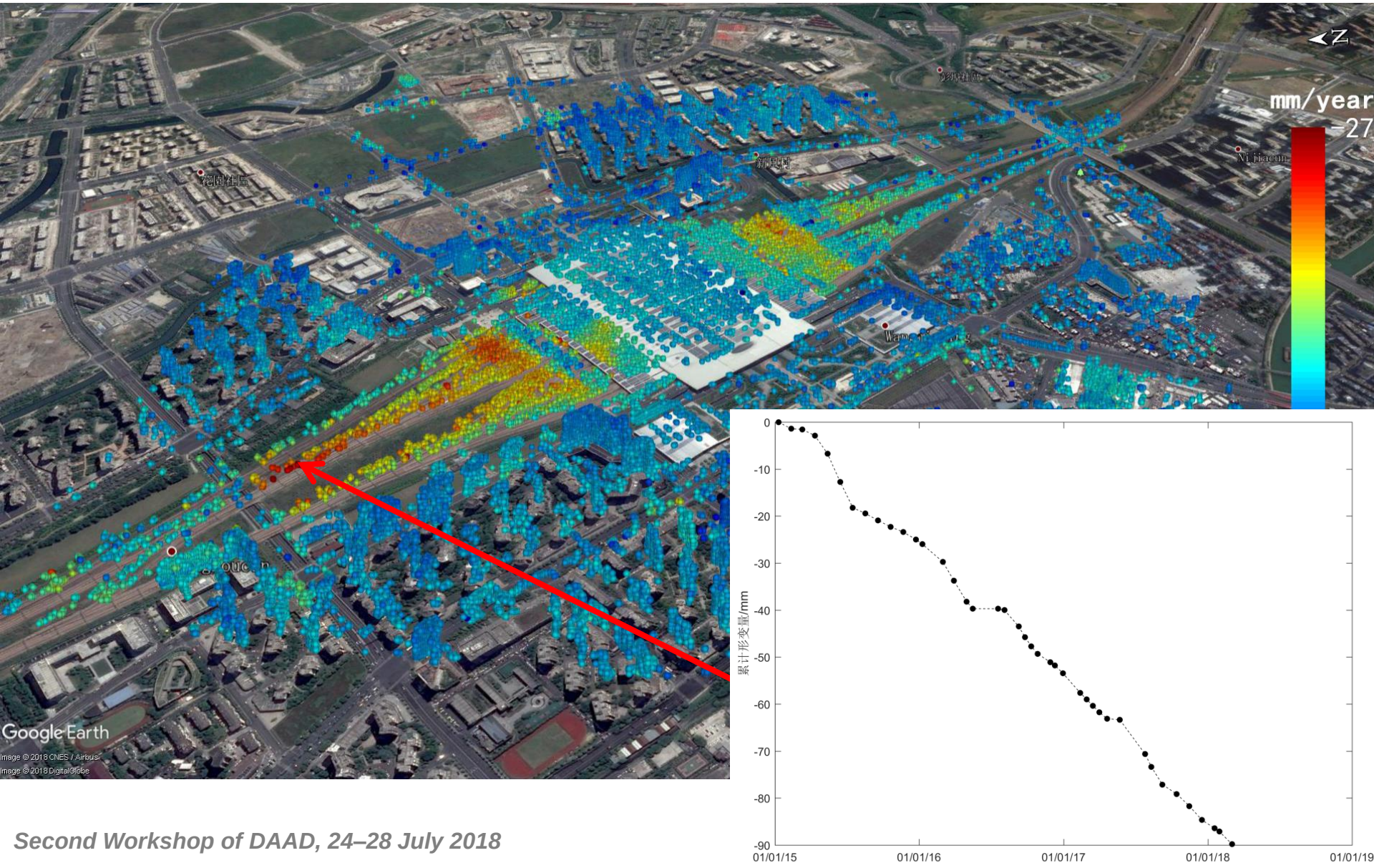


Average subsidence rate in Hangzhou from 201501 to 201803

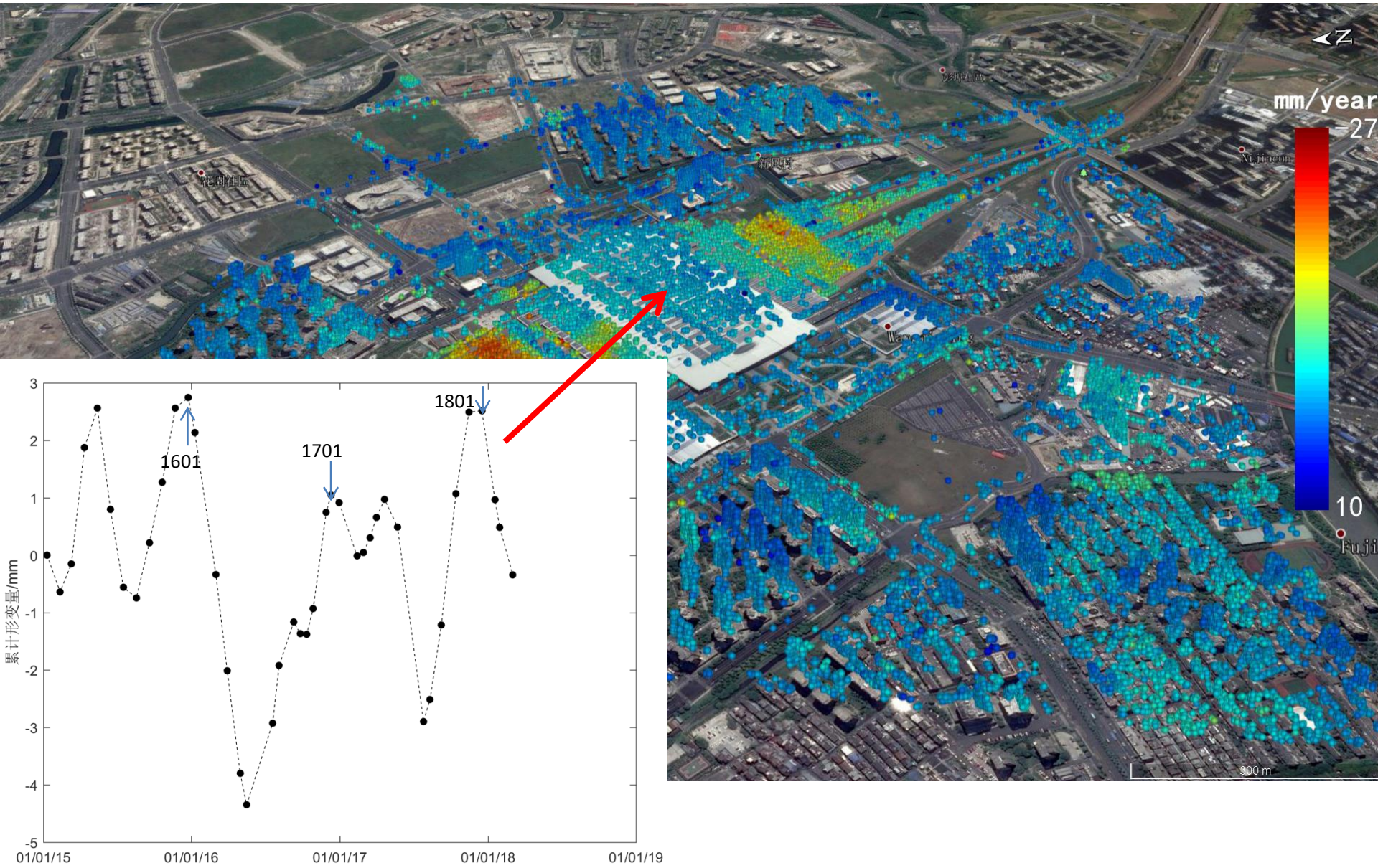
Hangzhou East Railway Station: 3-D display of average subsidence rate



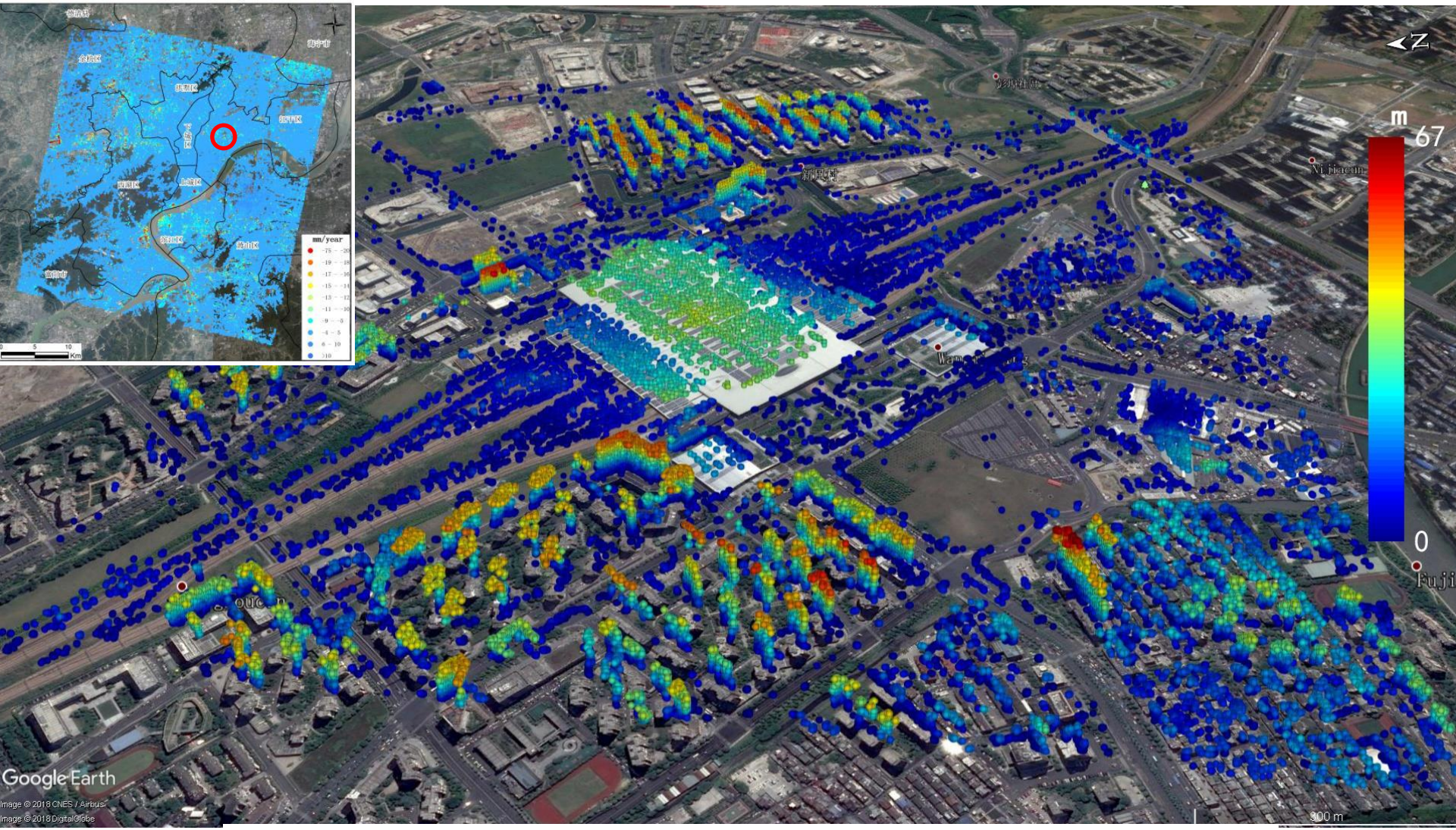
Hangzhou East Railway Station: time series accumulative subsidence of the railway track



Hangzhou East Railway Station: time series accumulative subsidence of the waiting hall



Hangzhou East Railway Station:
3-D display of building elevation on point targets

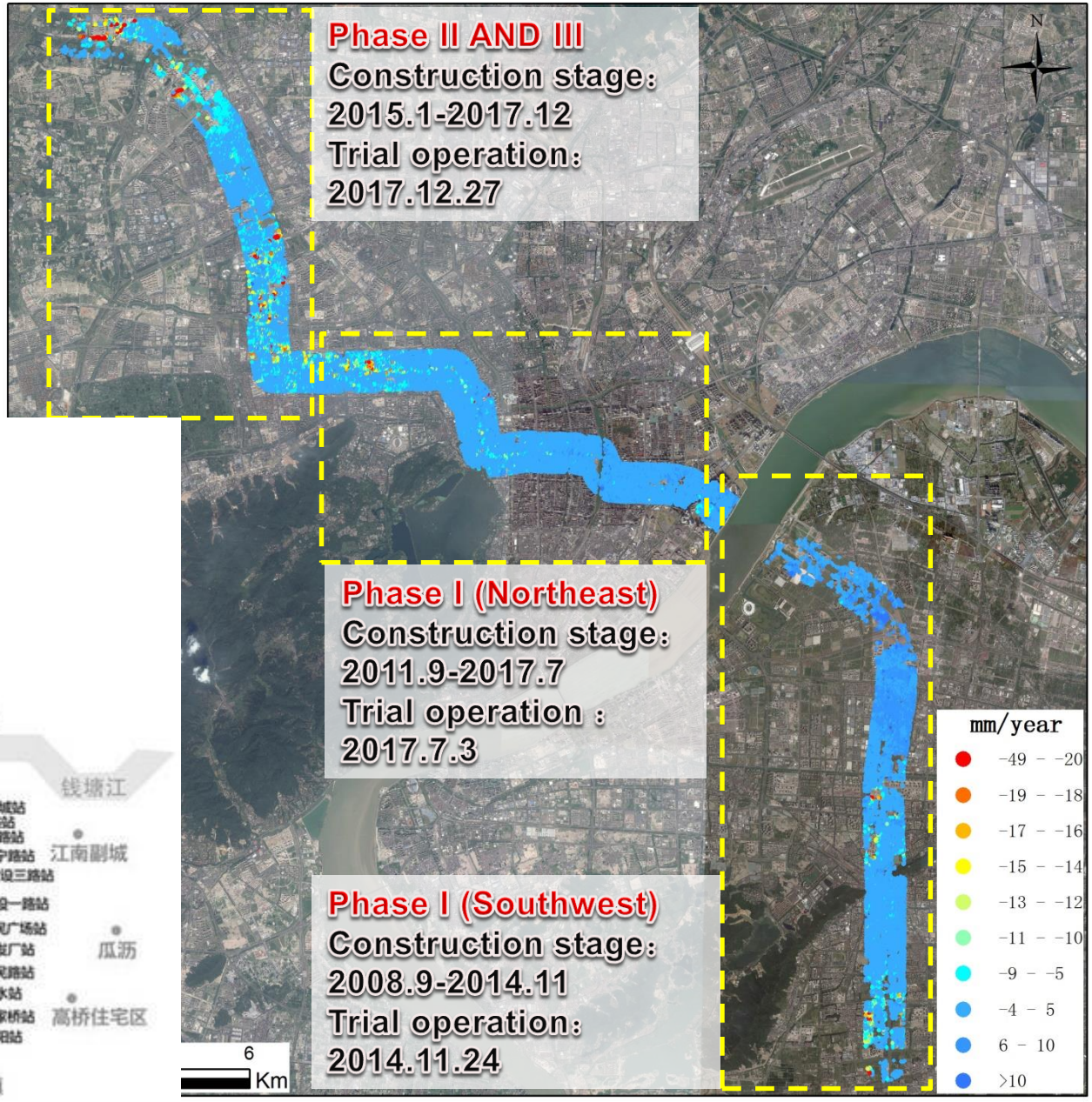


Hangzhou Metro Line 2: average subsidence rate

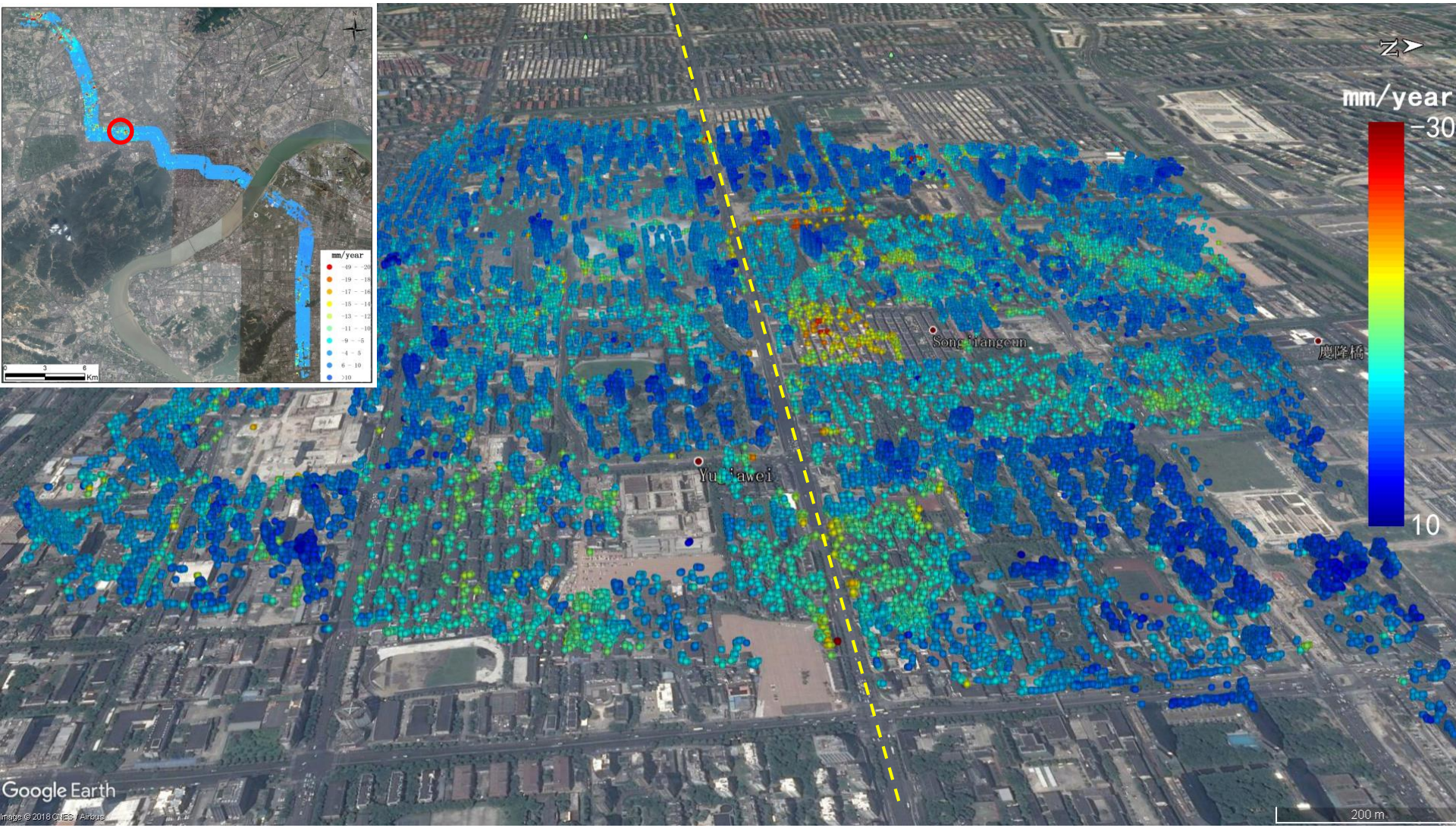
SAR aquizition:

2015.1.10 – 2018.3.3

Map of Metro Line 2



Hangzhou Metro Line 2: average subsidence rate from Gucui Road Station to Xueyuan Road station



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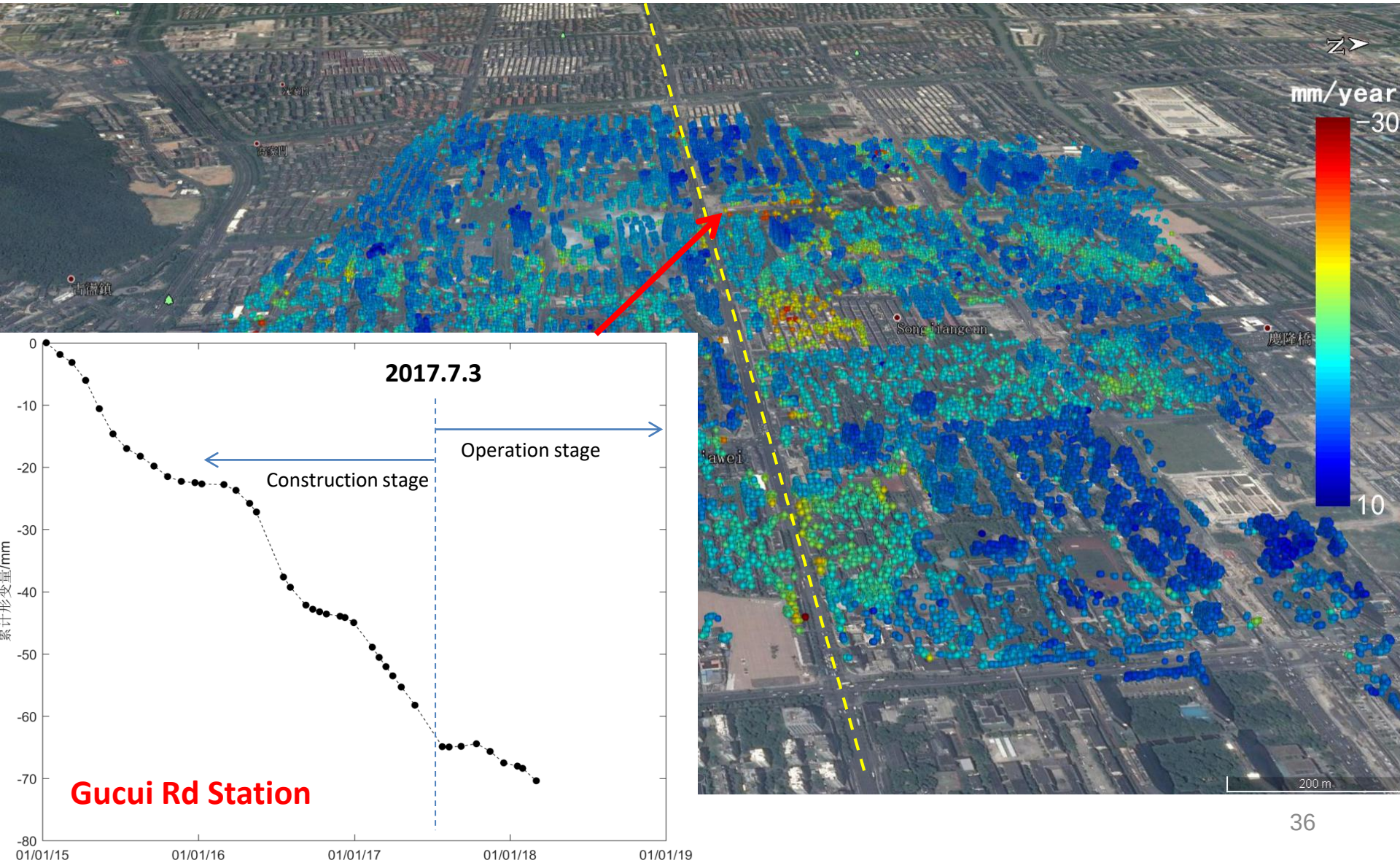
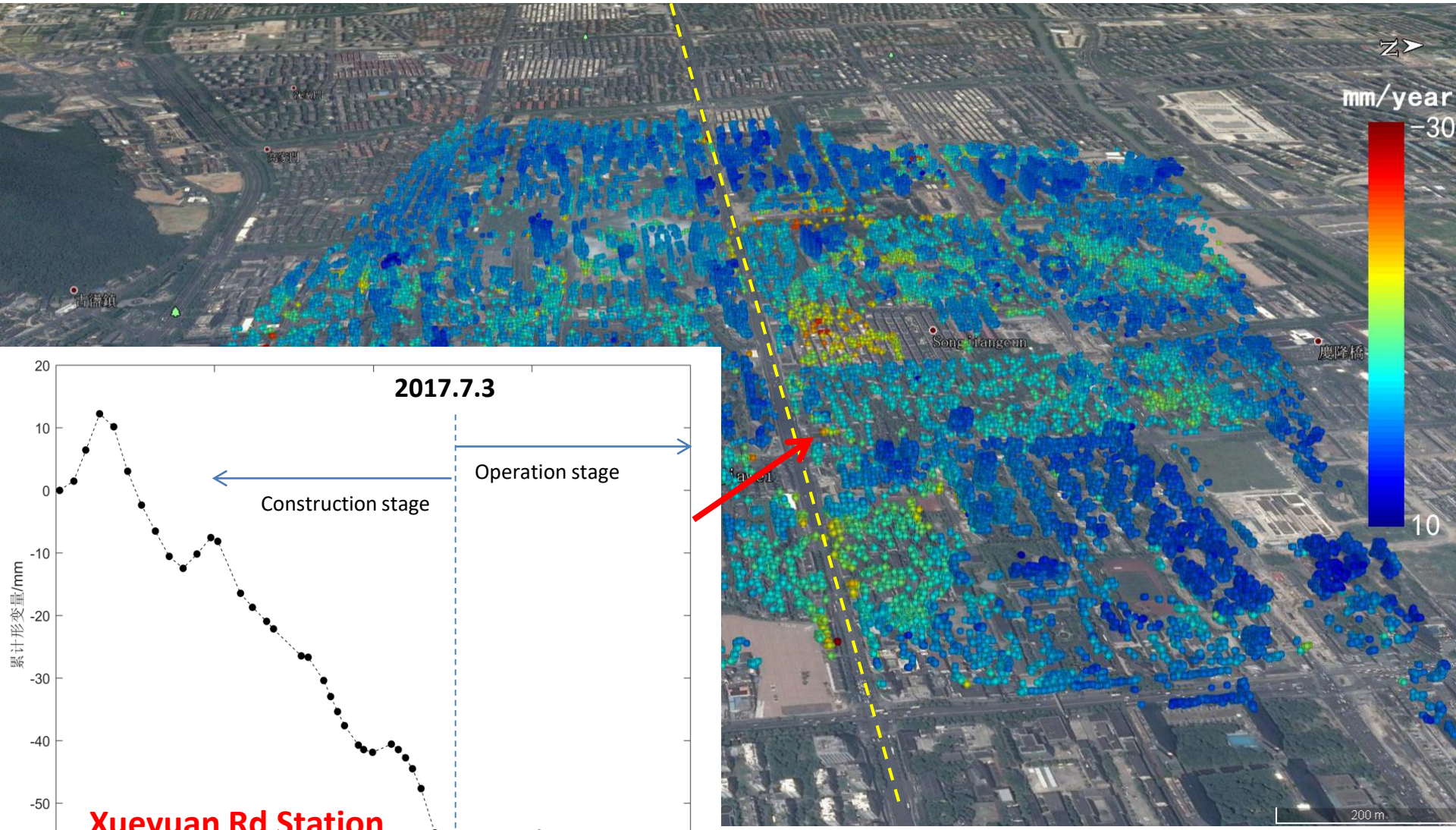
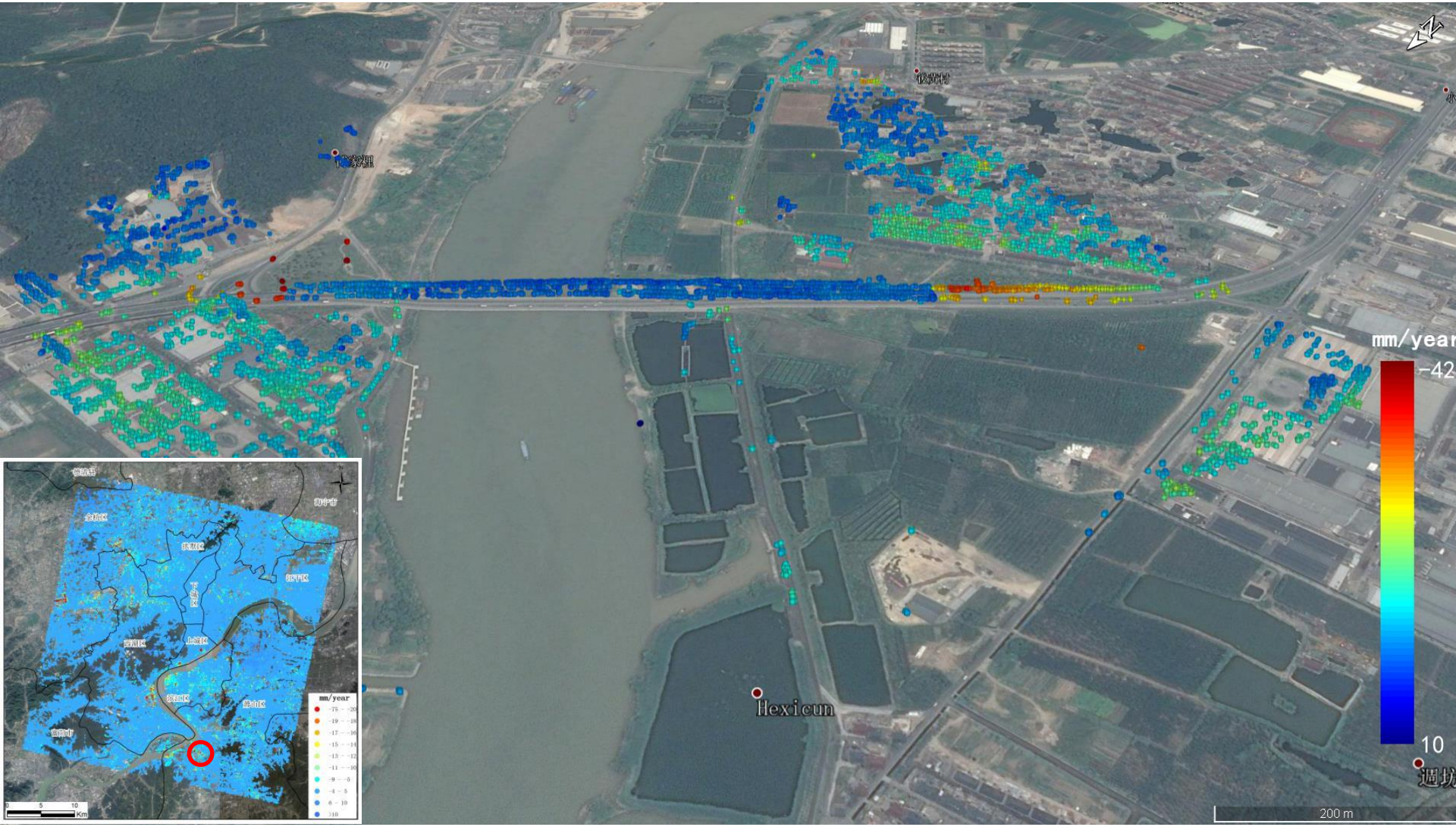


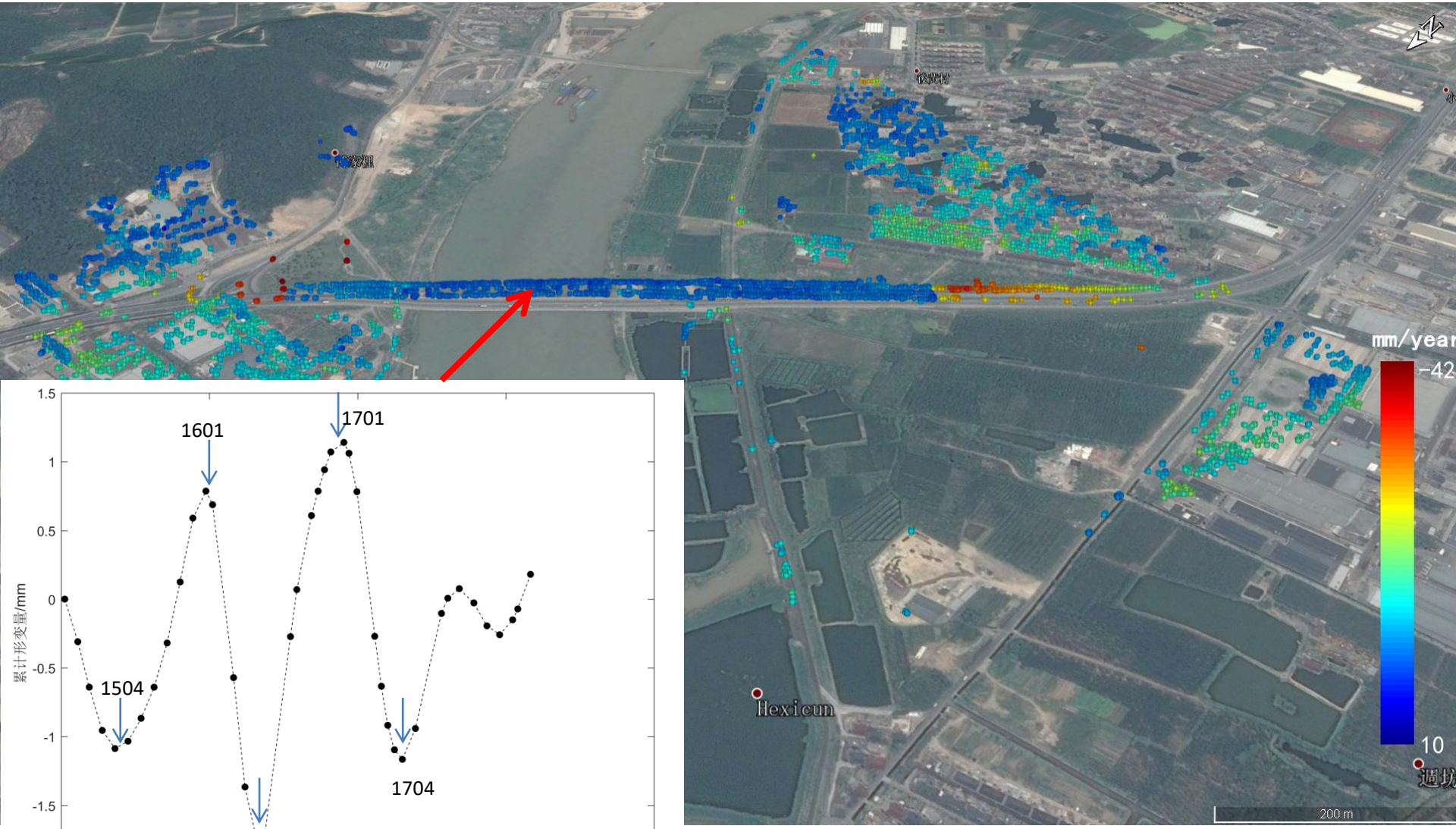
Hangzhou Metro Line 2: average subsidence rate from Gucui Road Station to Xueyuan Road station



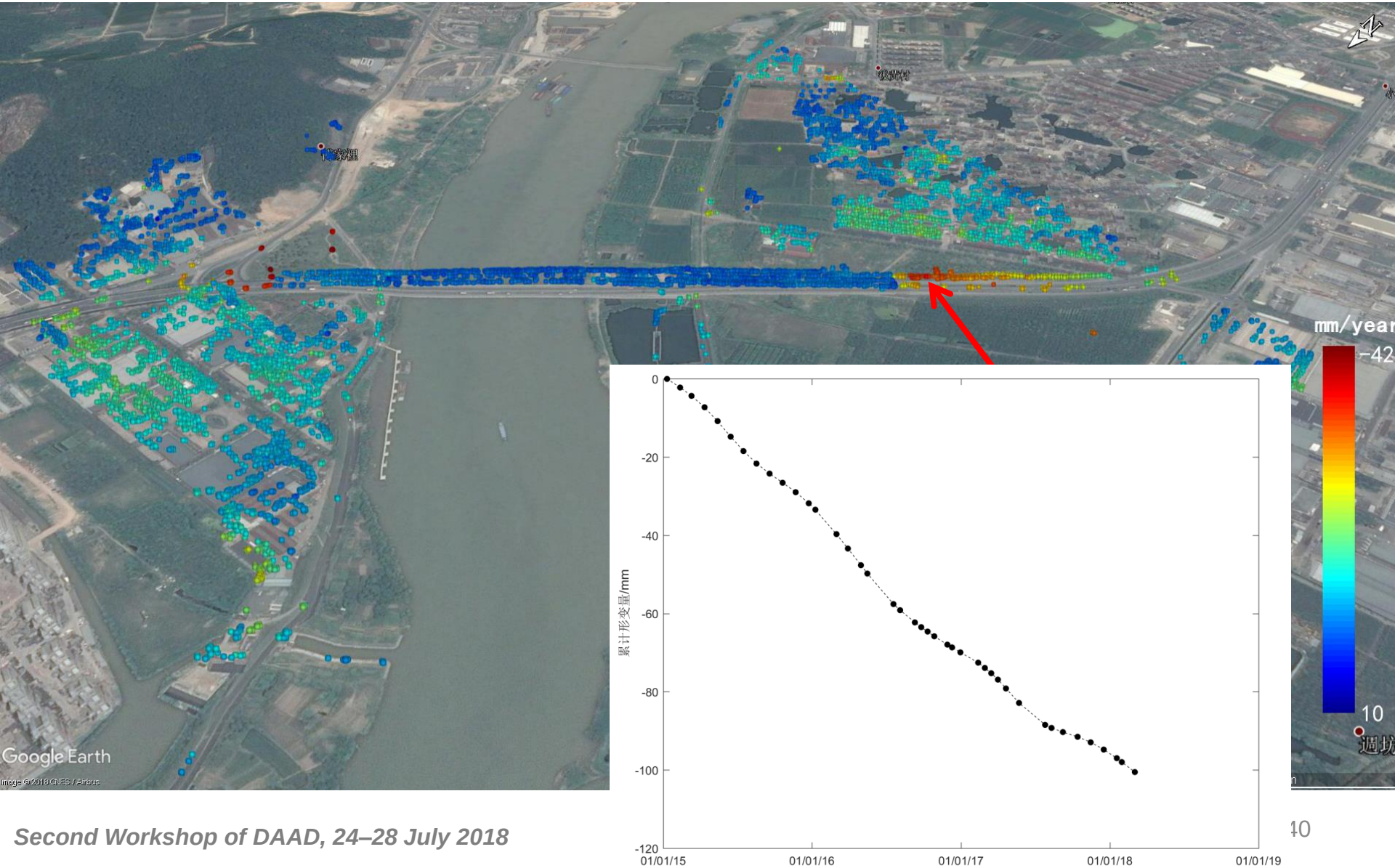
Yupu Bridge:
3-D display of average subsidence rate



Yupu Bridge:
time series accumulative subsidence of the main bridge



Yupu Bridge:
time series accumulative subsidence of the approach bridge



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Conclusion

- InSAR technique can monitor
  - land subsidence over large region
  - and detailed deformation along infrastructures/ buildings for health assessment

- ***If there is any deformation on the Earth surface,***

  then it can be uncovered precisely from space.

Acknowledgements

- Many graduated doctoral and master students in this team are appreciated for their wonderful work during the past several years. **They are**
  - Guangtong Sun, Chuangguang Zhu, Jufeng Lu, Shanshan Jin, Yousong Yin, Decai Jiang, Jie Wang, Xuejiao Fan, Yinghui Li, Weifan Zhong, Xiaolong Liu, Xiaolong Li

Thank you !

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