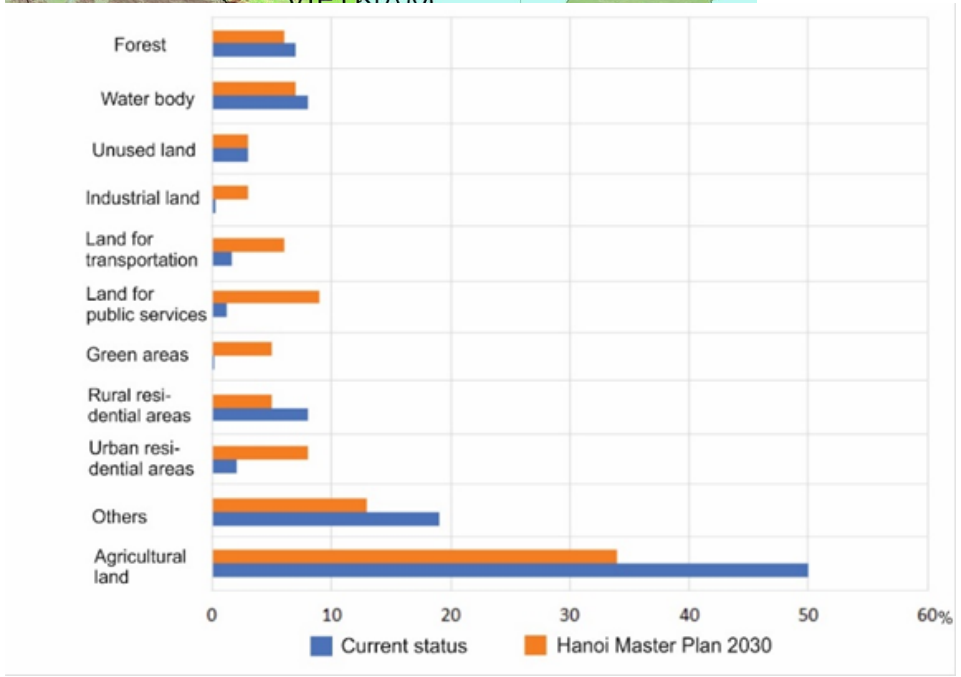
LUKE BATESON, ALESSANDRO NOVELLINO, EKBAL HUSSAIN, RAUSHAN ARNHARDT

Subsidence in Hanoi; is it all due to groundwater abstraction?

British Geological Survey

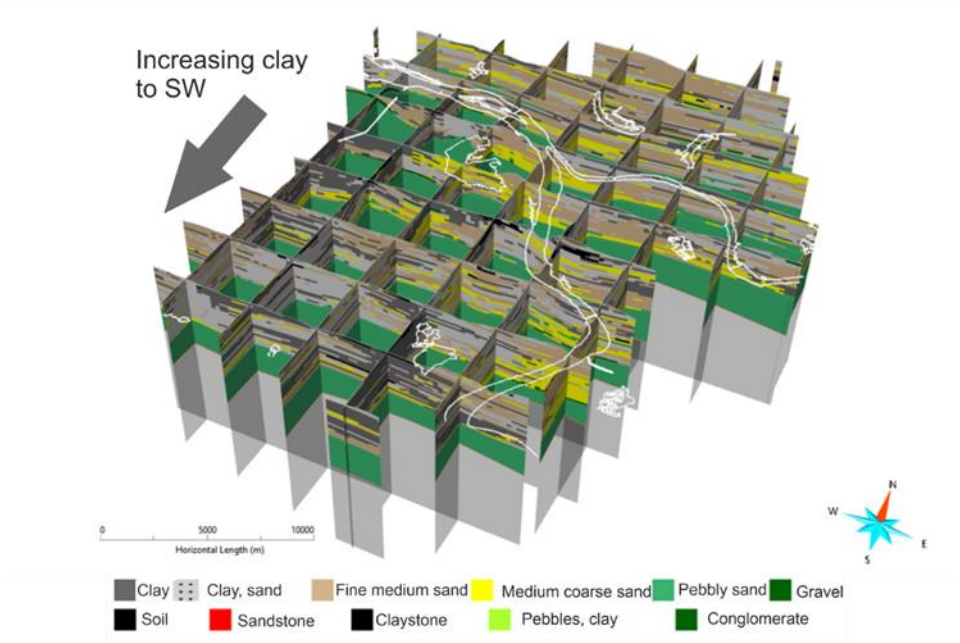
Hanoi

- Northern Vietnam
- Red River delta plain
- Rapid urban development
  - 15.5% increase in artificial surfaces in the last 50 years
- 7.4 million inhabitants
  - Projected to reach > 9 million by 2030
- Hanoi Master Plan to guide development
- Rapid development putting pressure on resources
  - Such as groundwater
  - Over extraction leading to subsidence



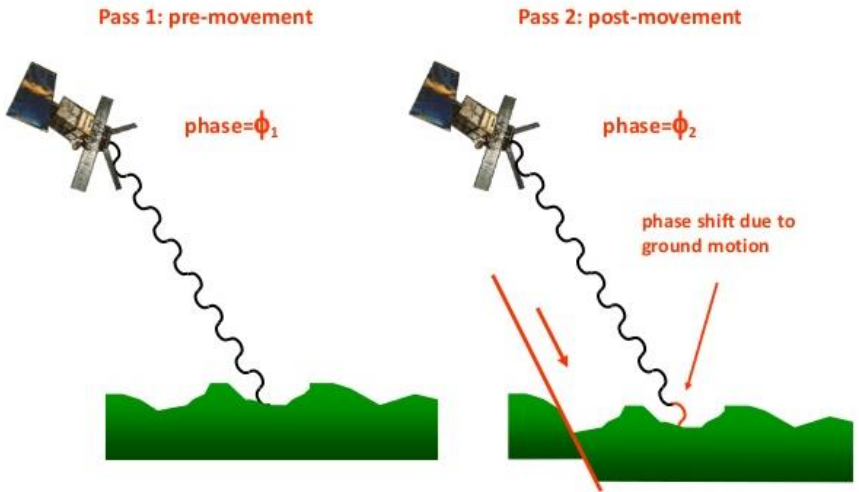
3D Geology

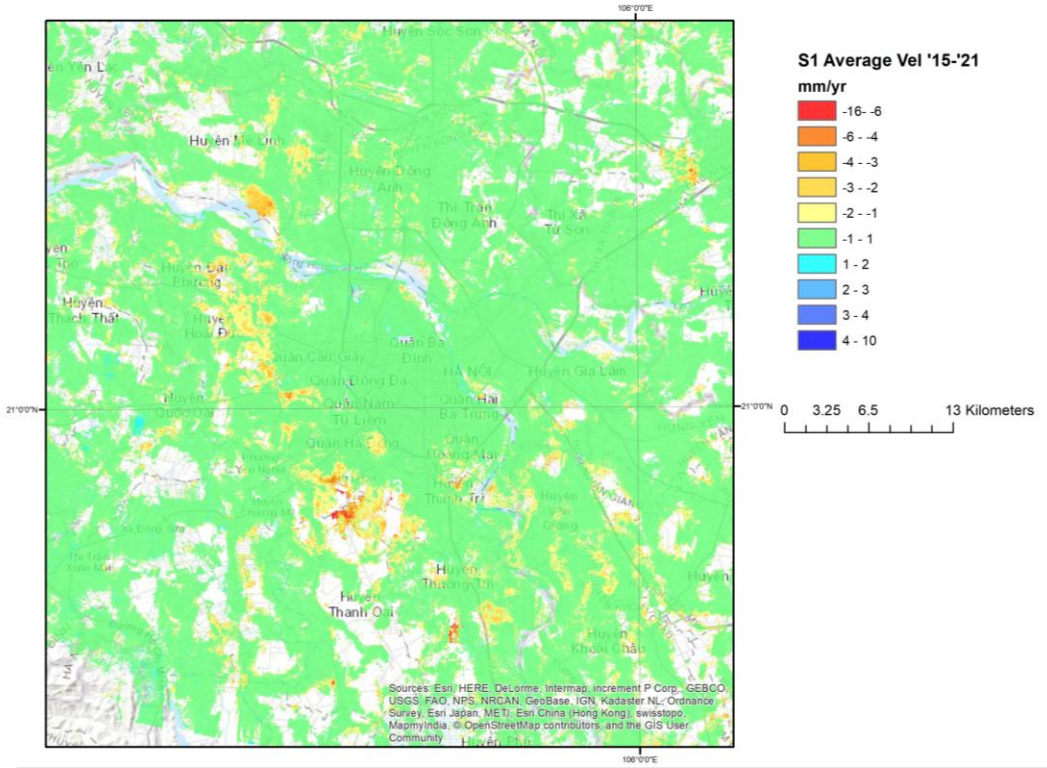
- unconsolidated Quaternary sediments of fluvial and marine origin between 50-90m thick
- resting on Neogene deposits
- 271 boreholes have been used to create cross sections and subsequently a 3D model.
- Clay = thicker to the SW



InSAR Data

- Persistent Scatter InSAR
  - Gamma IPTA
  - April 2016 – June 2017
- Small Baseline And Subset (SBAS)
  - Aug 2016 – Nov 2019
  - July 2015 – Jan 2021

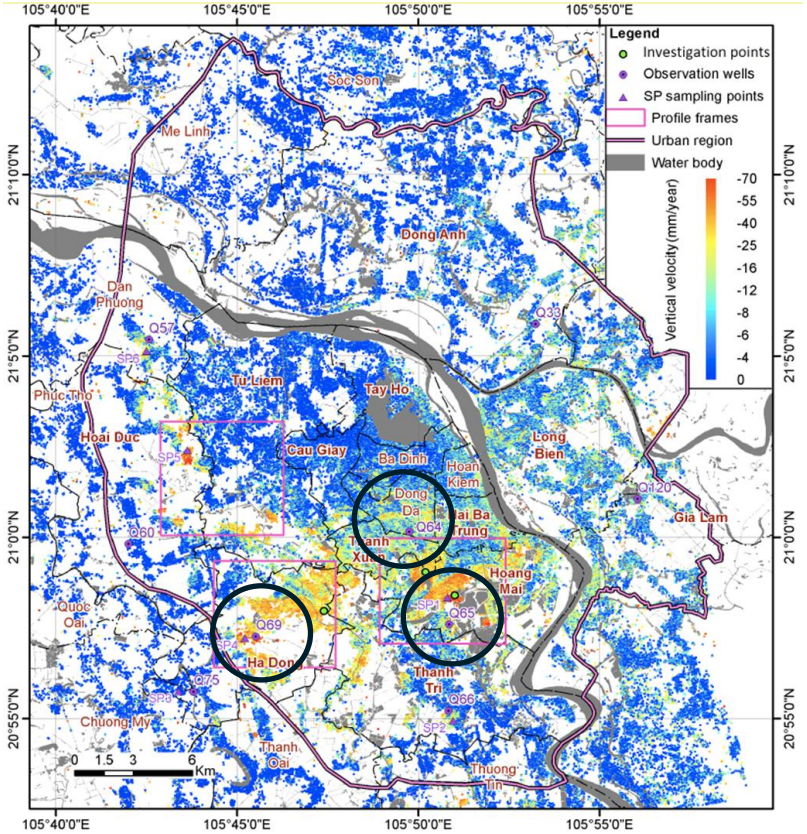




https://comet.nerc.ac.uk/

Groundwater level change and InSAR

- Dang et al (2014)
  - subsidence 2007 - 2011 relates to ground water abstraction from wells Q65, Q64 and Q69.
- Q64 is now stable
- Q65 is now stabilising
- motion that Q69 was sitting directly above in the ALOS has now migrated to the south



ALOS INSAR Feb 2007 – Feb 2011

V. K. Dang et al. 2014.

Groundwater level change and InSAR

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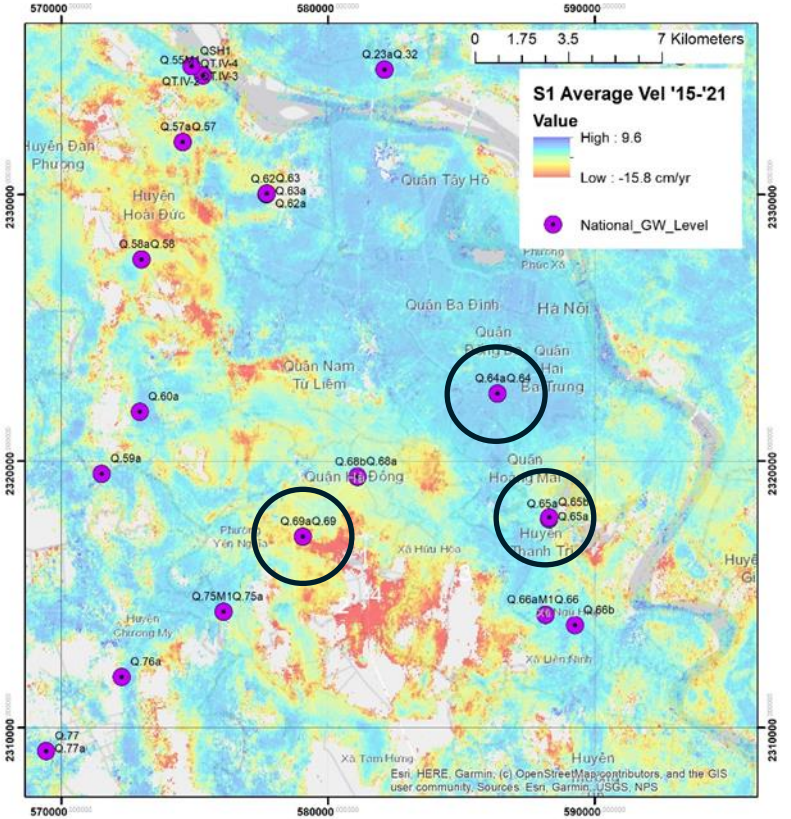
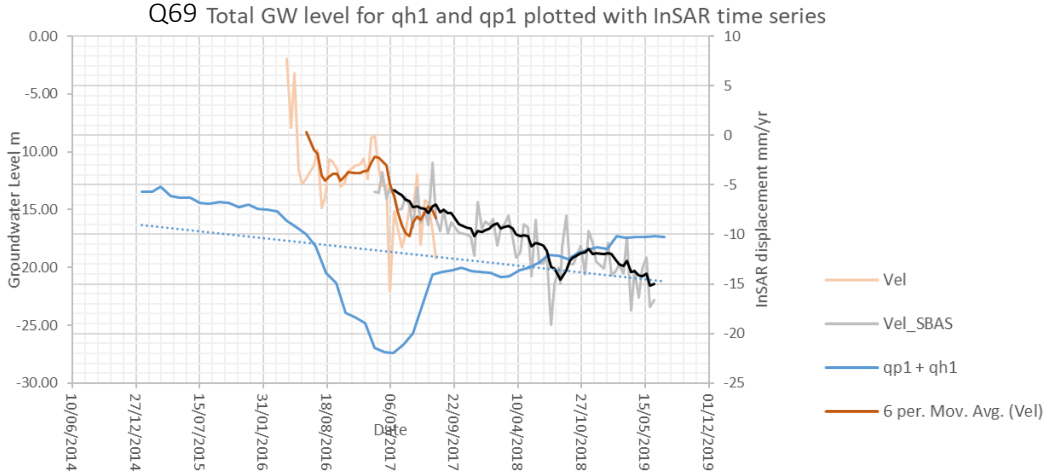
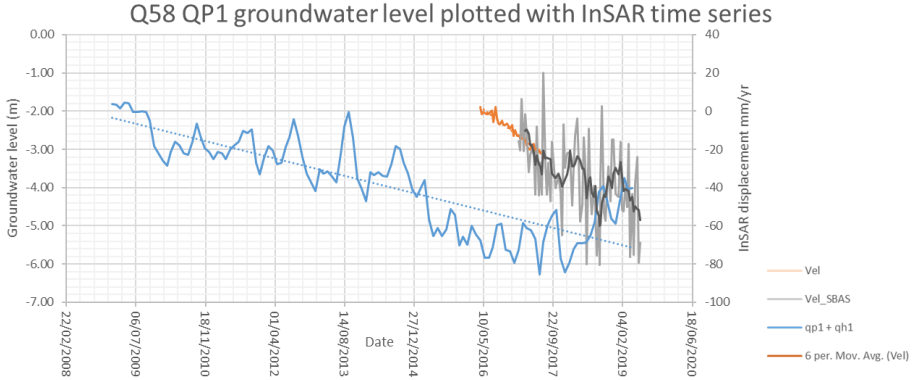
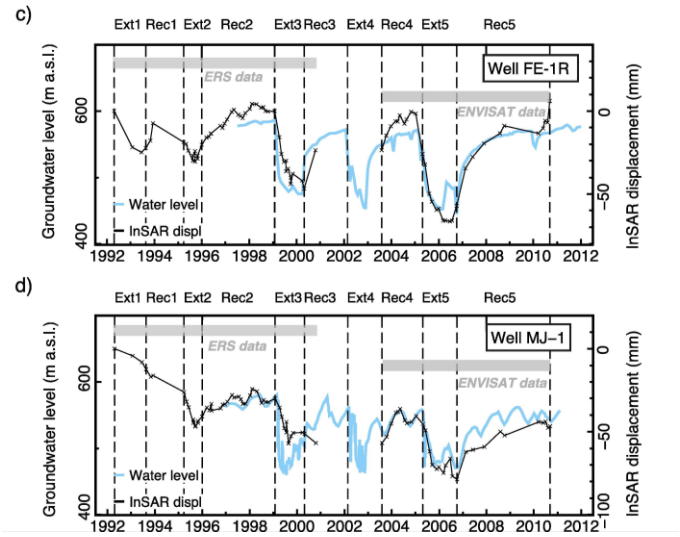


Groundwater level change and InSAR





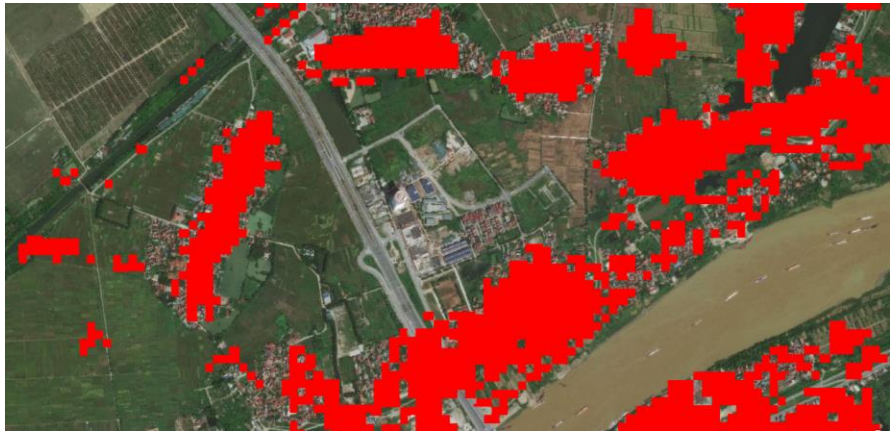
Although the trend is the same we do not see the detail of the GW level change reflected in the ground motion as we see in other studies



Béjar-Pizarro et al, 2017

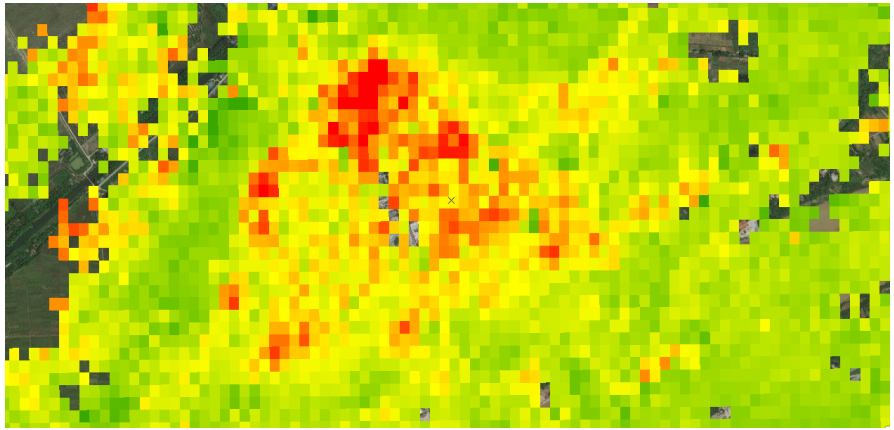
Urban Development and InSAR

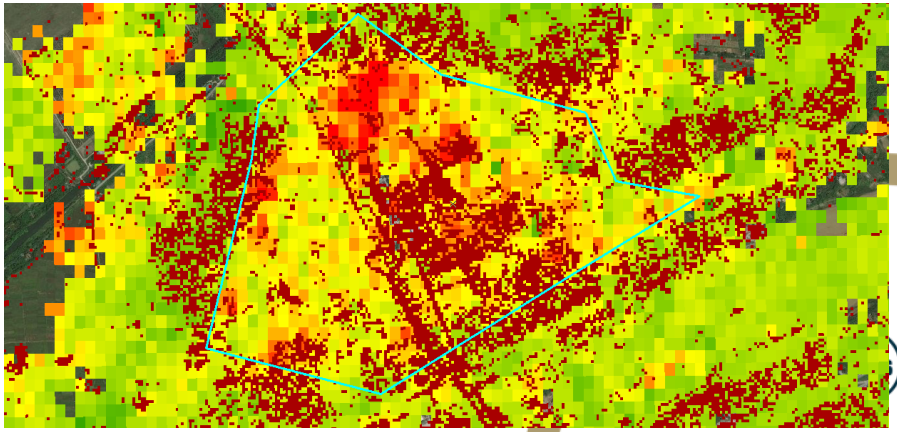
1996 Urban landcover

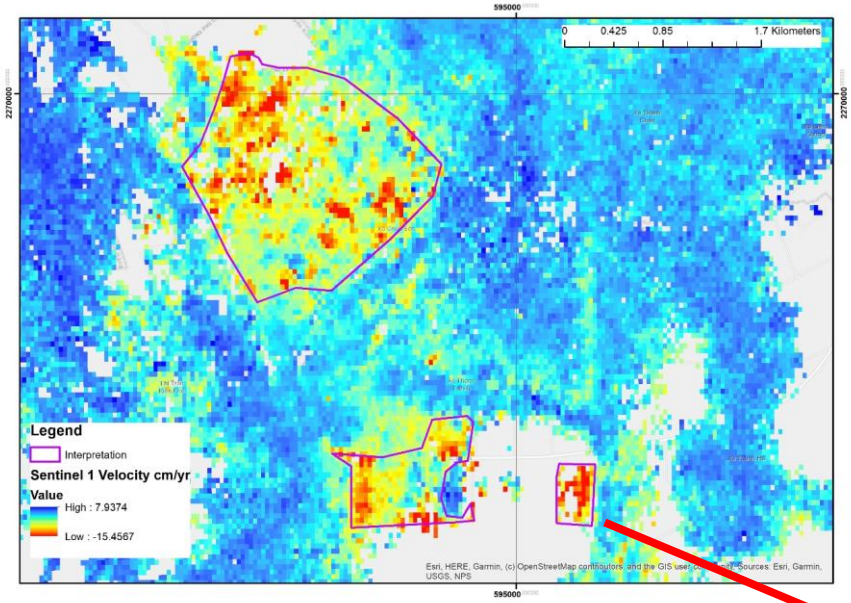


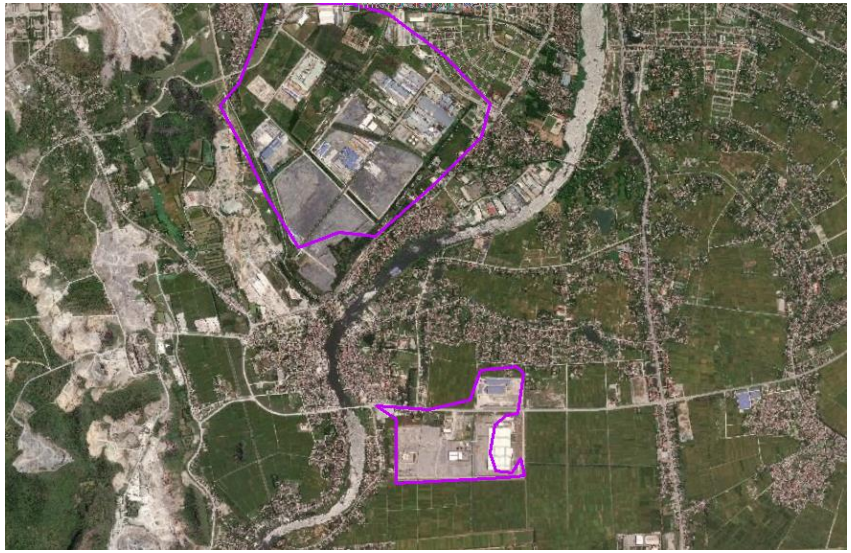
2019 Urban landcover

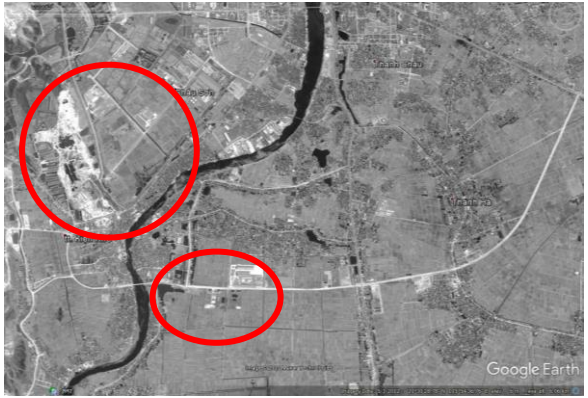
2016-2019 InSAR







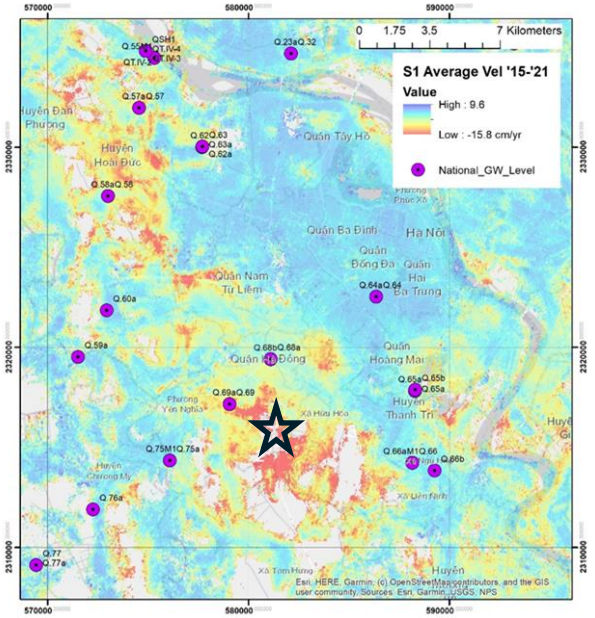


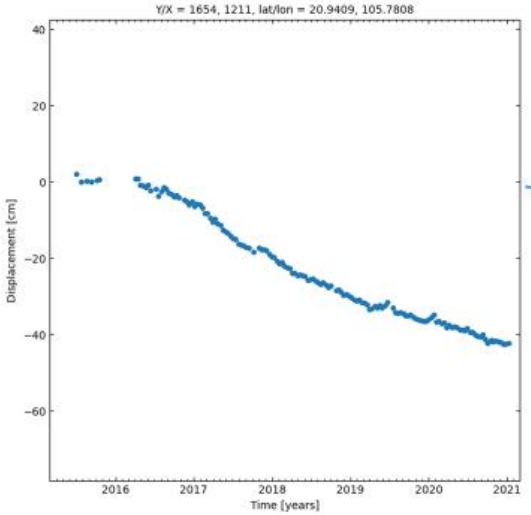


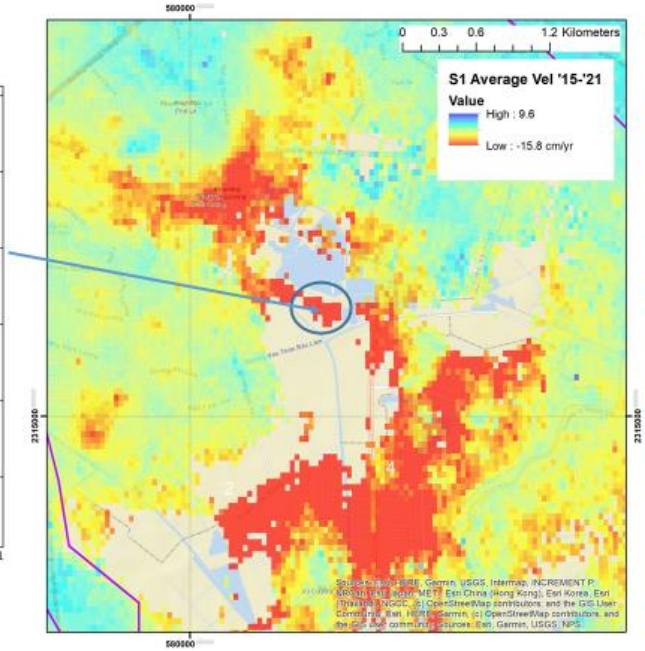
2012

2014

2018







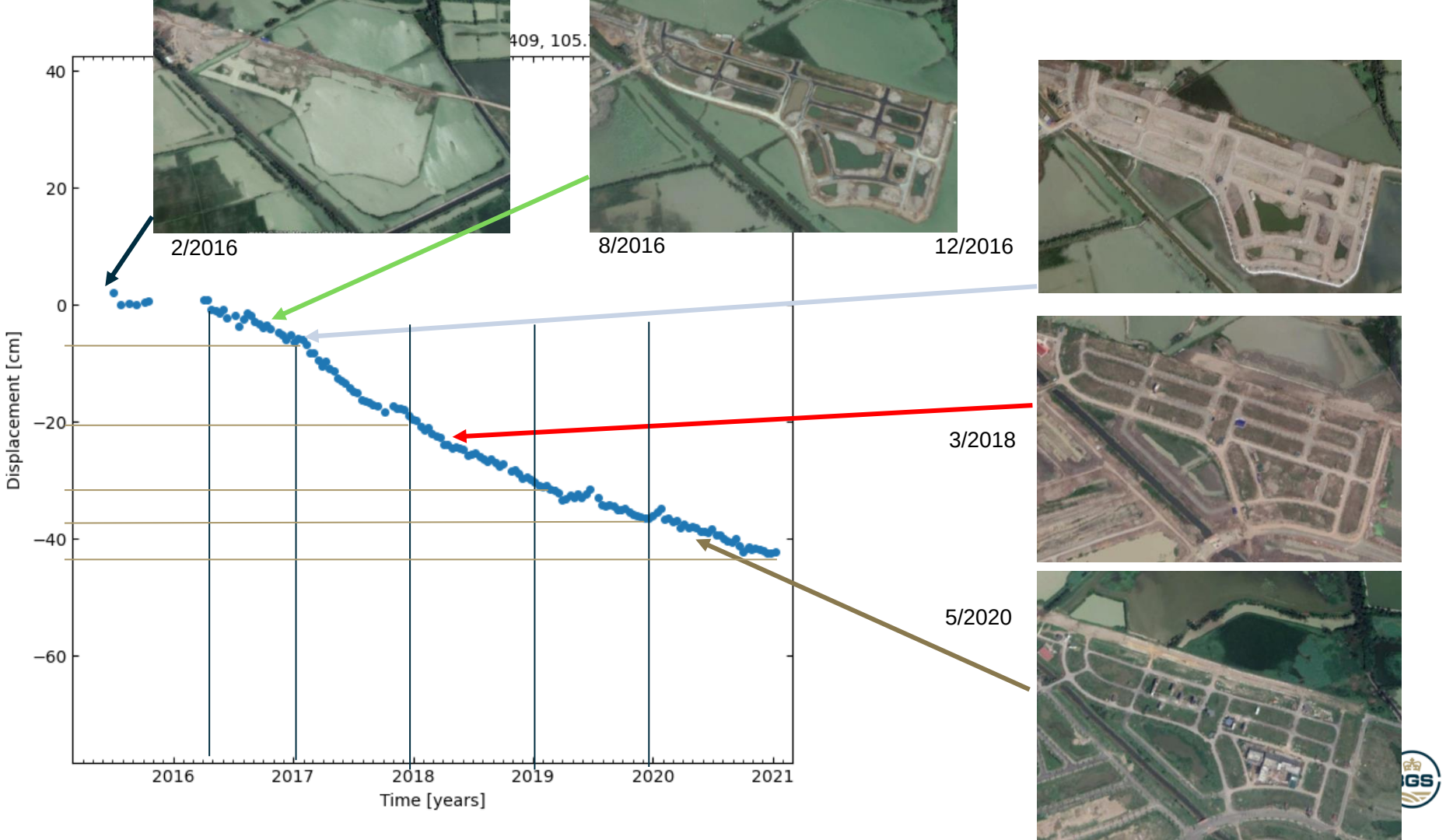
2/2016

8/2016

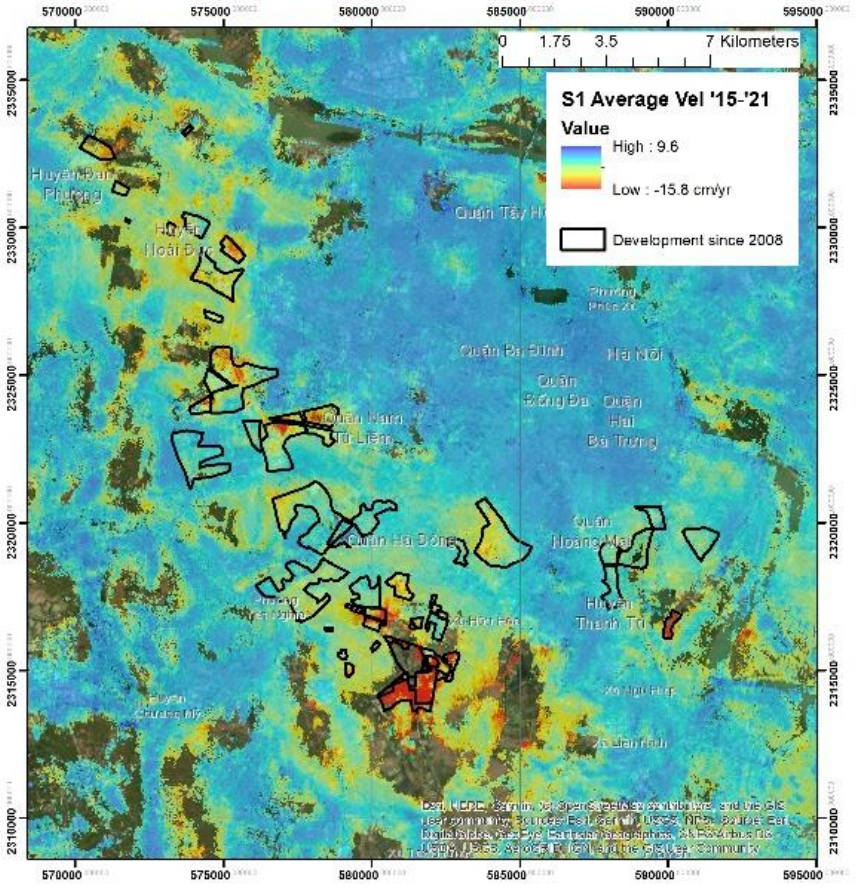
12/2016

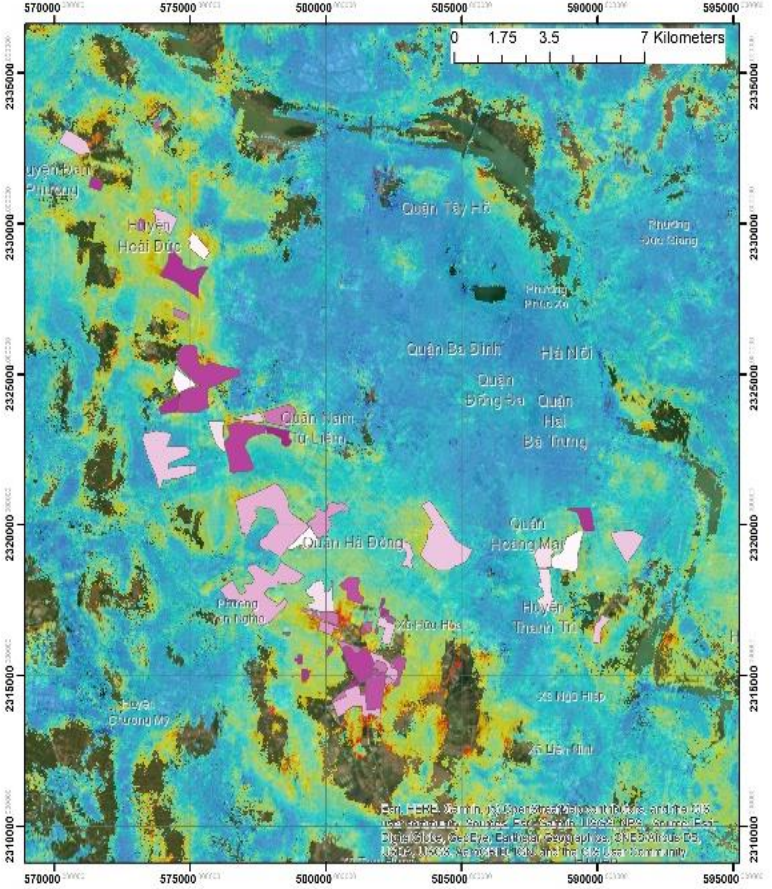
3/2018

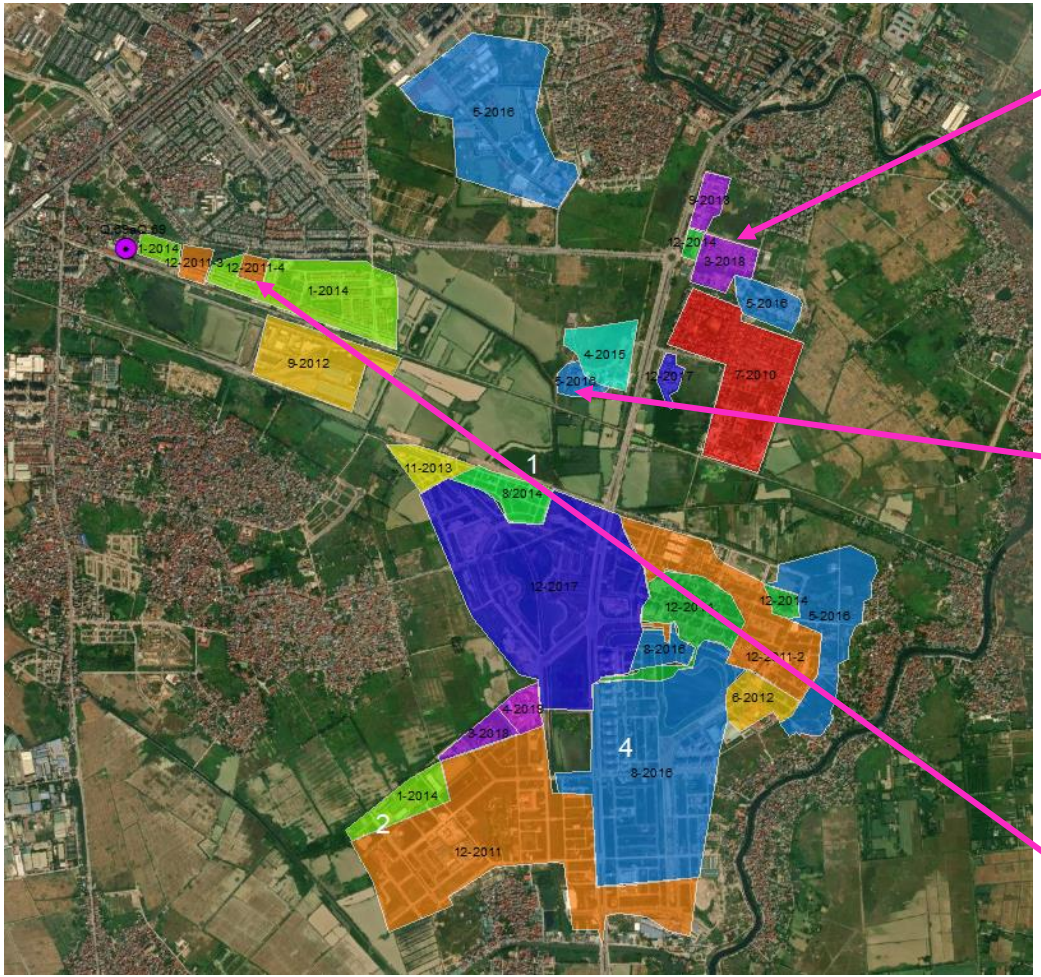
5/2020

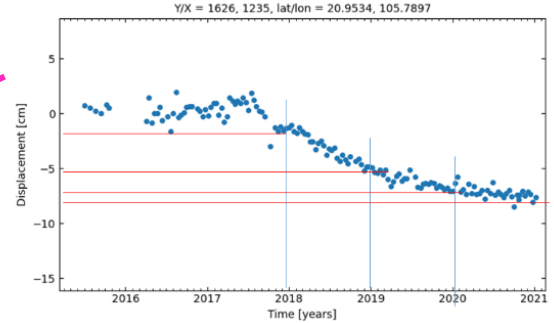

409, 105.
2/2016
8/2016
12/2016
3/2018
5/2020
Displacement [cm]
Time [years]
40
20
0
−20
−40
−60
2016
2017
2018
2019
2020
2021

Development areas since 2008 and InSAR

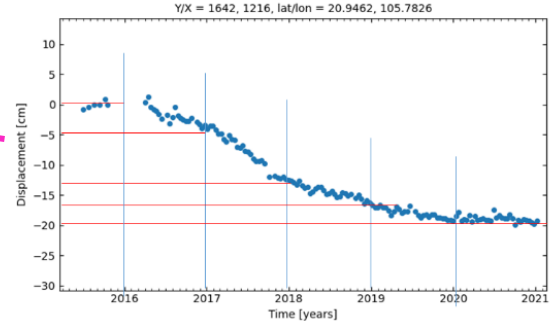




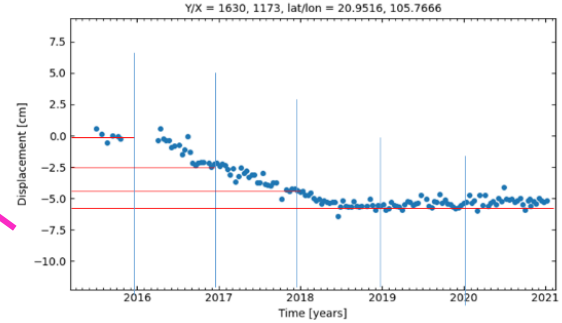




2018

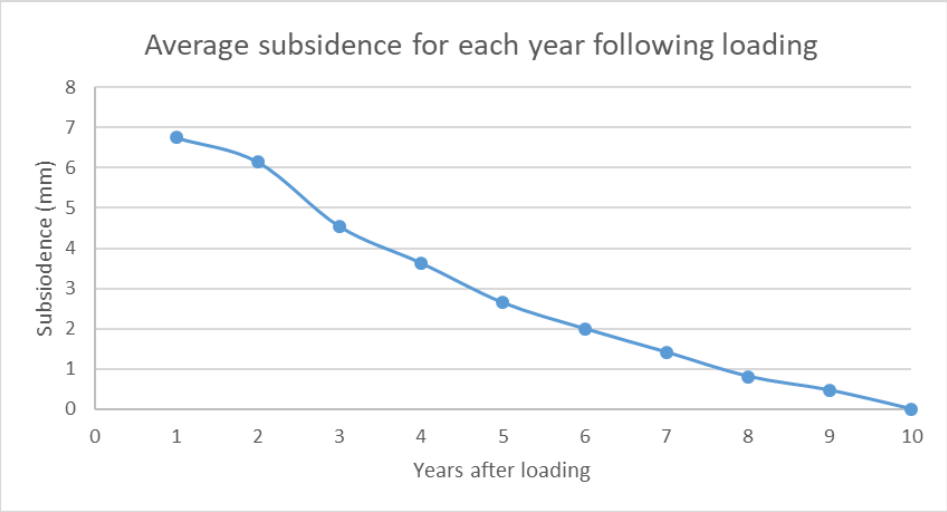


2016



2014

Expected rate of subsidence following loading of the ground



Year of first loading	Subsidence, in cm, for each year following the loading									
	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	year 9	year 10
2008								3	2	0
2010					0	0	0	0	0	0
2010						1	0	0	0	0
2010						1	1	0.5	0	0
2012					11	11	11	9	5	
2012					6	7	6	3	1.5	
2012					5	7	4	2	2	
2012					2.5	2	1	0.5	0	0
2012					5	5	4	3	2	
2012					2.5	2	1	0	0	0
2012					2.5	2.5	2.5	1	0	0
2014			4	2	0	0	0	0	0	0
2014			8	10	9	4	3			
2014			5	6	5	2	2			
2014			5	6	4	2	1			
2014			2.5	2.5	2.5	1	0	0	0	0
2015	6	6	3	2	1					
2015		5.5	4.5	2.5	0.5	0	0	0	0	0
2015		10	11	7	3	1.5				
2016	7	13	11	5	5					
2016	5									
2016	9	9	7	4	4					
2016	7	6	3	2.5	2.5					
2016	6	6	0	0	0	0	0	0	0	0
2016	15	15	10	7	6					
2016	7	7	8	5						
2016	3.5	3.5	2	1.5	0	0	0	0	0	0
2016	4	2	2	1.5	1					
2016	5	8	3	3	0	0	0	0	0	0
2016	7	6	7	3	2					
2016	6	4.5	4	0.5	0.5					
2017	7	7	6	5						
2017	10	10	8							
2018	11	5	3							
2018	3	1.5	0							
2018	2	2	0							
2018	3.5	2	1							
2018	9	5	4							
2018	6	3	1.5							
2019	10	9								
Average	6.77	6.35	4.57	3.80	3.10	2.45	1.92	1.29	0.74	0.00

Conclusion

- InSAR data reveals rapid rates of subsidence to the south and west of Hanoi centre
- Hanoi centre is stable
- The centres of subsidence have migrated further out from the centre
  - Do not directly overlie the predictions
  - Are not centred on the major ground water wells
  - Time series does not directly reflect GW abstraction rates
- Good spatial association with areas of development since 2008
  - Not related to buildings but to loading of wet areas
  - Able to link rate of subsidence to phases of ground loading
- Able to extract expected rates of subsidence for each year following the loading