International Meeting on Land Cover/Land Use Change (LCLUC)
In South/Southeast Asia and Synthesis

Monitoring land subsidence by using InSAR technique. Ho Chi Minh City and Mekong Delta case studies

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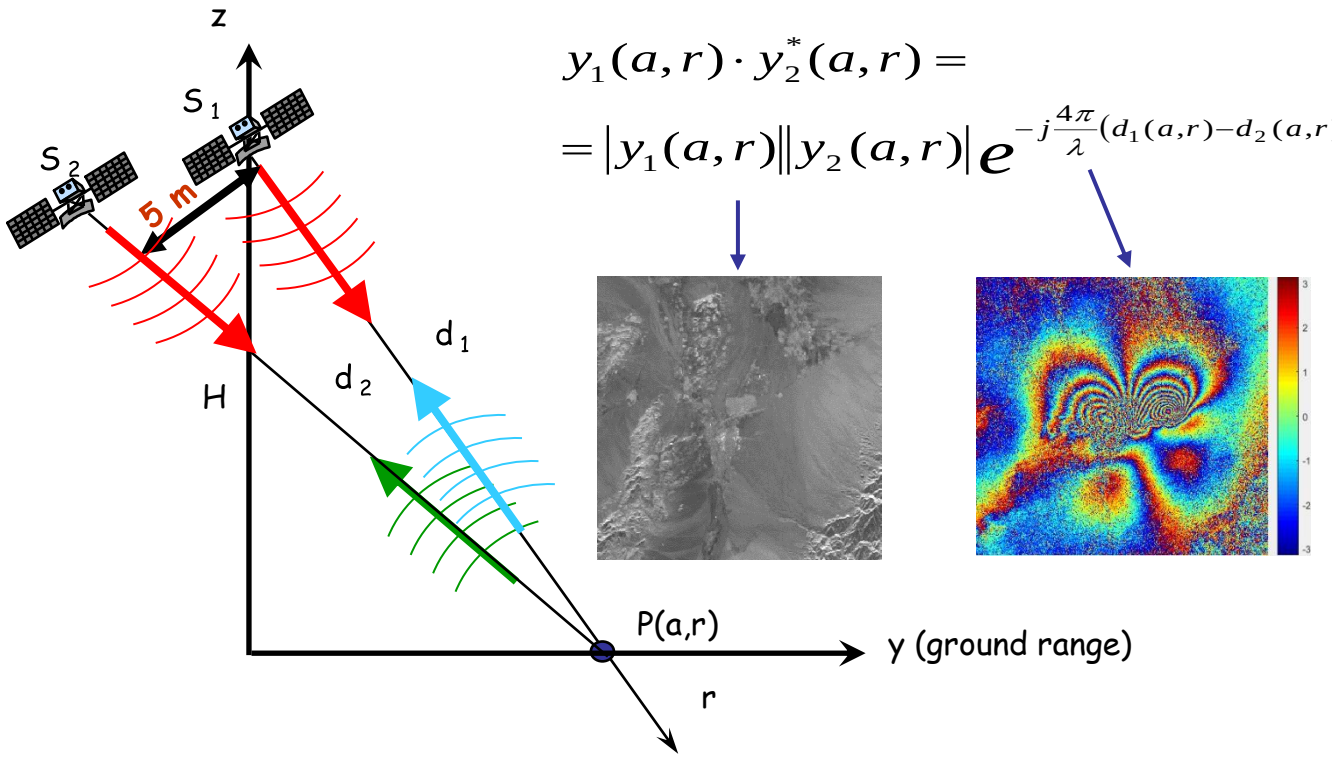
Contents

- Brief about TOMOSAR
- Land subsidence in Hochiminh City, Vietnam
- Land subsidence in Mekong Delta
- Focasting land subsidence in Hochiminh City: Preliminary results

SAR: Interferometric phases

Interferometry SAR (InSAR) quantifies a phase shift of radar waves.

An example (BAM earthquake 2003)



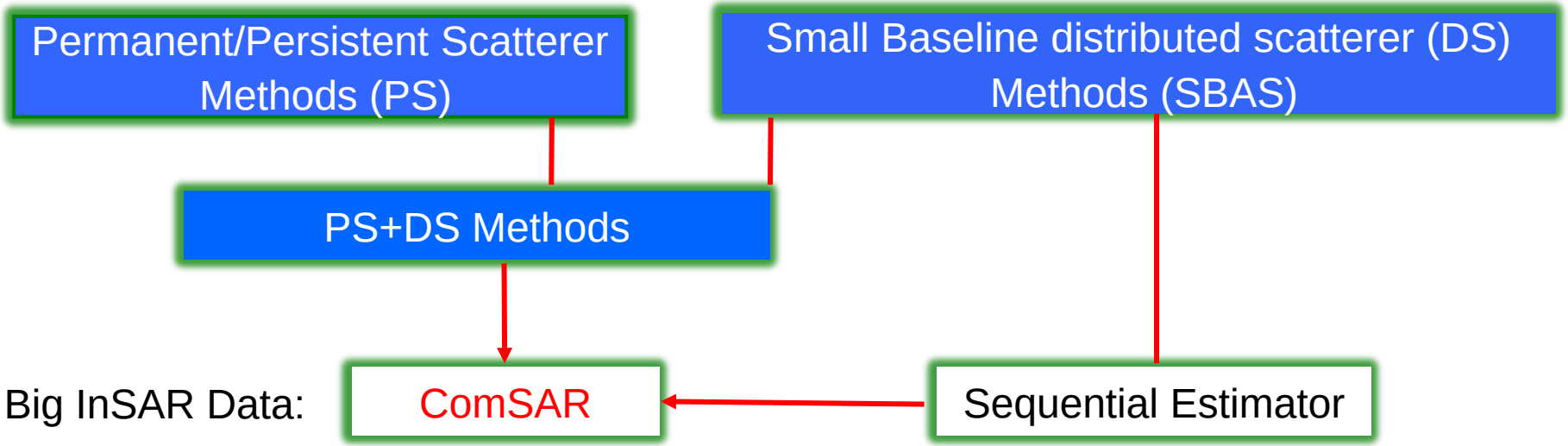
$$y_1(a,r)\cdot y_2^*(a,r) =$$

$$= |y_1(a,r)||y_2(a,r)|\, e^{-j\frac{4\pi}{\lambda}(d_1(a,r)-d_2(a,r))}$$

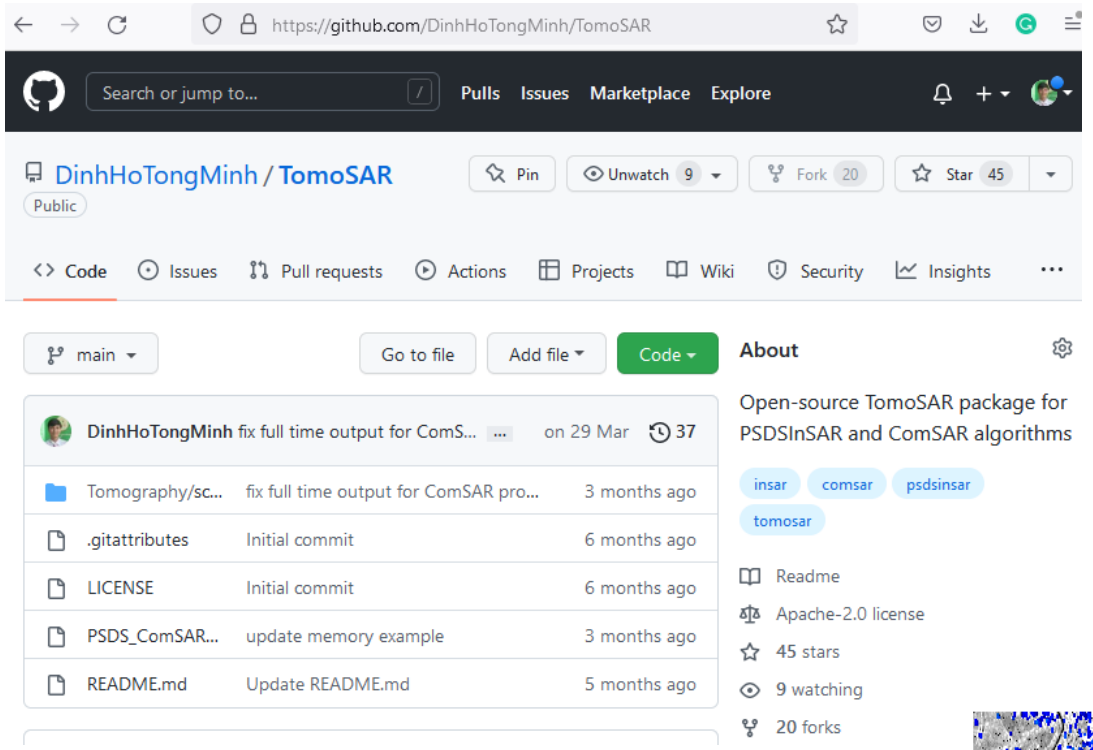
InSAR time series approaches

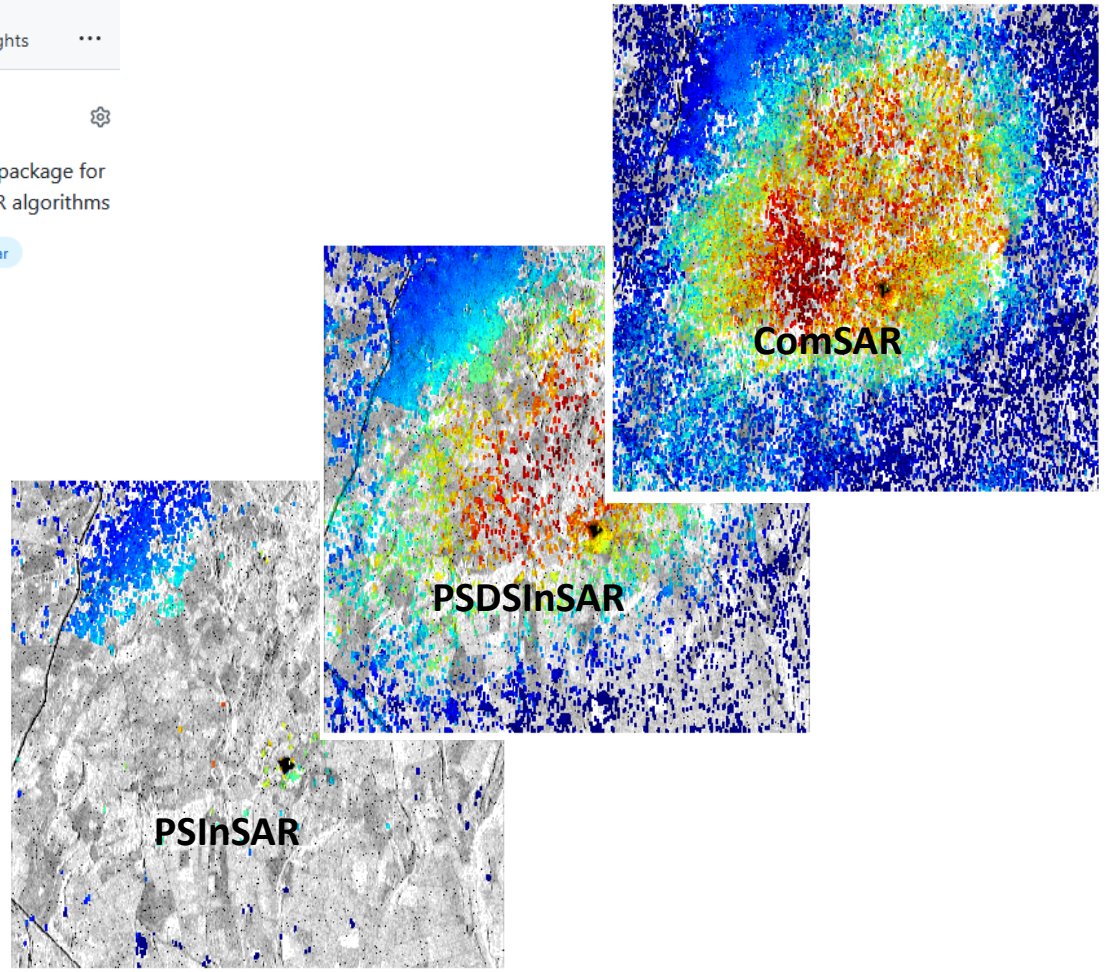
- Analysis wrapped phase
- High resolution – single look
- PS limitation in rural environments
- PS+DS is best for all

- Analysis unwrapped phase
- Low/high resolution – multi/single look
- Works better in rural environments
- Phase unwrapping error
- Lower performance



TomoSAR: open-source PSDS and ComSAR





ComSAR is friendly Big Data processing.

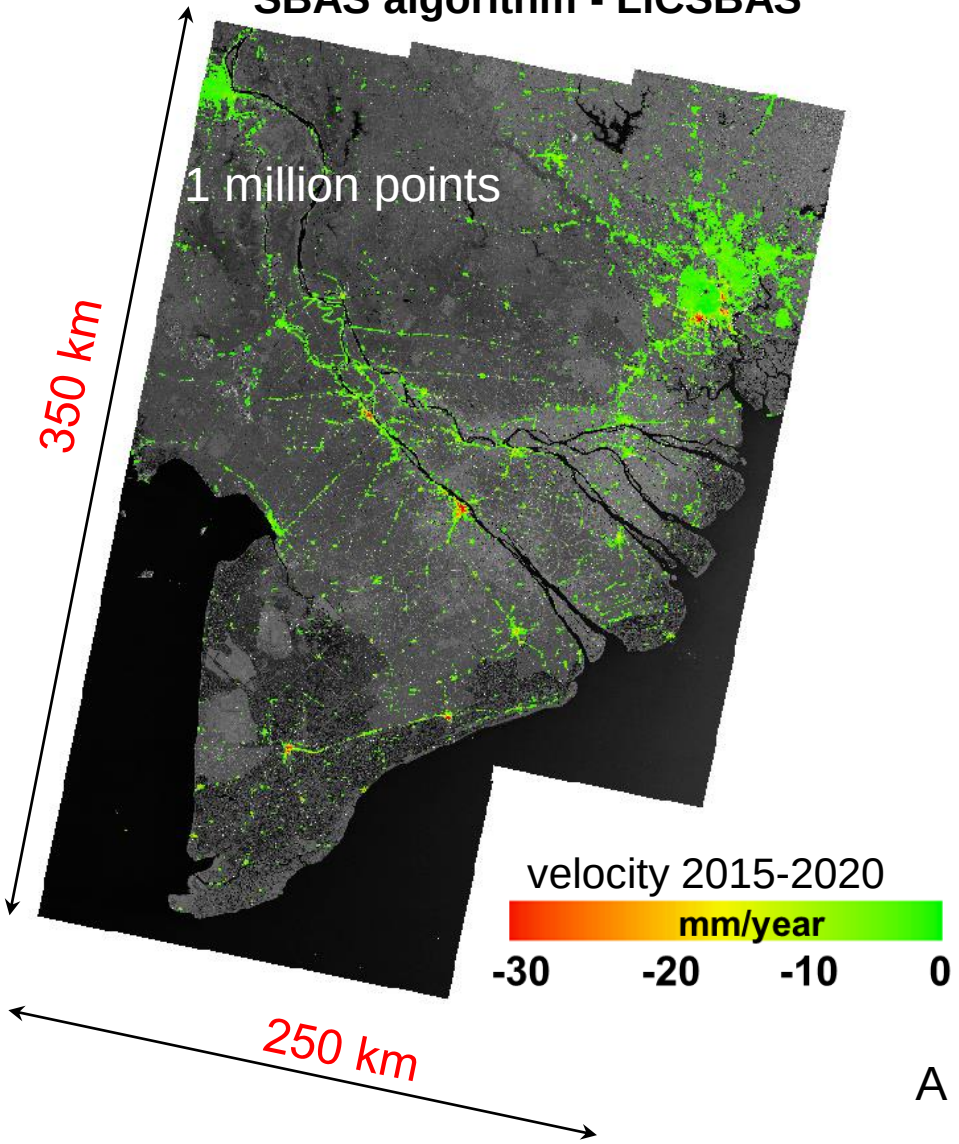
i.e:

200 images of 500x2000 size

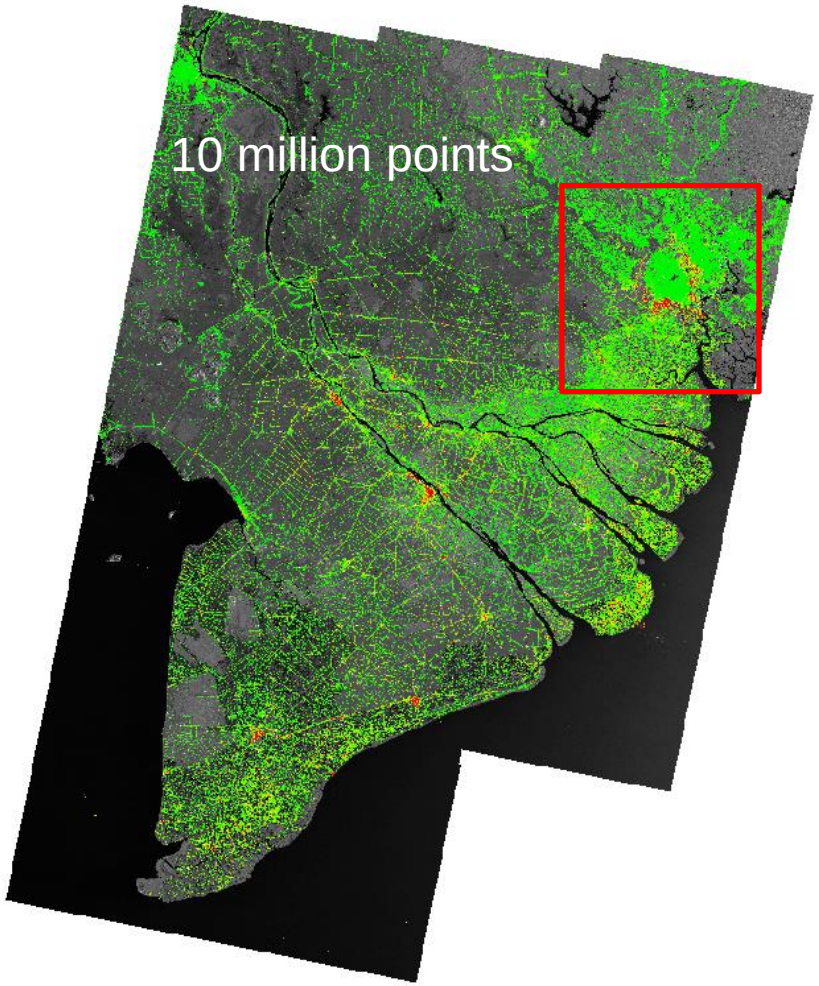
- 220 GB is for PSDS
- 45 GB for ComSAR

Delta-wide subsidence

SBAS algorithm - LiCSBAS



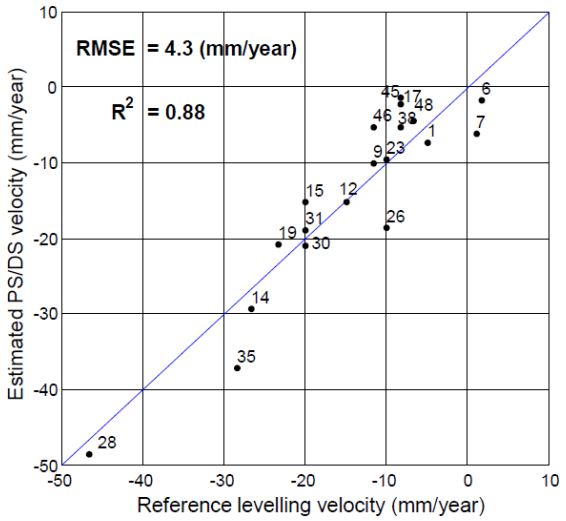
PSDS algorithm - TomoSAR

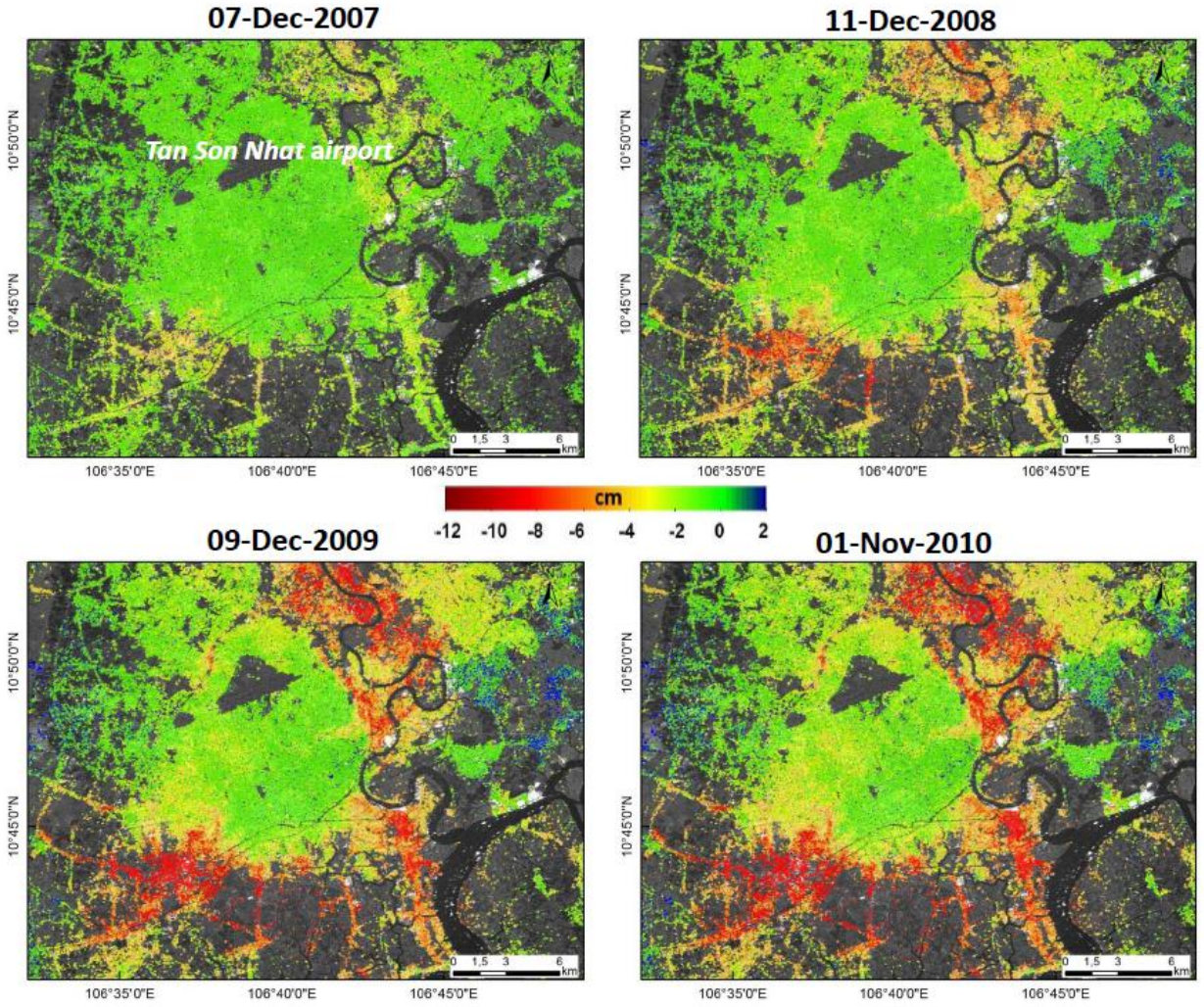


A coherent processing in one SLC coverage !

Land subsidence in HCMC by InSAR (2007-2010)

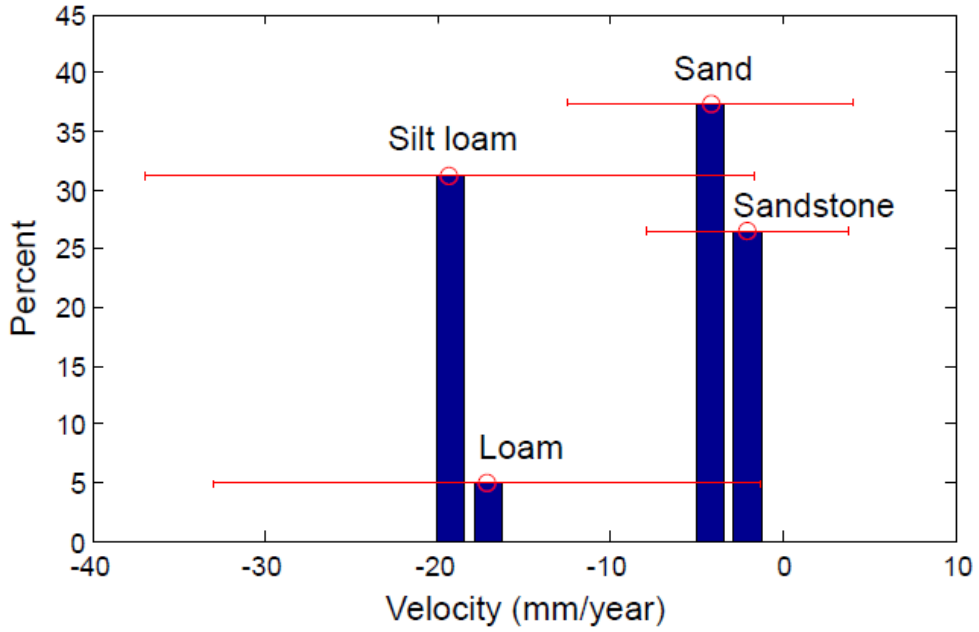
- Used 18 ALOS-1/PALSAR images in 2006-2010
- Subsidence is clearly defined in the area along the Saigon River, south and southwest of the HCMC



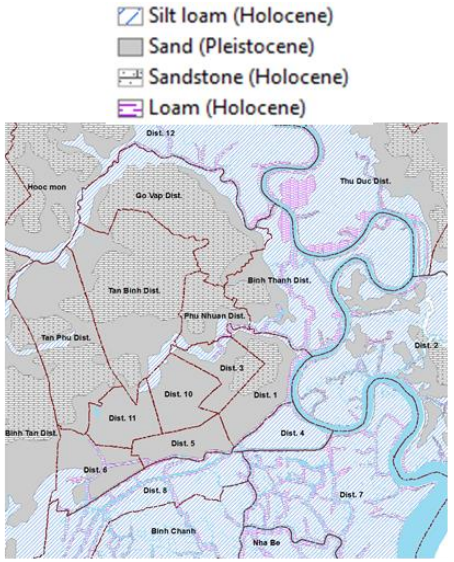


Sources: Dr. Hab Ho Tong Minh Dinh el

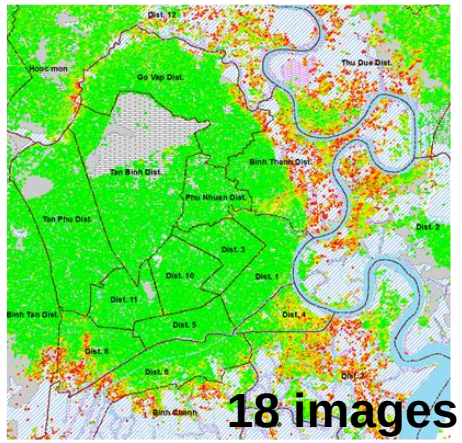
Correlation between geological factors and subsidence



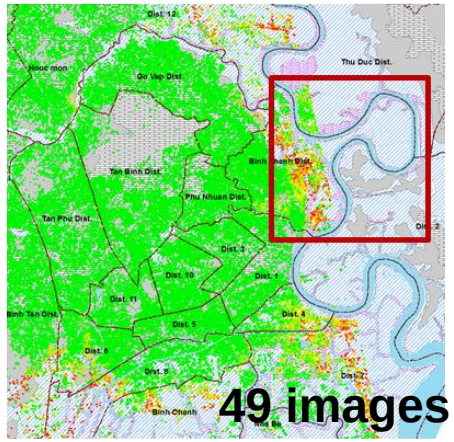
- The weak land has a high subsidence rate!
- Cosmos SkyMED vs Sentinel-1.



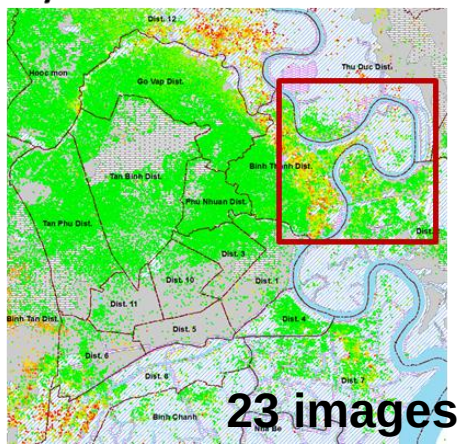
2006-2010 average velocity by L-band ALOS



2014-2016 average velocity by X-band Cosmos SkyMED

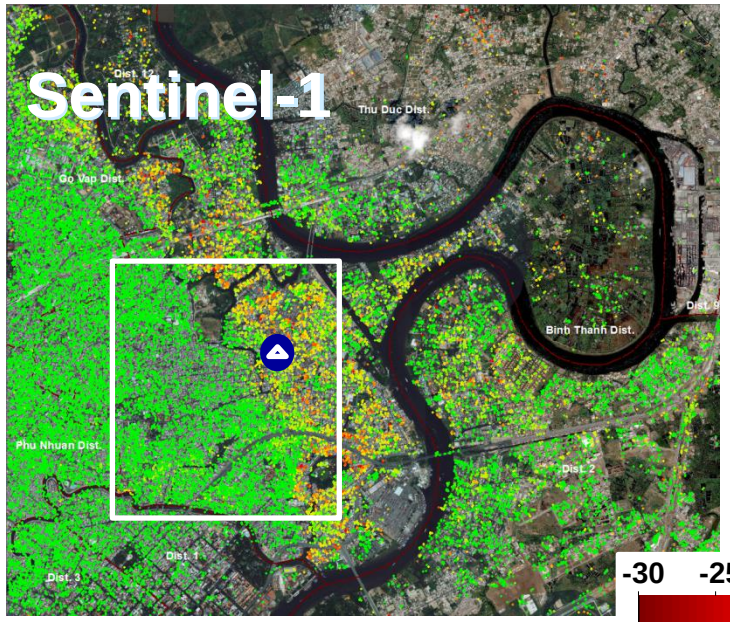


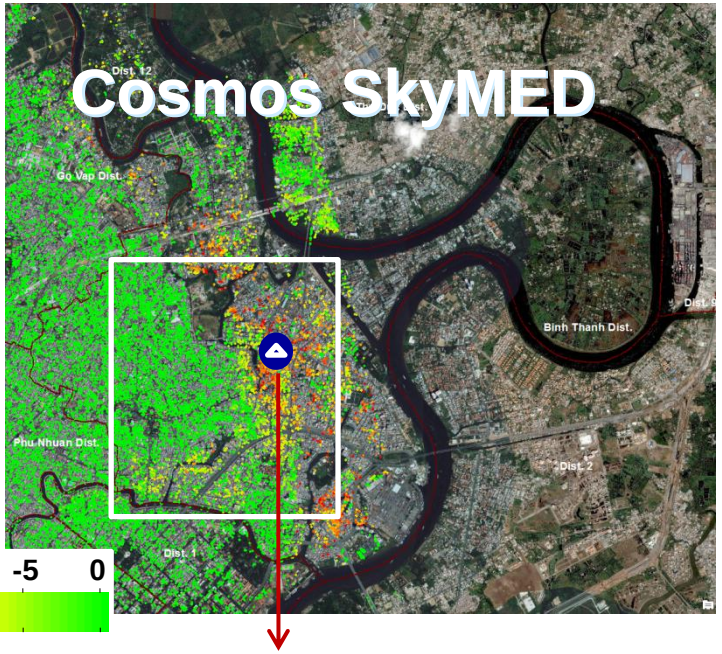
2014-2016 average velocity by C-band TOPS Sentinel-1

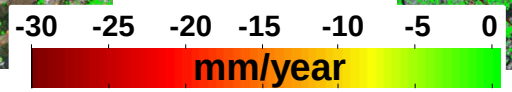


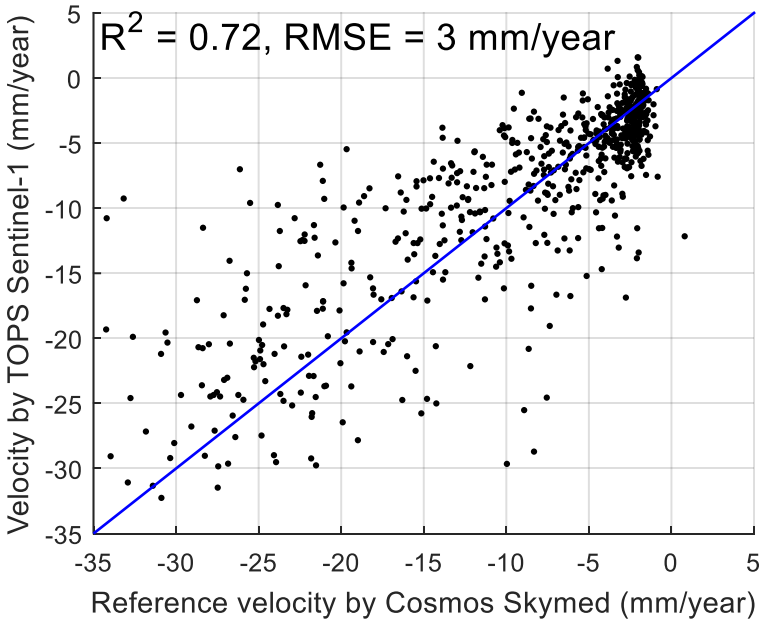
Sources: Dr. Hab Ho Tong Minh, Dinh el

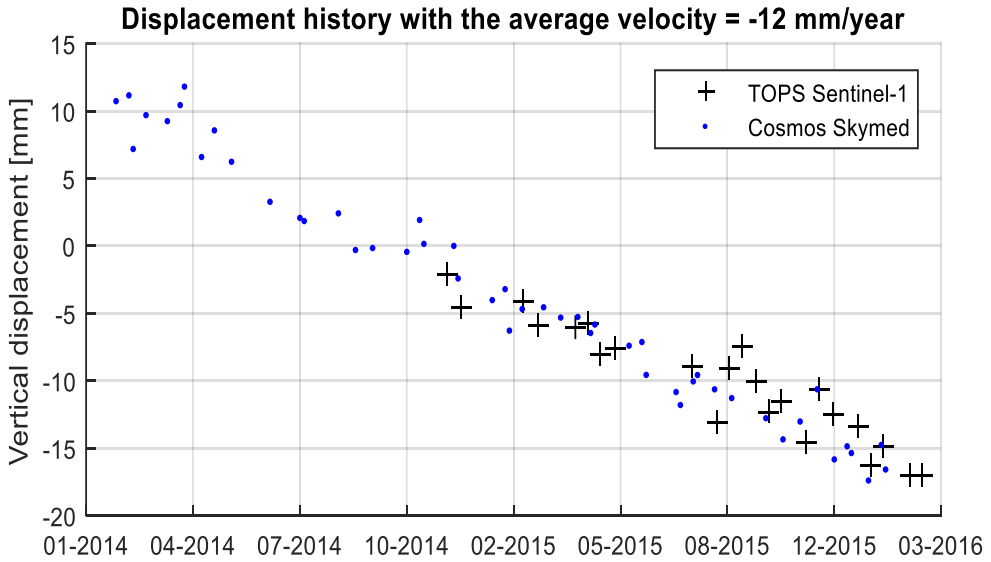
Comparison Stripmap Cosmos Skymed and TOPS Sentinel-1



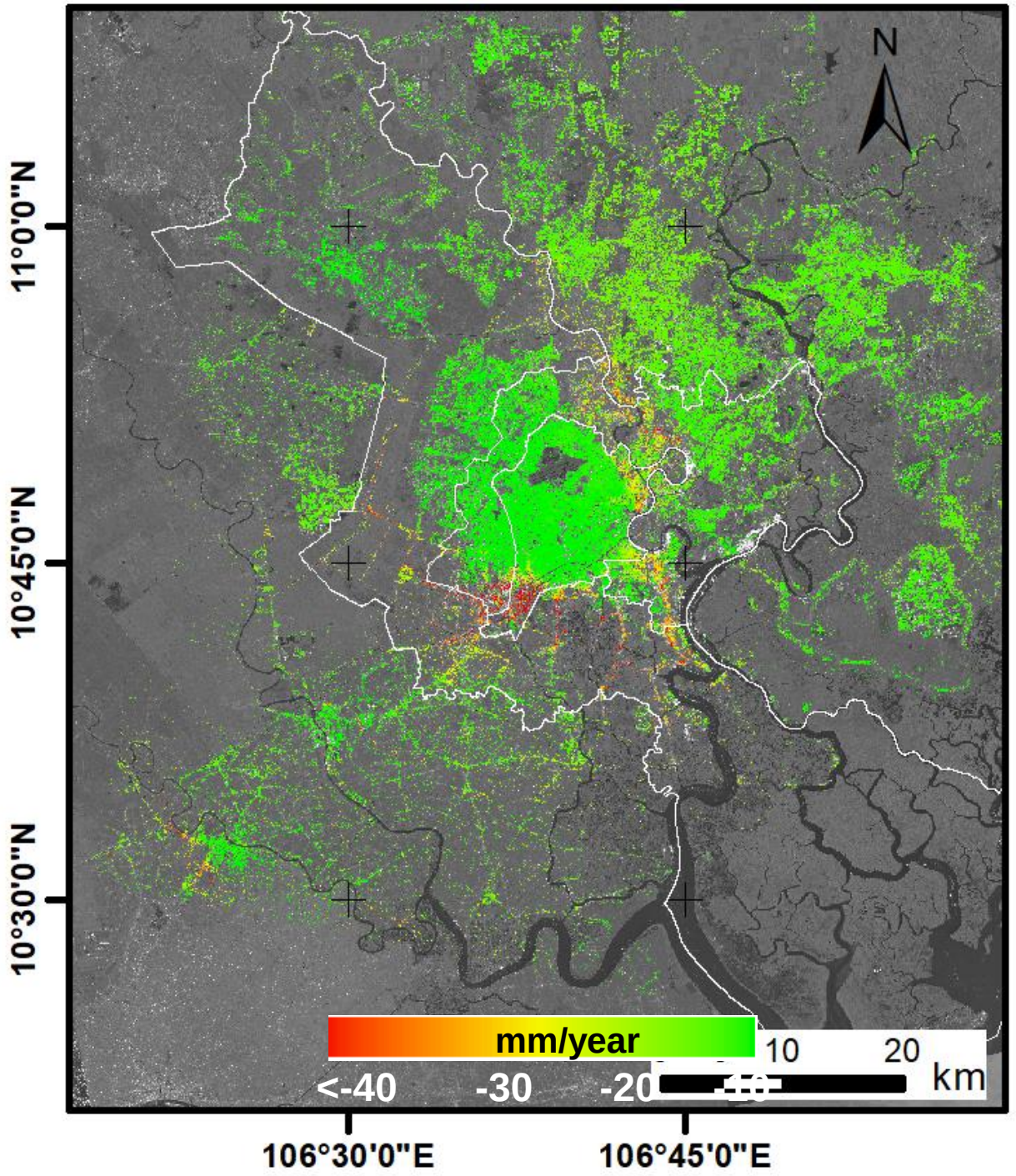




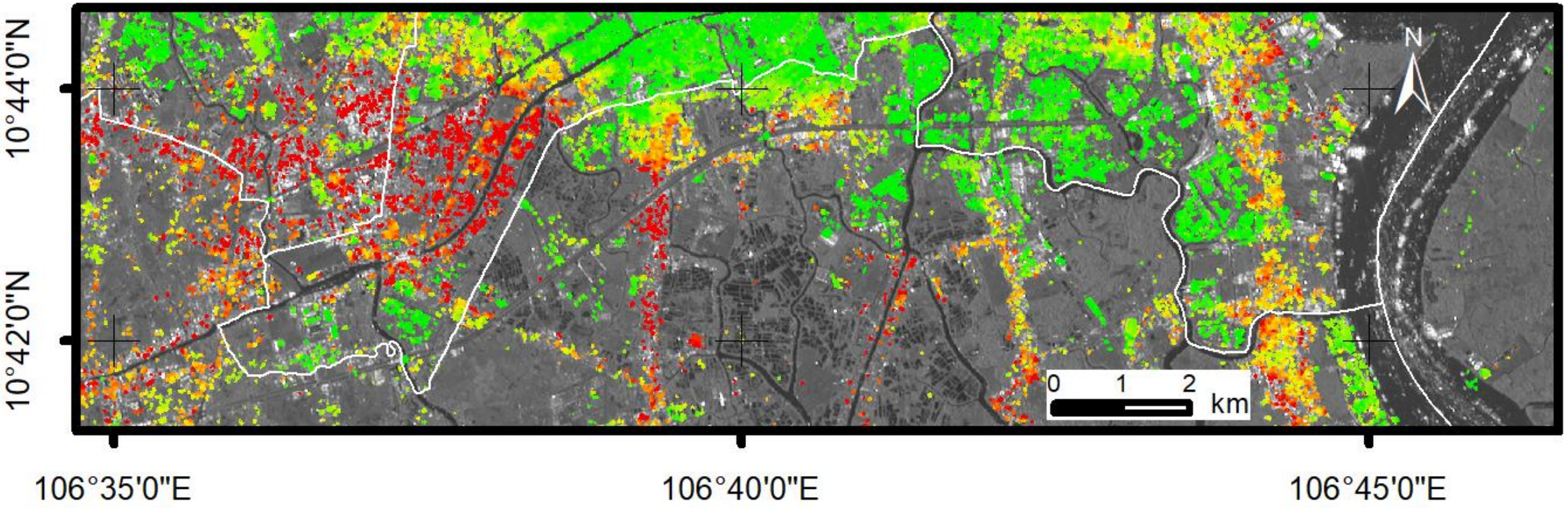




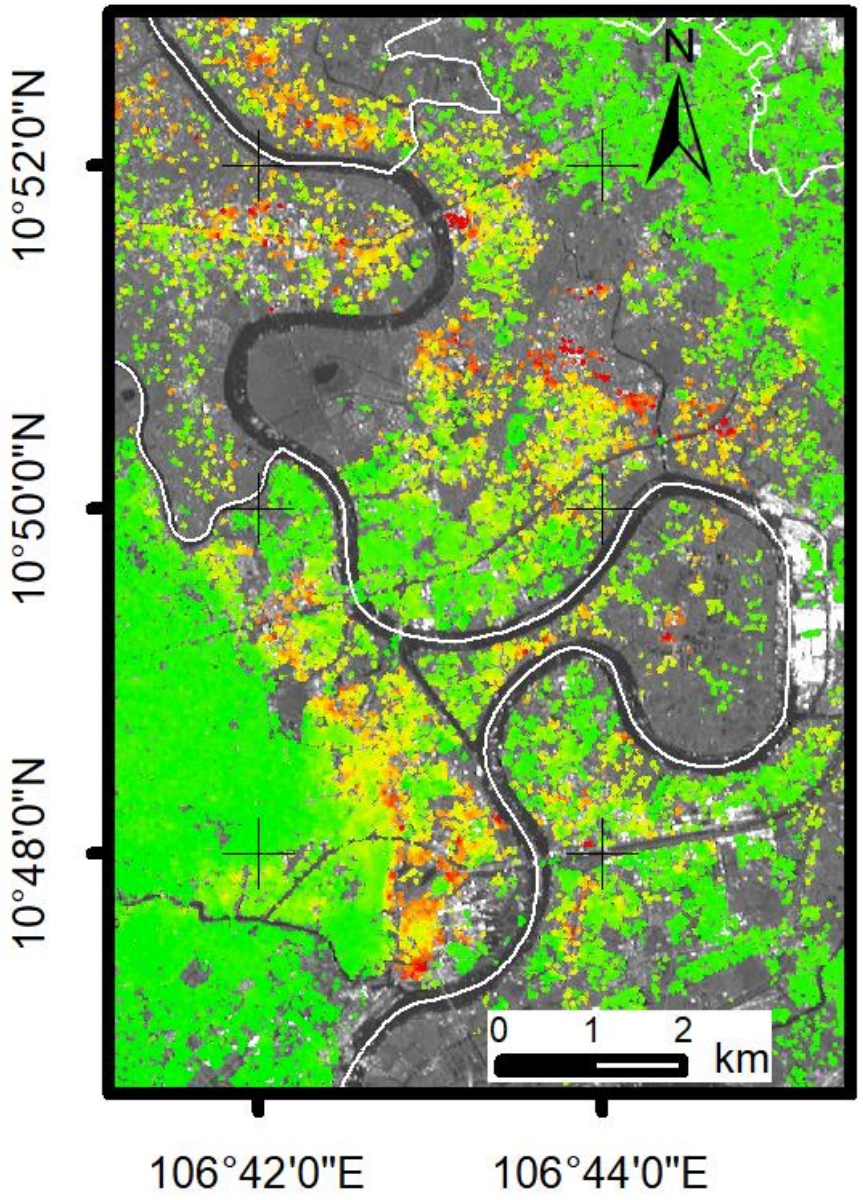
Land subsidence velocity in HCMC in the period 2015-2020 (Sentinel-1)



Areas with high subsidence velocity (Binh Tan and District 8)

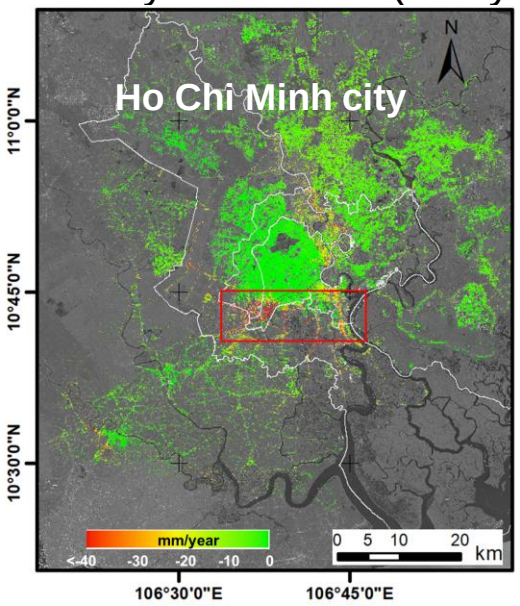


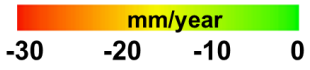
The area along the Saigon River

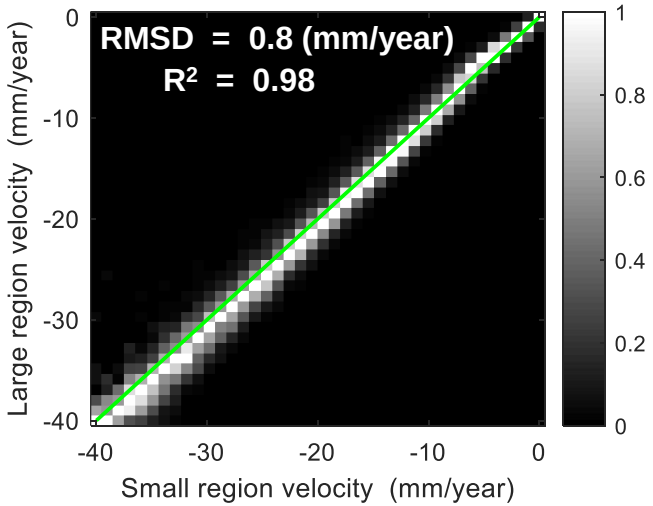


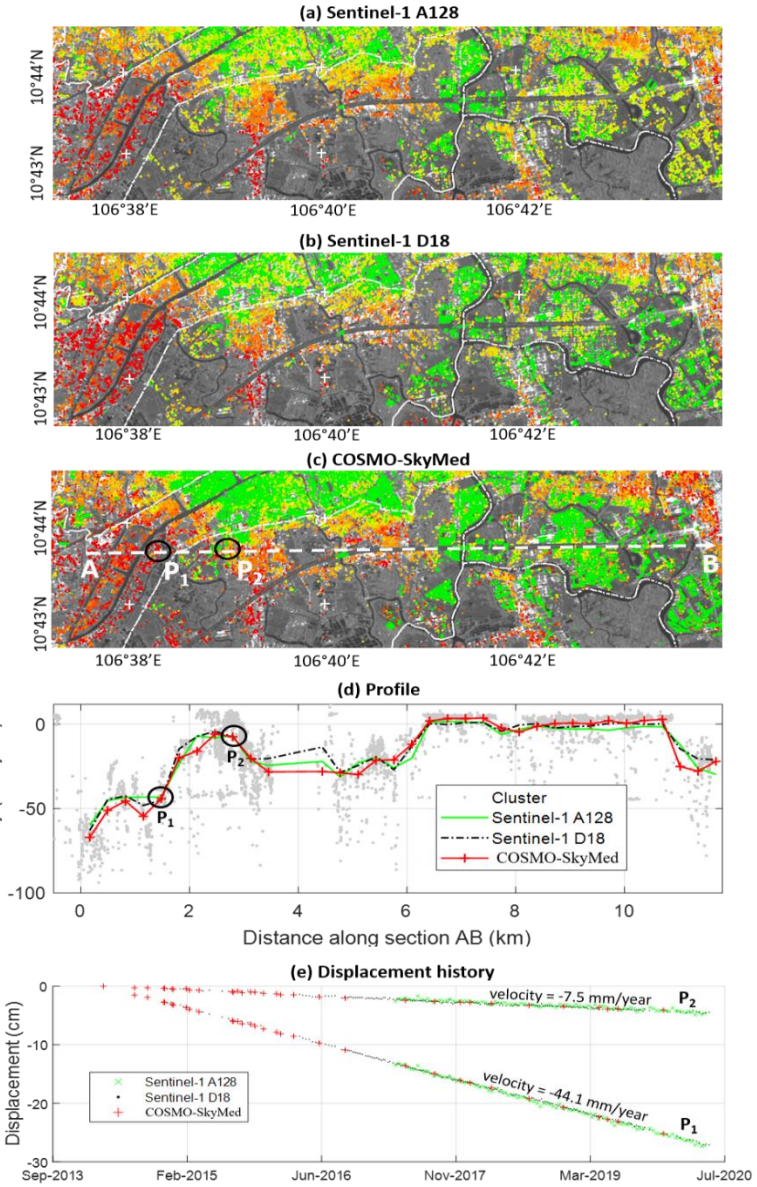
Delta-wide subsidence

Velocity 2015-2020 (mm/year)



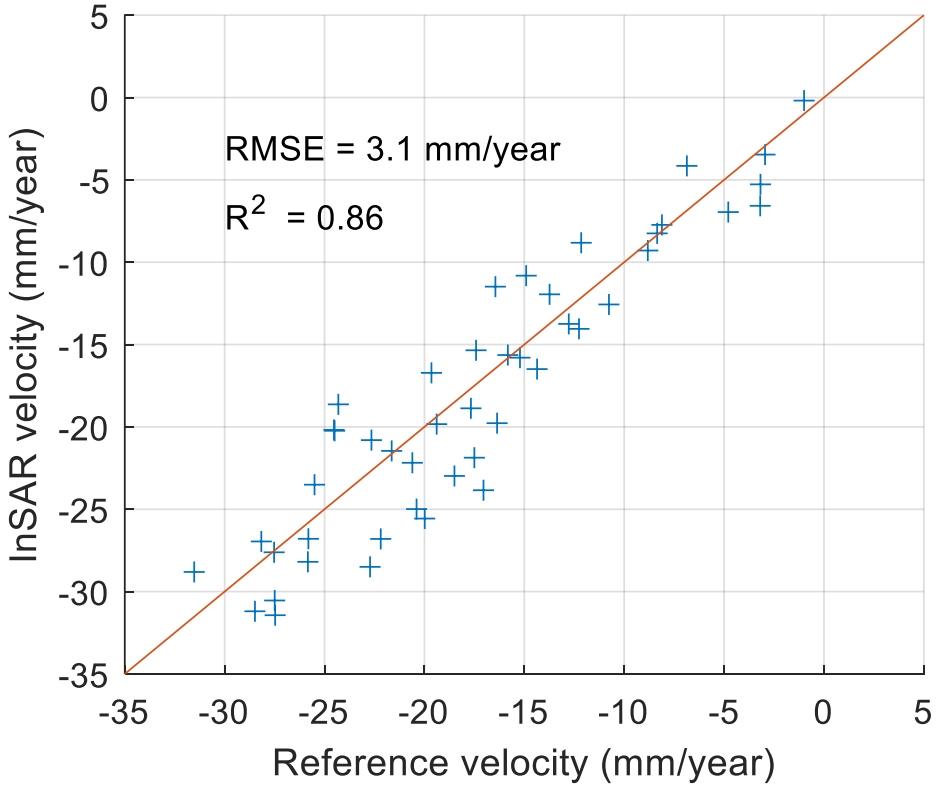


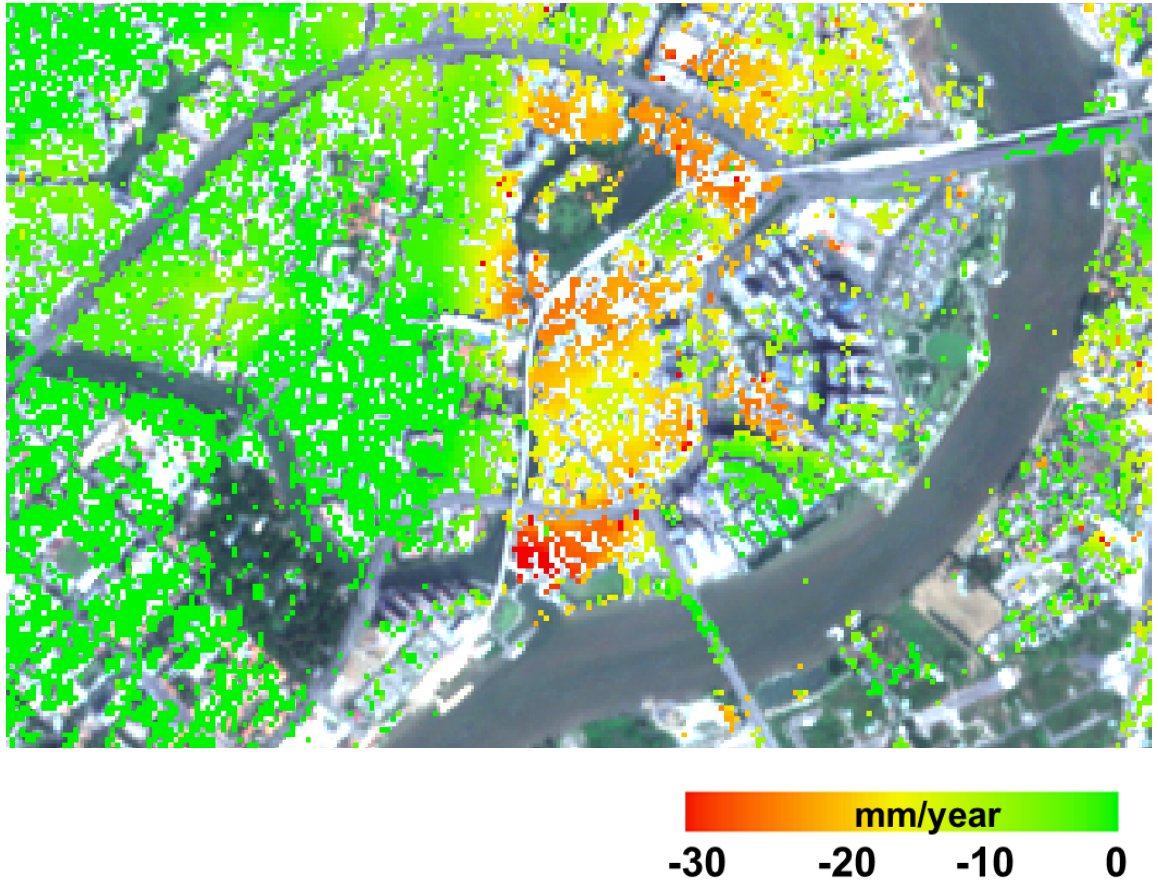




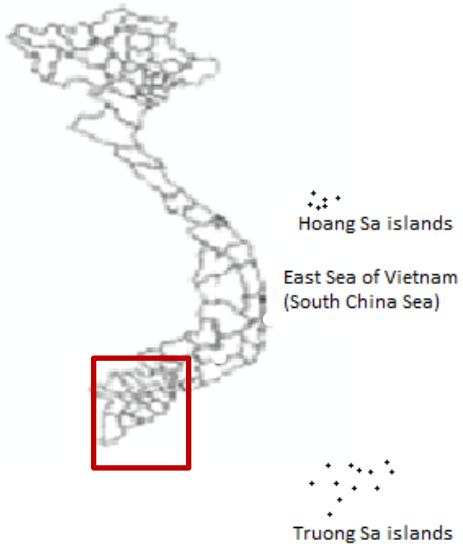
(The HCMC velocities are freely available for download from https://zenodo.org/record/5497723)

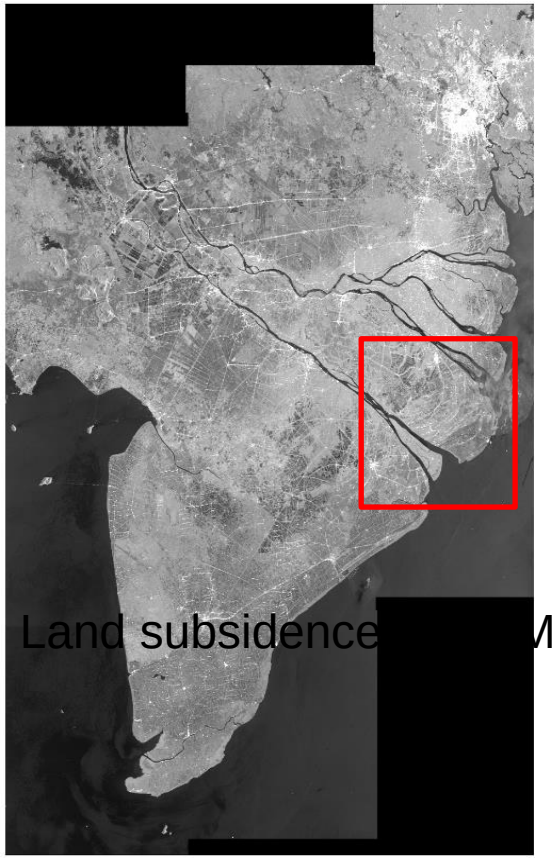
Subsidence in Tan Cang area





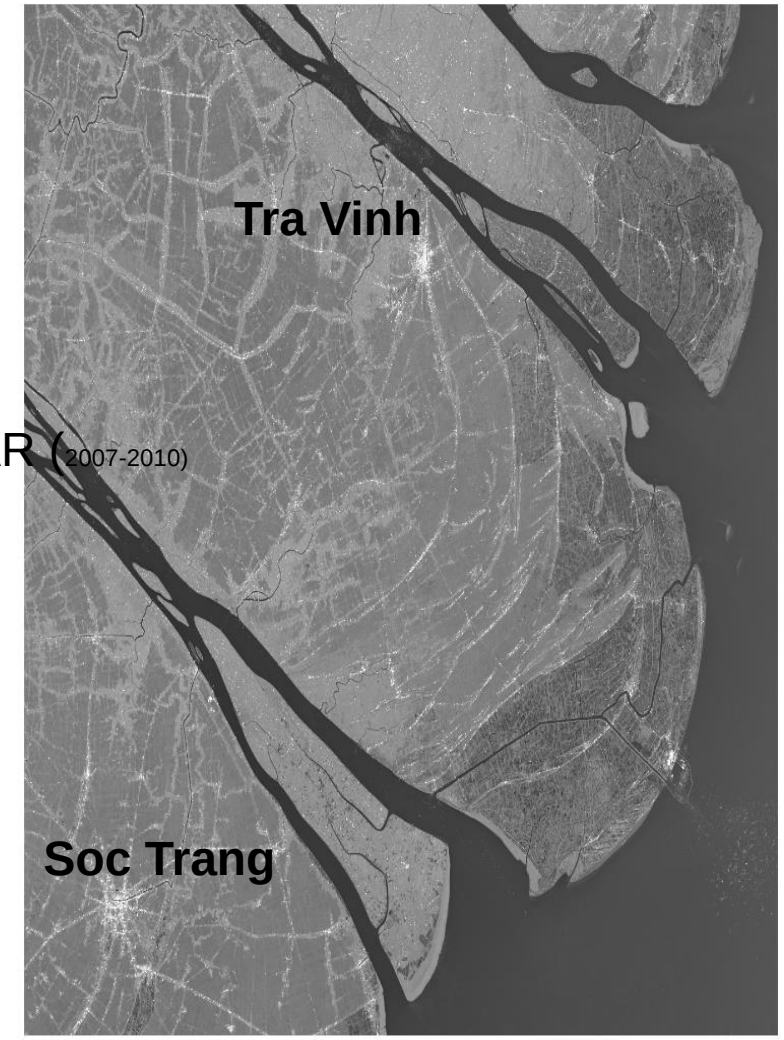
Good agreement in vertical velocity between reference and InSAR velocity (2017 - 2021)





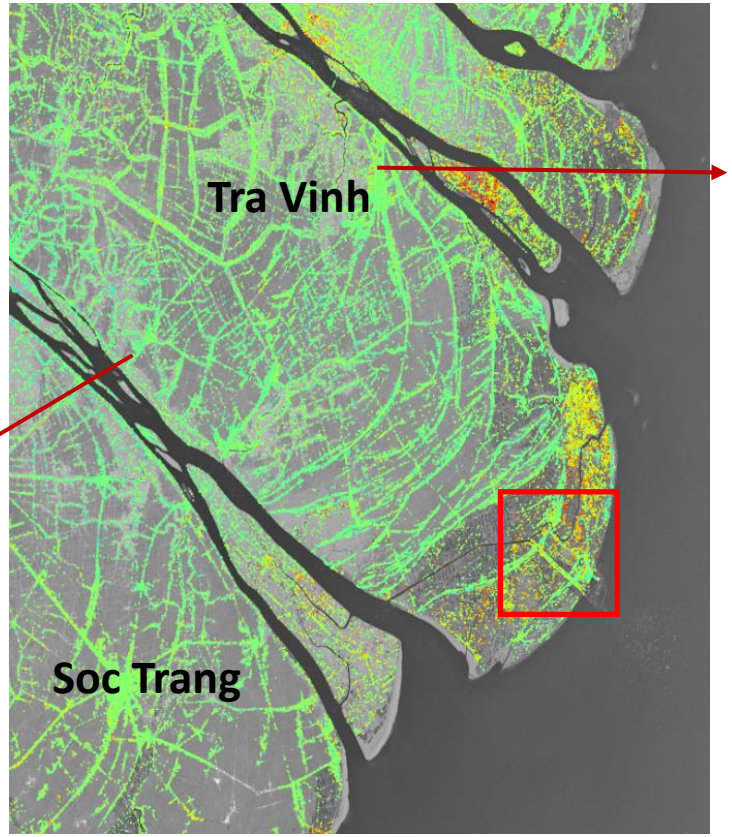
Land subsidence MC by InSAR (2007-2010)

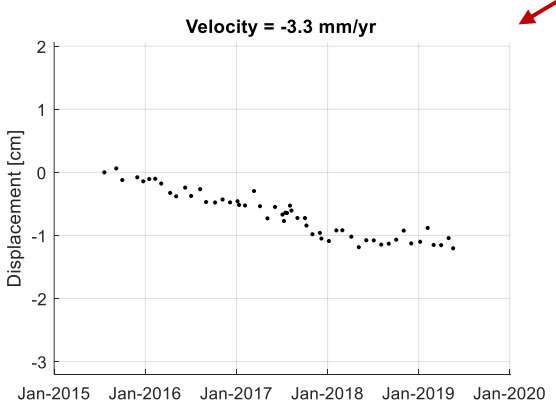
SAR intensity image

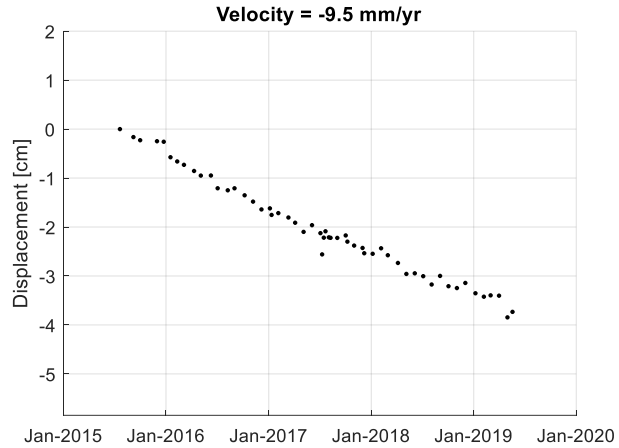


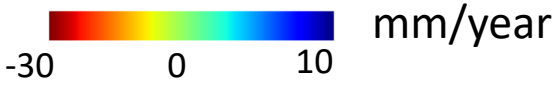
Land subsidence in Tra Vinh by InSAR (2015-2020)

Ground subsidence velocity (mm/year)

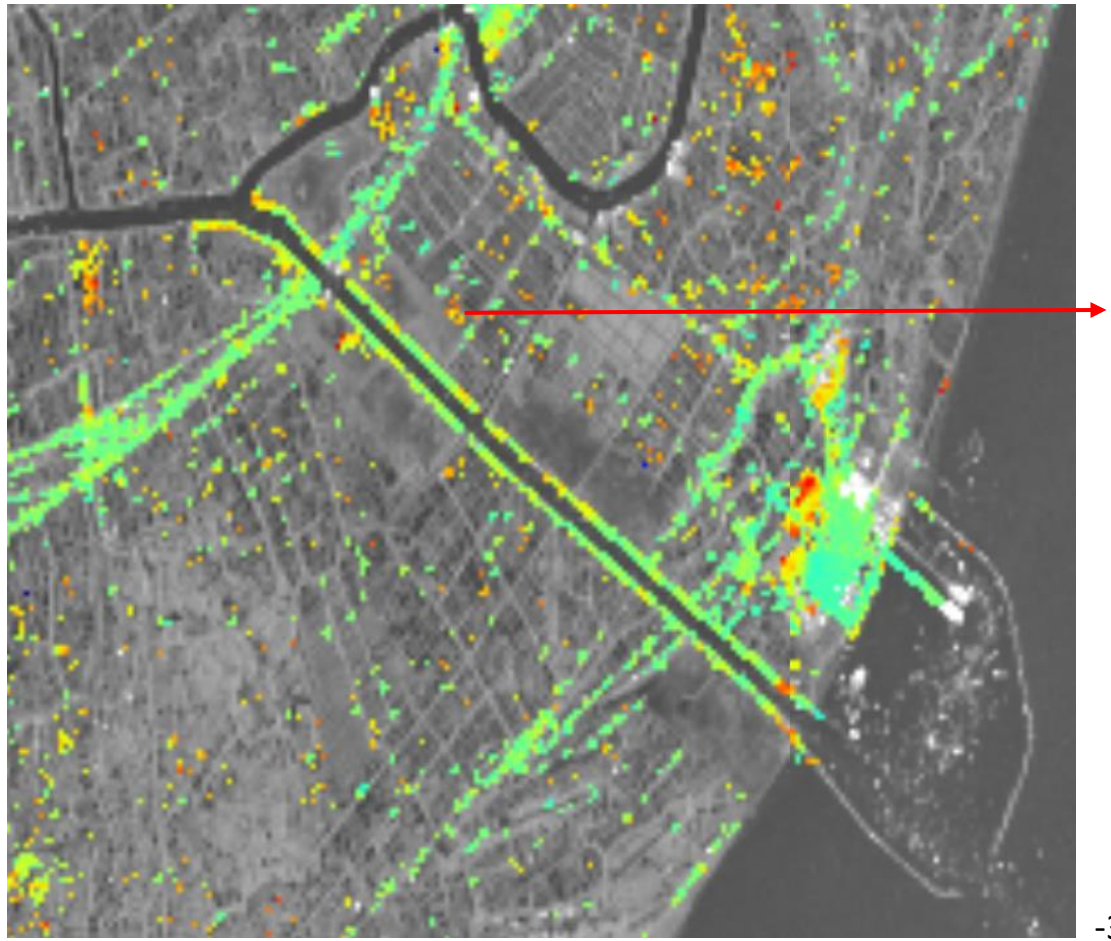


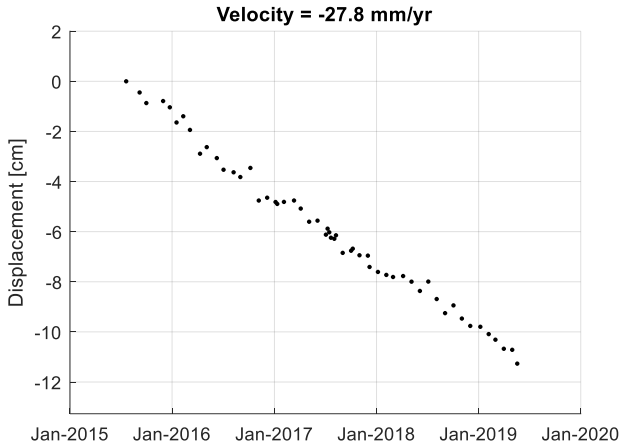


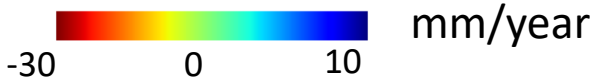




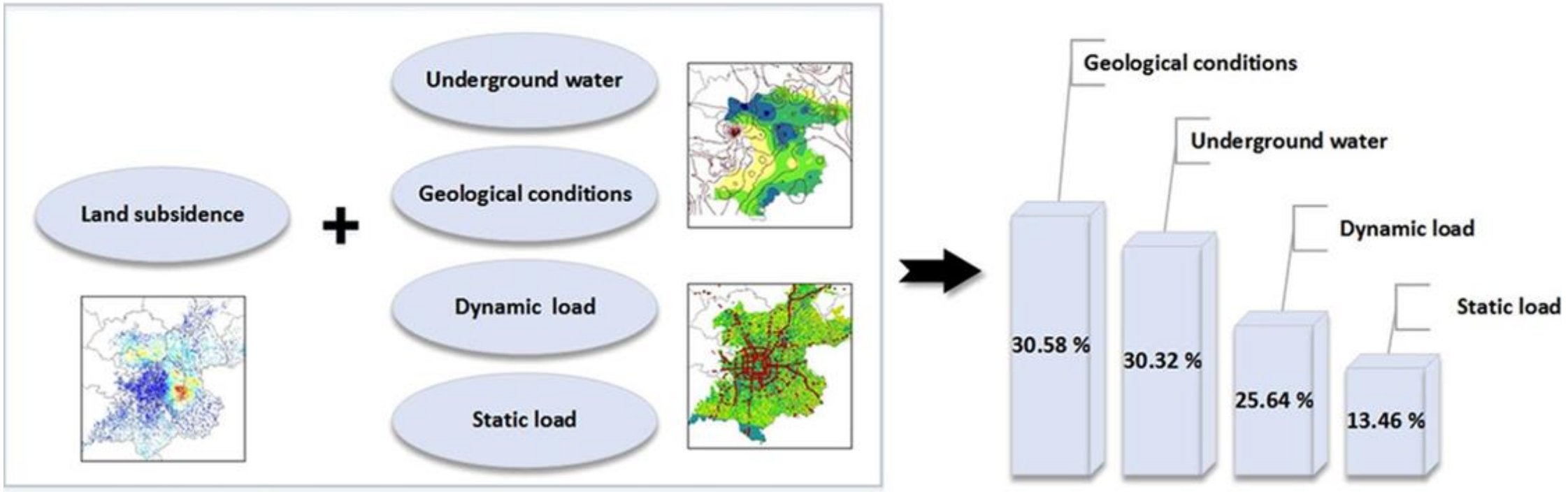
Ground subsidence velocity (mm/year)







Contribution of multiple factors to land subsidence

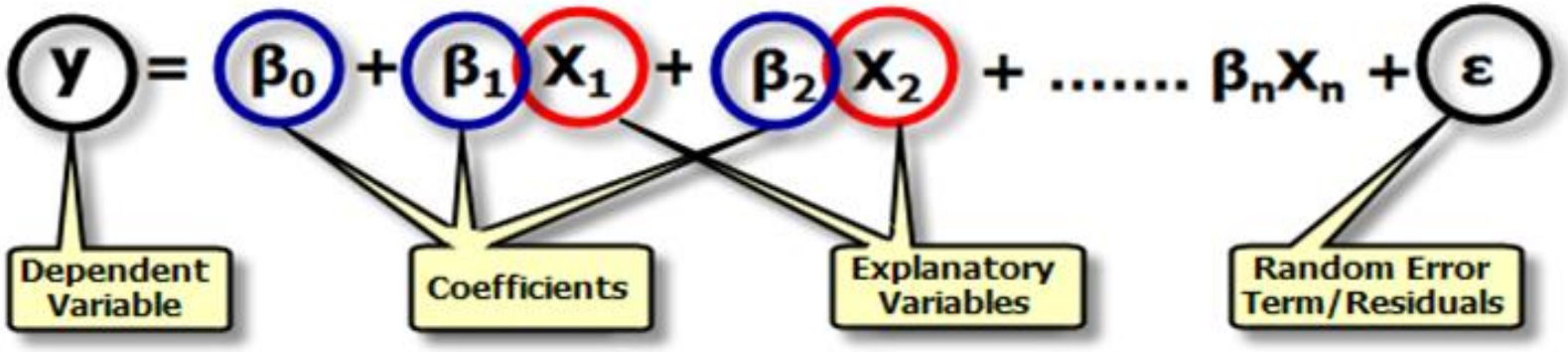


Nguồn: Quantifying the contribution of multiple factors to land subsidence in the Beijing Plain, China with machine learning technology
https://www.sciencedirect.com/science/article/abs/pii/S0169555X19301114

Land subsidence forecast

- **GIS regression model + Machine learning**

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots \beta_n X_n + \varepsilon$$



VelocityOfCell = W0 + W1xDTXDKC + W2xKCGT + W3xGWT + W4xGeo + ε

- There are about 50.000 regression equations/cell/ year
- From year 2000 to year 2020: 20*50000 equations => W(i); ε

Dependent Variable

Explanatory Variables

Table

SampleData

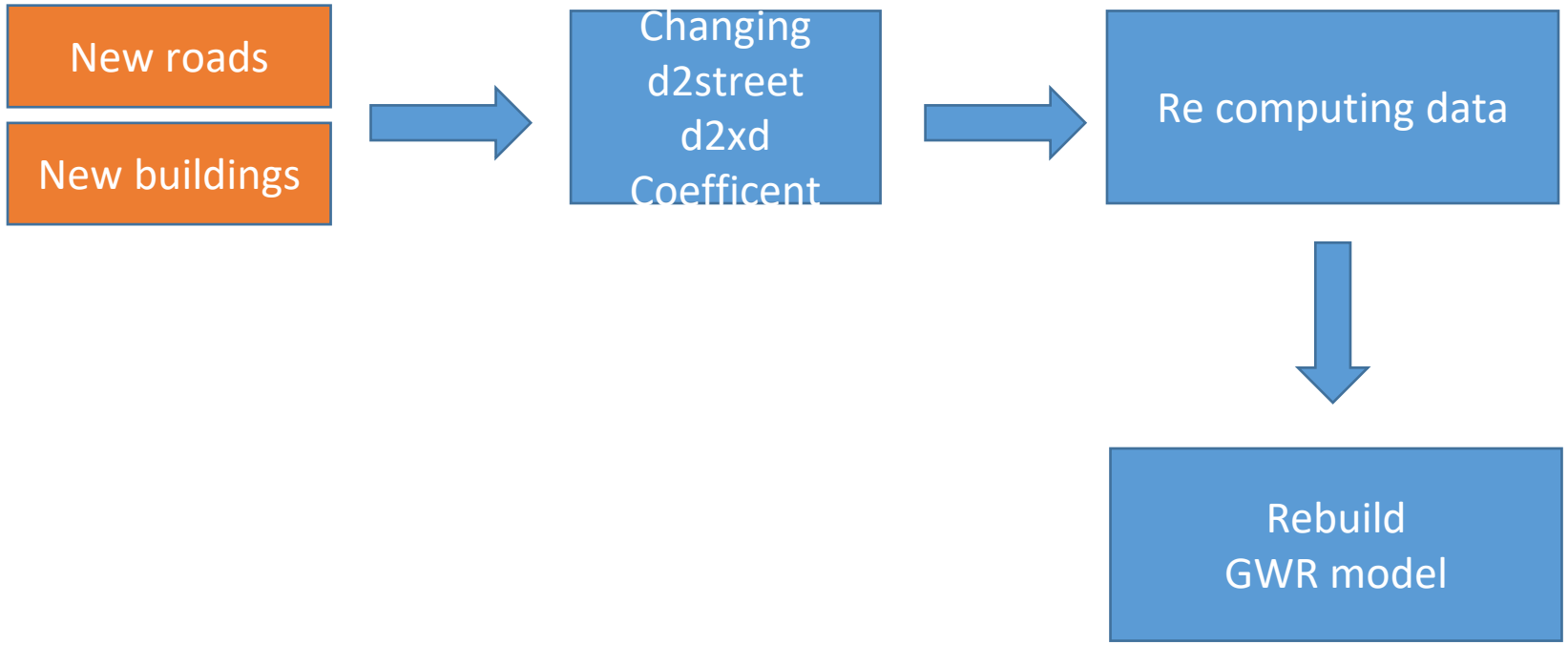
FID	Shape	fid_1	id	velocity	d2street	d2xd	elevation
0	Point	188	188	-3.111604	16.591471	7894	0.573
1	Point	1084	1084	-3.22888	90.057308	7798	0.68916
2	Point	1085	1085	-2.821293	144.047628	7816	0.64581
3	Point	1978	1978	-3.536514	263.593287	7667	0.4364
4	Point	1979	1979	-3.308235	206.100831	7683	0.53044
5	Point	1980	1980	-3.135798	187.870598	7701	0.65788
6	Point	1981	1981	-2.824193	161.846659	7720	0.65752
7	Point	1982	1982	-2.625478	63.936251	7739	0.57088
8	Point	2873	2873	-3.211986	403.536355	7555	0.455
9	Point	2874	2874	-3.174938	340.611482	7570	0.57464
10	Point	2875	2875	-3.097609	298.349551	7587	0.41924
11	Point	2876	2876	-2.95429	272.380977	7604	0.49108
12	Point	2877	2877	-2.751439	179.619722	7623	0.53624
13	Point	2878	2878	-2.581582	100.782629	7643	0.65704
14	Point	2879	2879	-2.441184	45.883563	7665	0.71128
15	Point	2880	2880	-2.334838	20.913987	7687	0.543818
16	Point	3768	3768	-2.734734	543.482223	7444	0.458909

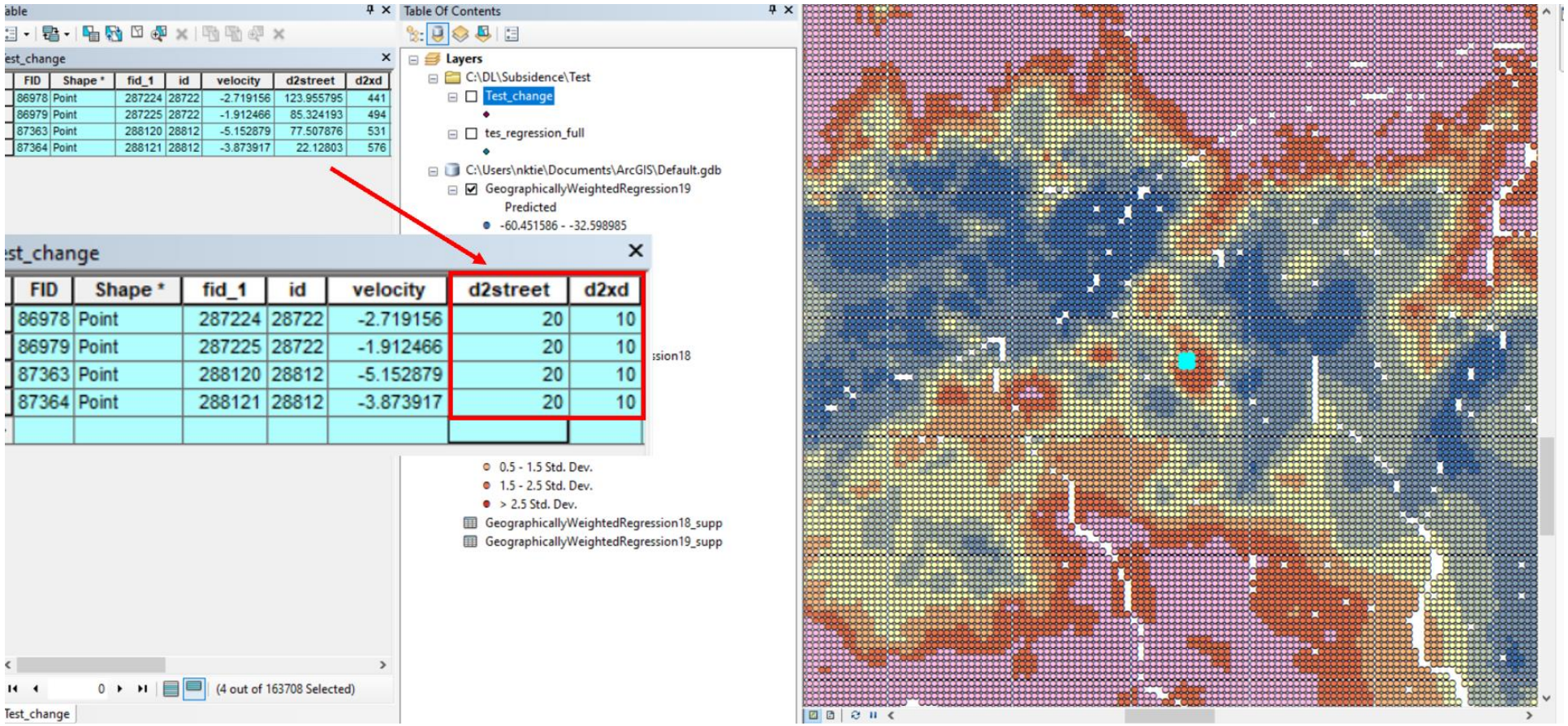
Velocity: land subsidence rate by year (mm/yr - pixel) calculated by InSAR
d2street: distance from a cell to nearest street
d2xd: distance from a cell to large building
elevation: topographic elevation of cell

Data by cell

- Transportation data: infrastructure, vehicle density, load...
- Construction data: Area, density, number of floors, load...
- Geological data: maps, drilling…
- Ground water data: maps, bore hole, excavation…
- DTM

The impact of changes in traffic and construction projects on the rate of land subsidence



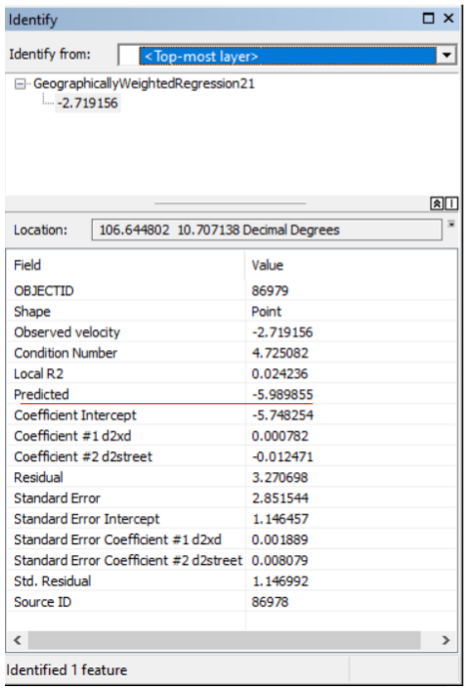


FID	Shape *	fid_1	id	velocity	d2street	d2xd
86978	Point	287224	28722	-2.719156	20	10
86979	Point	287225	28722	-1.912466	20	10
87363	Point	288120	28812	-5.152879	20	10
87364	Point	288121	28812	-3.873917	20	10

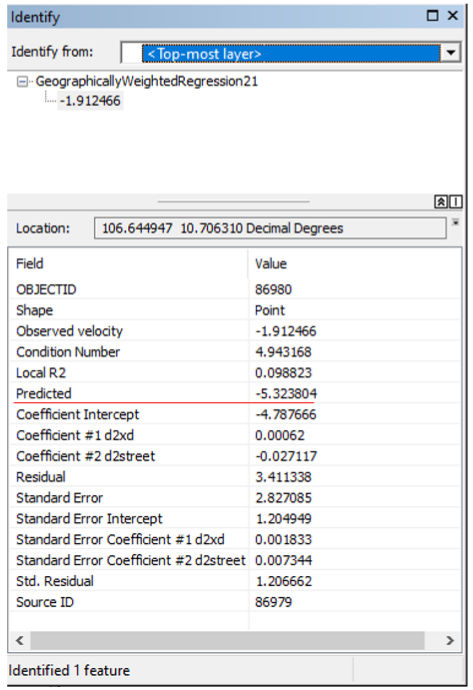
Test_change

FID	Shape *	fid_1	id	velocity	d2street	d2xd
86978	Point	287224	28722	-2.719156	20	10
86979	Point	287225	28722	-1.912466	20	10
87363	Point	288120	28812	-5.152879	20	10
87364	Point	288121	28812	-3.873917	20	10

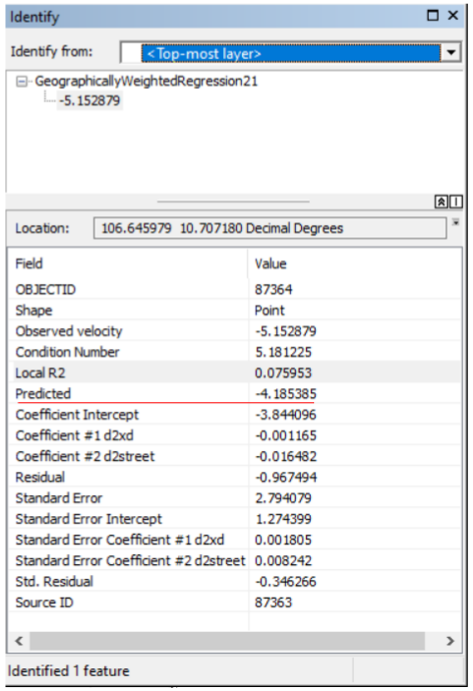
86978



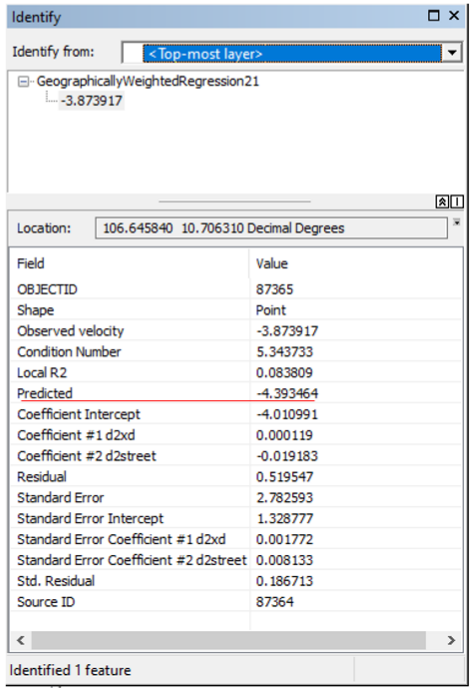
86979



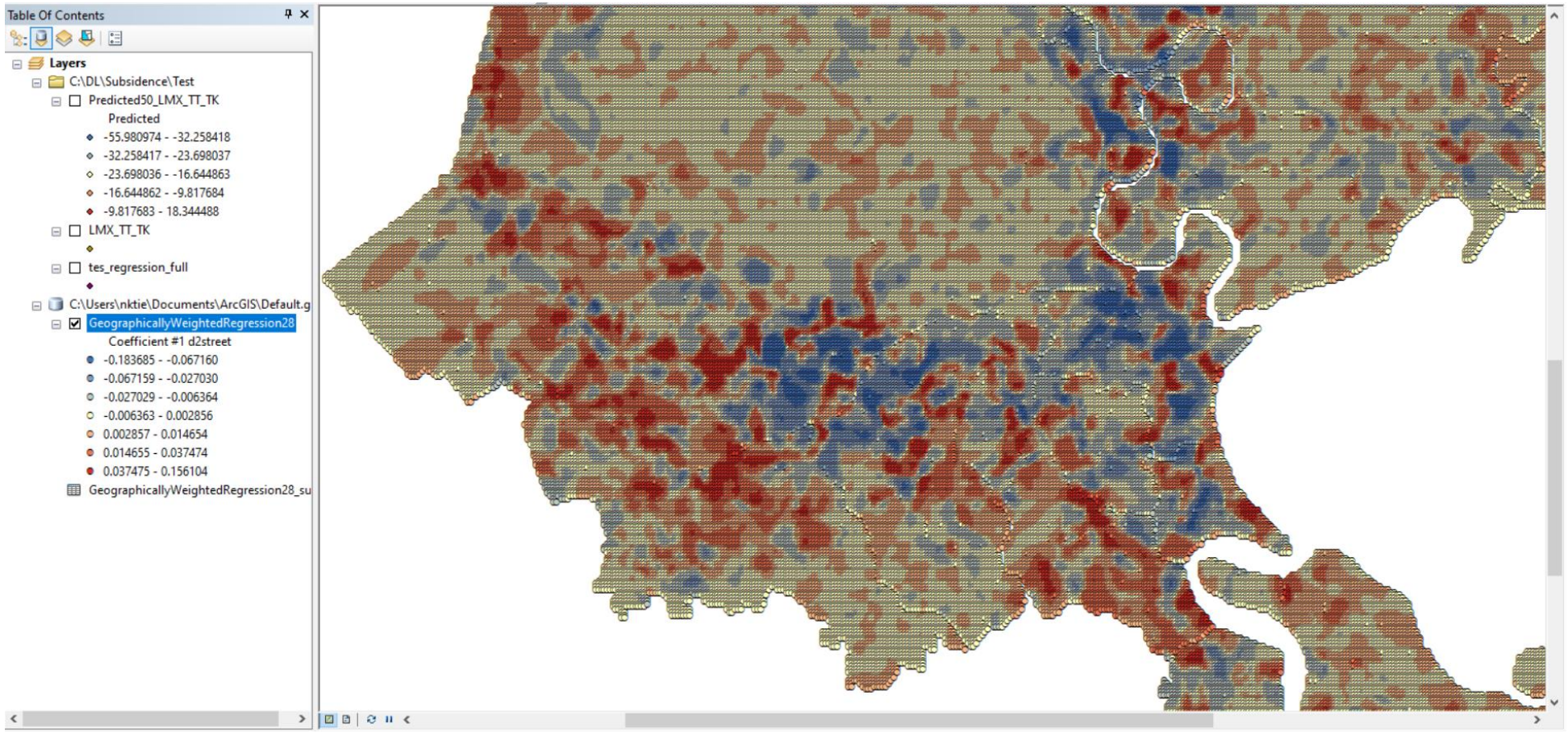
87363



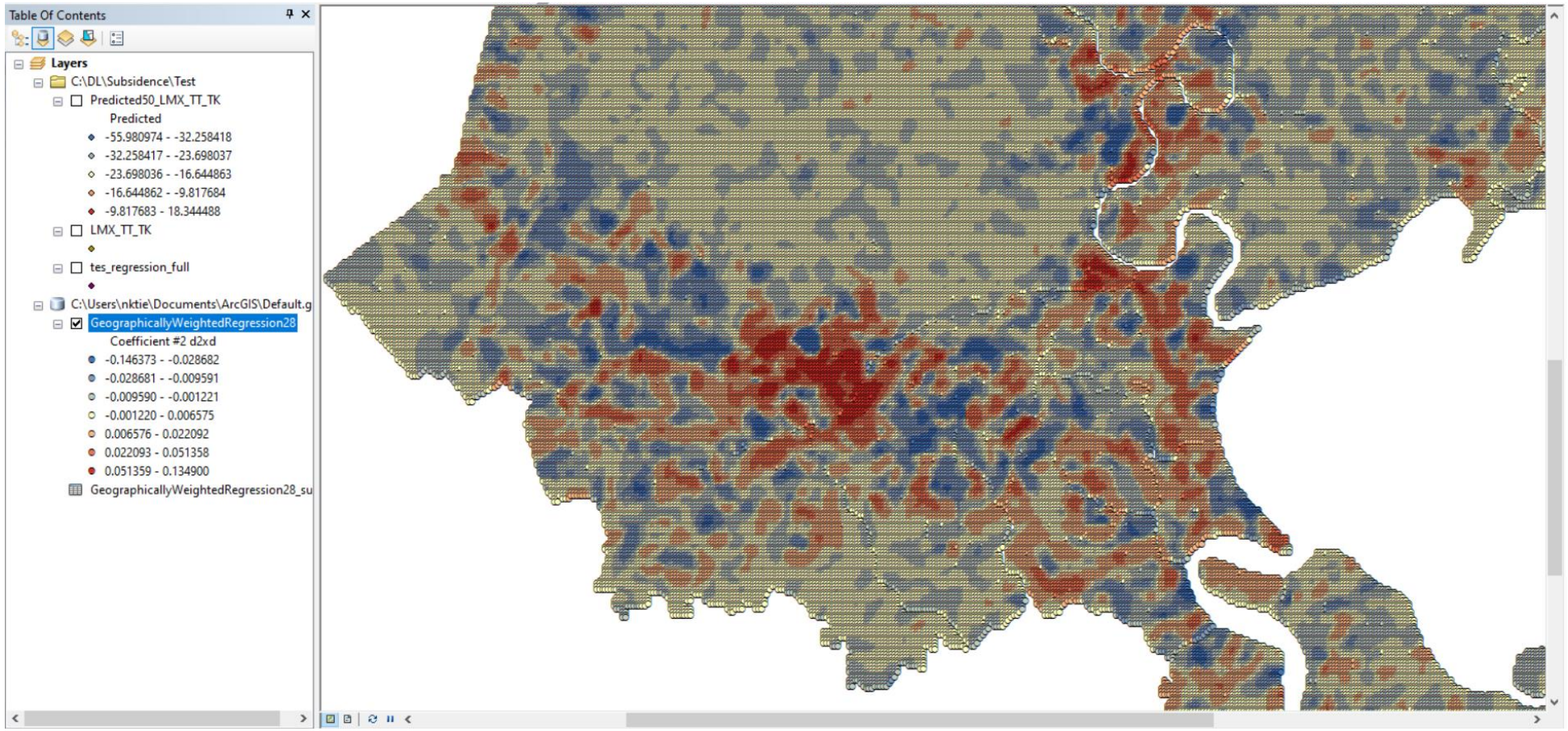
87364



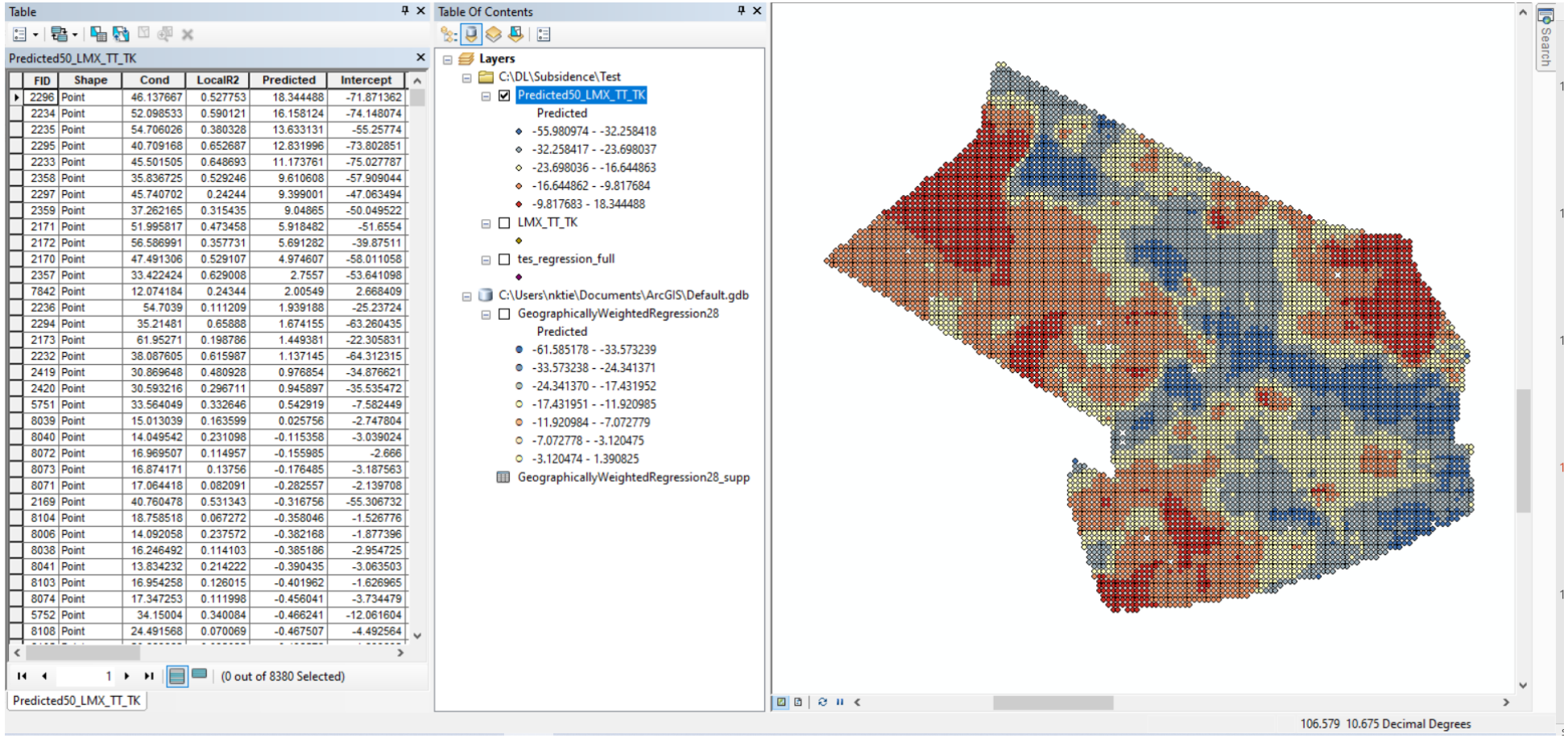
Distribution map of the impact of traffic construction changes on land subsidence D2STREET:



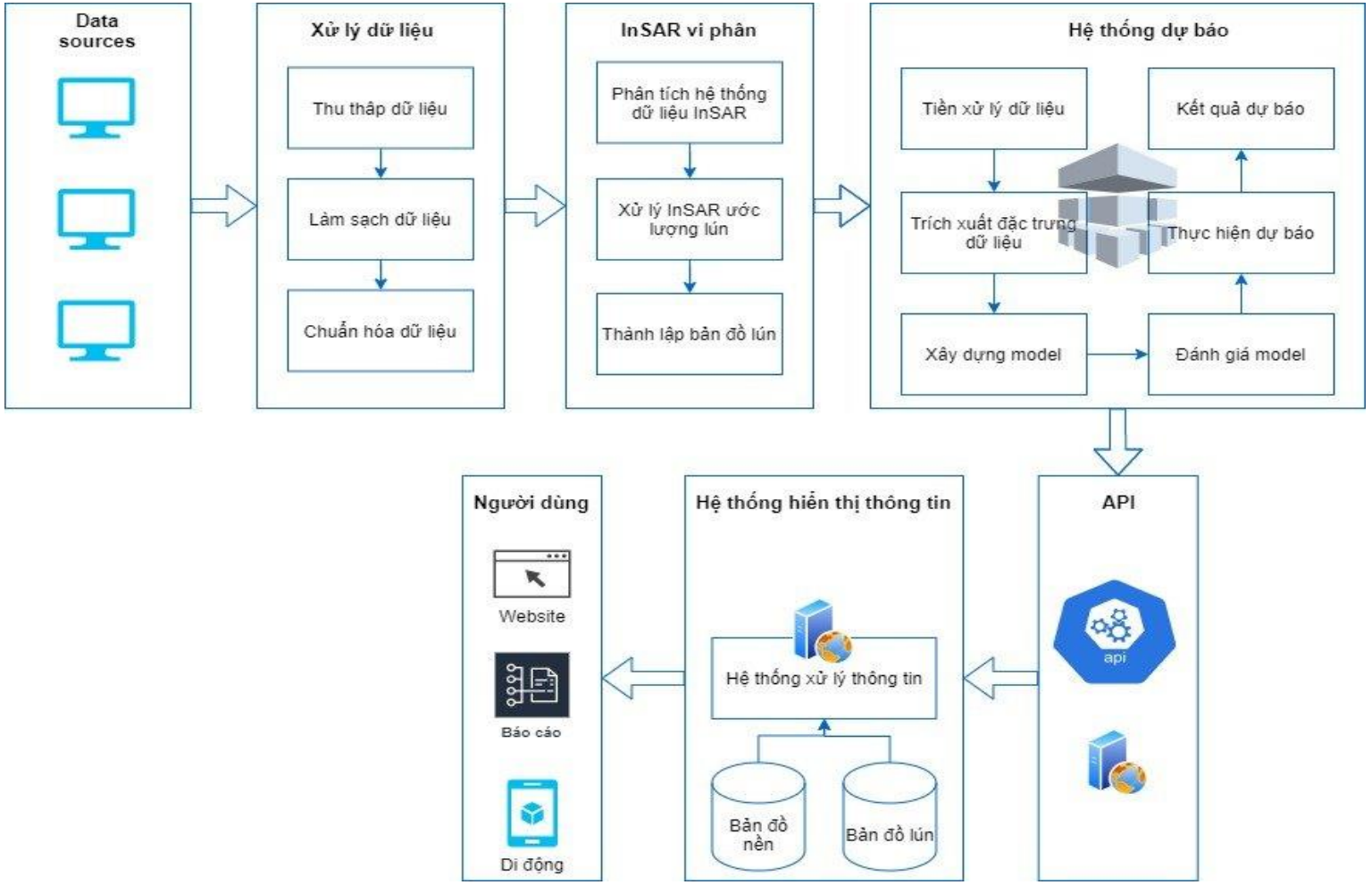
Distribution map of the influence of construction changes on land subsidence D2XD:



The map simulates subsidence when the distance from 1 cell (1 hectare) to the road is 50m : (d2Streeet = 50 m)



Land subsidence forecast system



Some recent typical publications

1. **Chon Le Trung**, Hồ Tống Minh Định, Huỳnh Quyền, Bùi Trọng Vinh, Trần Văn Hung, Measuring land subsidence in Tra Vinh by SAR interferometry Sentinel–1, Vietnam Journal of Hydrometeorology, 11, 36-42, 2022
2. D.Ho Tong Minh, **Chon Trung Le,** Ngo Yen Nhi, Le Toan Thuy. MEKONG SAR INTERFEROMETRY BIG DATA: PRELIMINARY RESULTS. 2020 IEEE International Geoscience and Remote Sensing Symposium, IGARSS 2020
3. Minh, D.H.T., Ngo, Y.N., Lê, T.T., **Le, T.C.,** Bui, H.S., Vuong, Q.V. and Le Toan, T., 2022, July. Mapping ground motions by open-source persistent and distributed scatterers Sentinel-1 radar interferometry: Ho Chi Minh city case study. In IGARSS 2022-2022 IEEE International Geoscience and Remote Sensing Symposium (pp. 1632-1635).

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