



**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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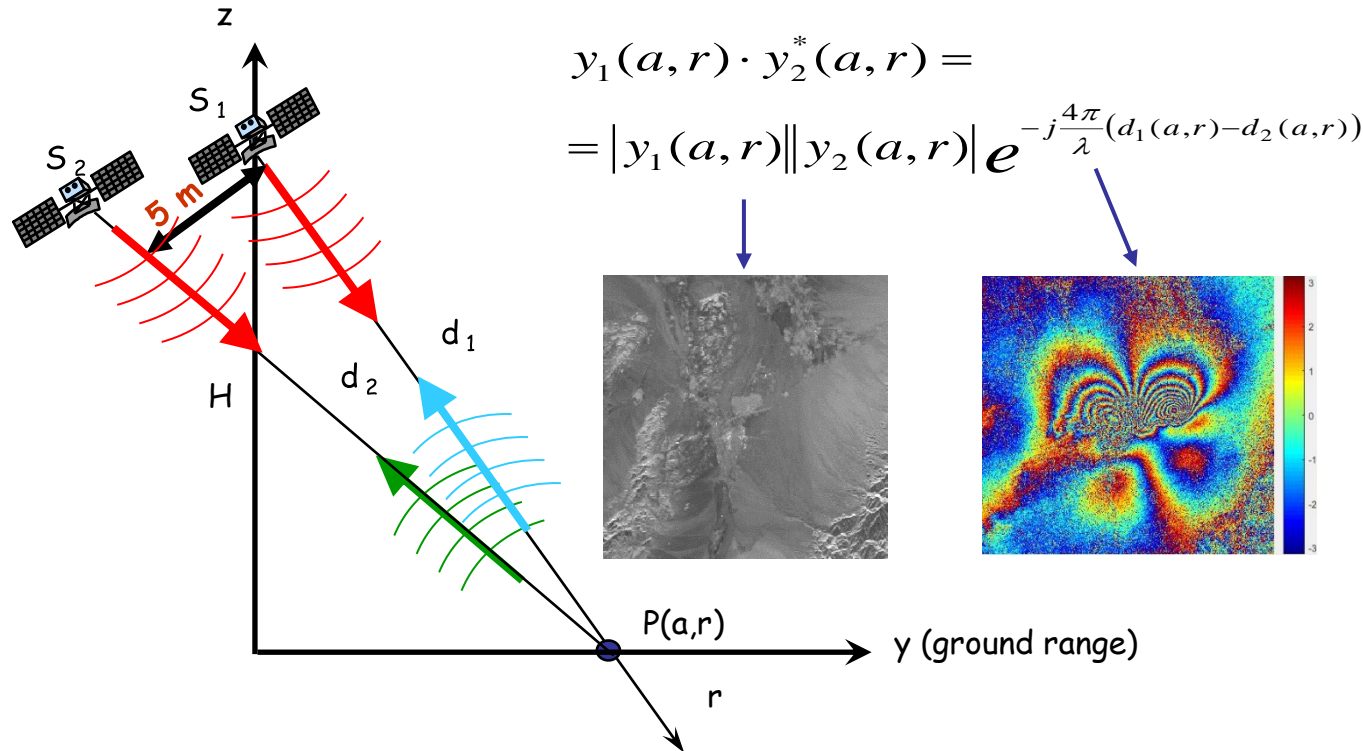


- Brief about TOMOSAR
- Land subsidence in Hochiminh City, Vietnam
- Land subsidence in Mekong Delta
- Focasting land subsidence in Hochiminh City:
Preliminary results

SAR: Interferometric phases

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

An example (BAM earthquake 2003)

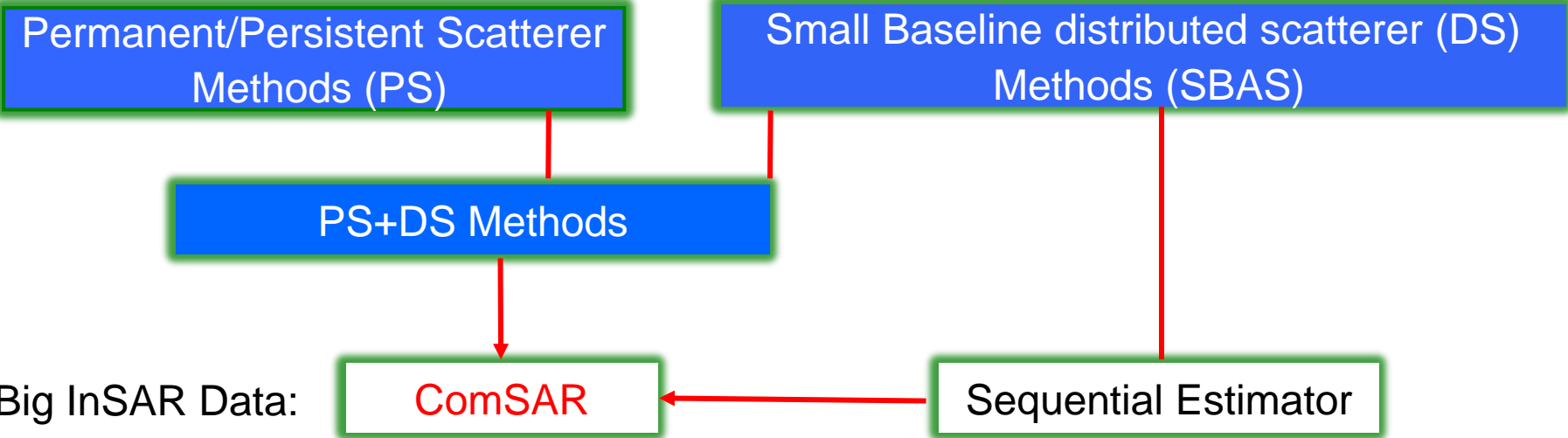




InSAR time series approaches

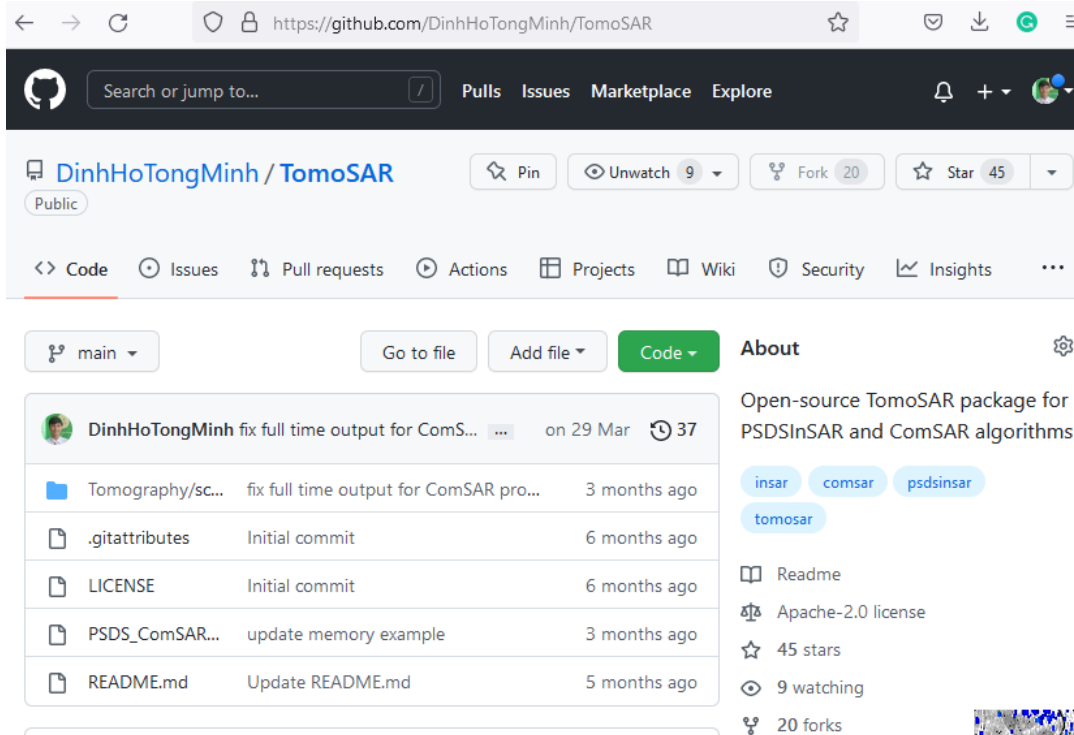
- Analysis wrapped phase
- High resolution – single look
- PS limitation in rural environments
- PS+DS is best for all

- 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



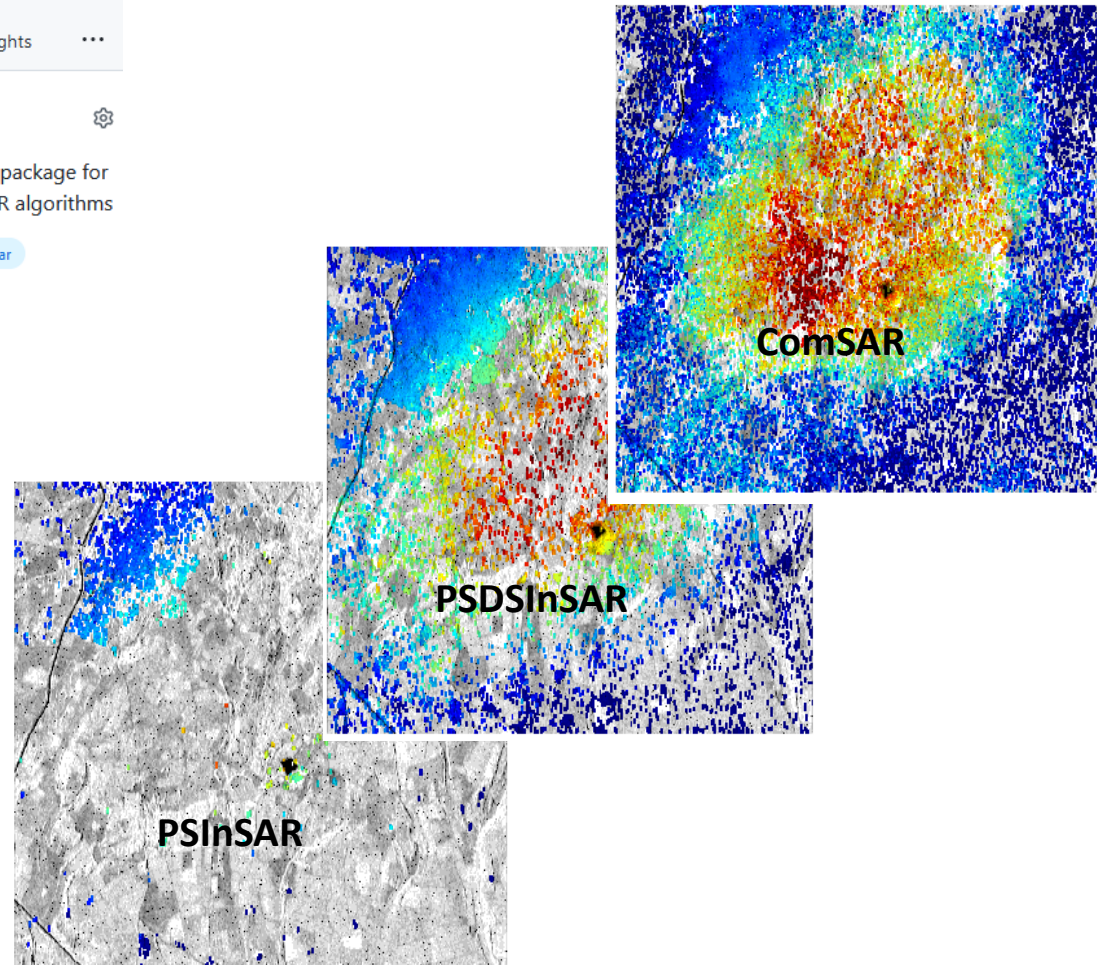
ComSAR is friendly Big Data processing.

i.e:

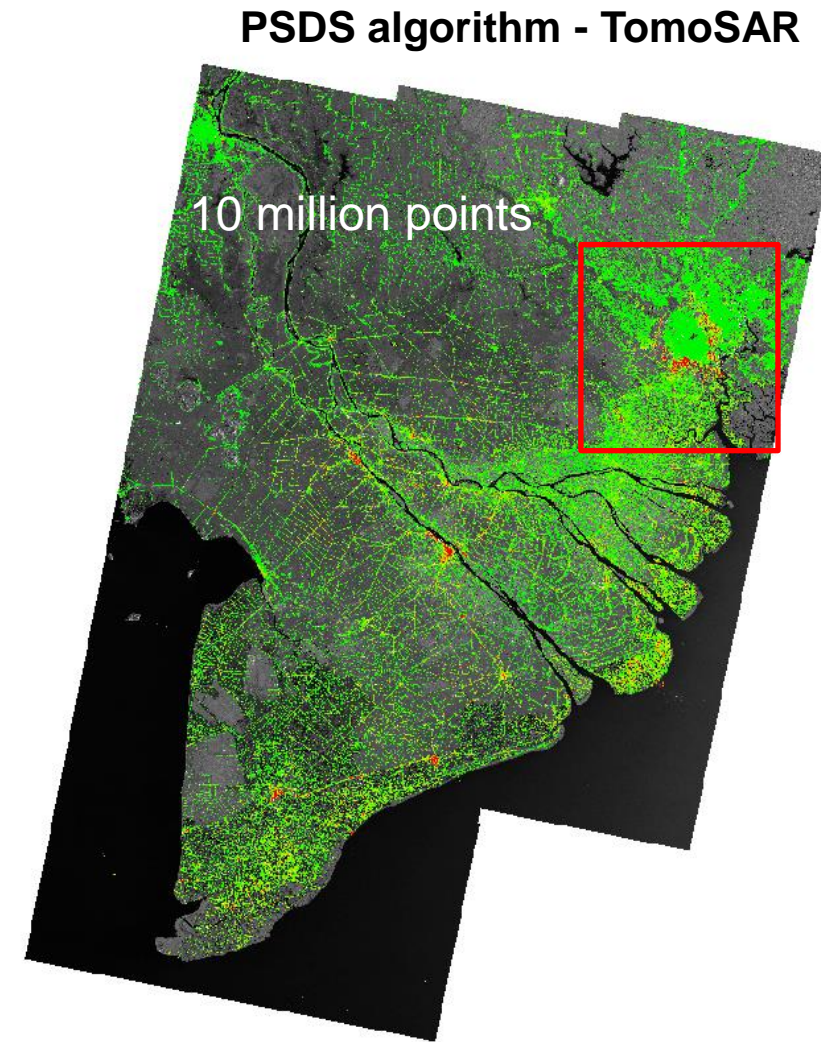
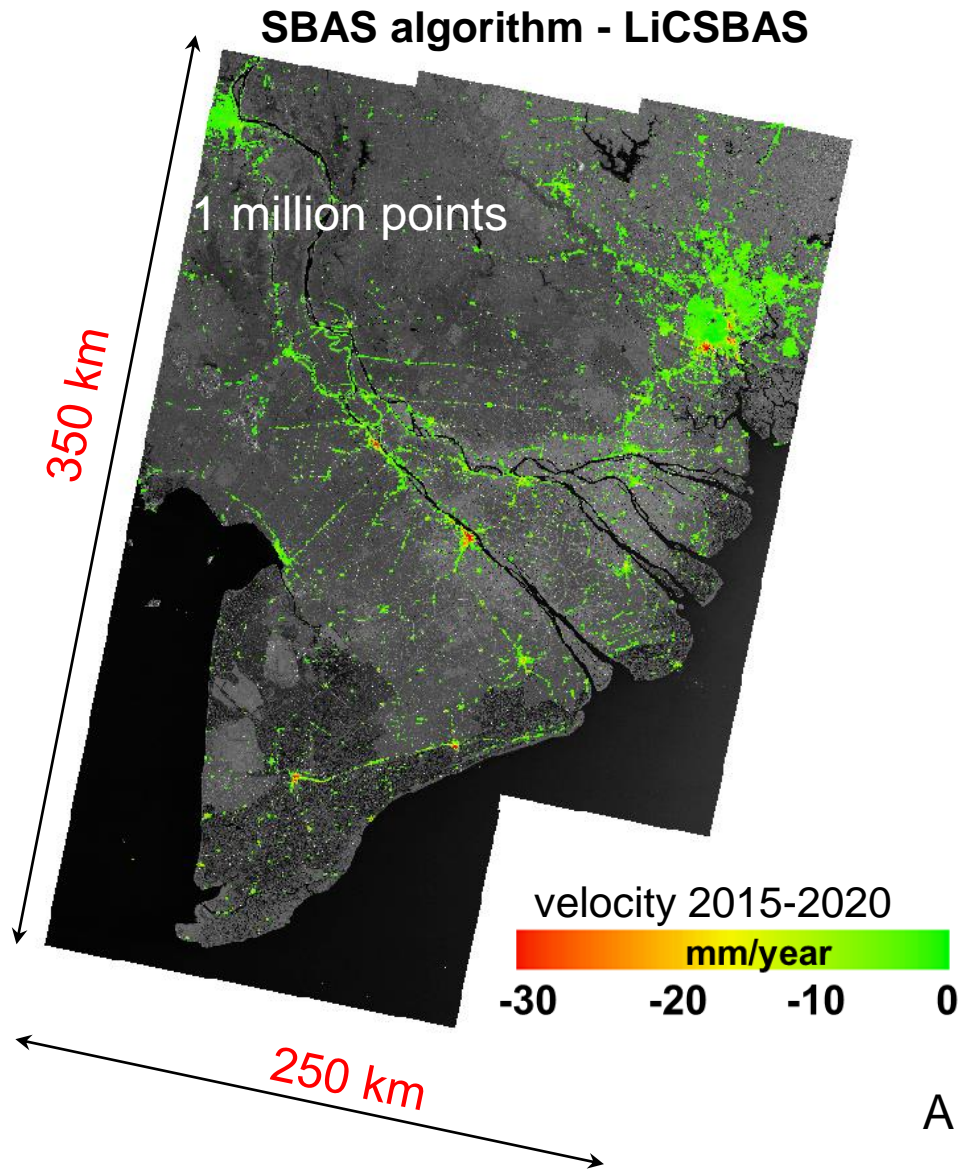
200 images of 500x2000 size

- 220 GB is for PSDS

- 45 GB for ComSAR



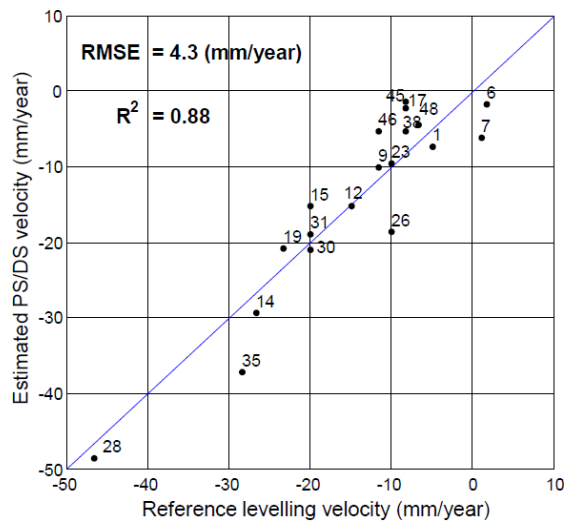
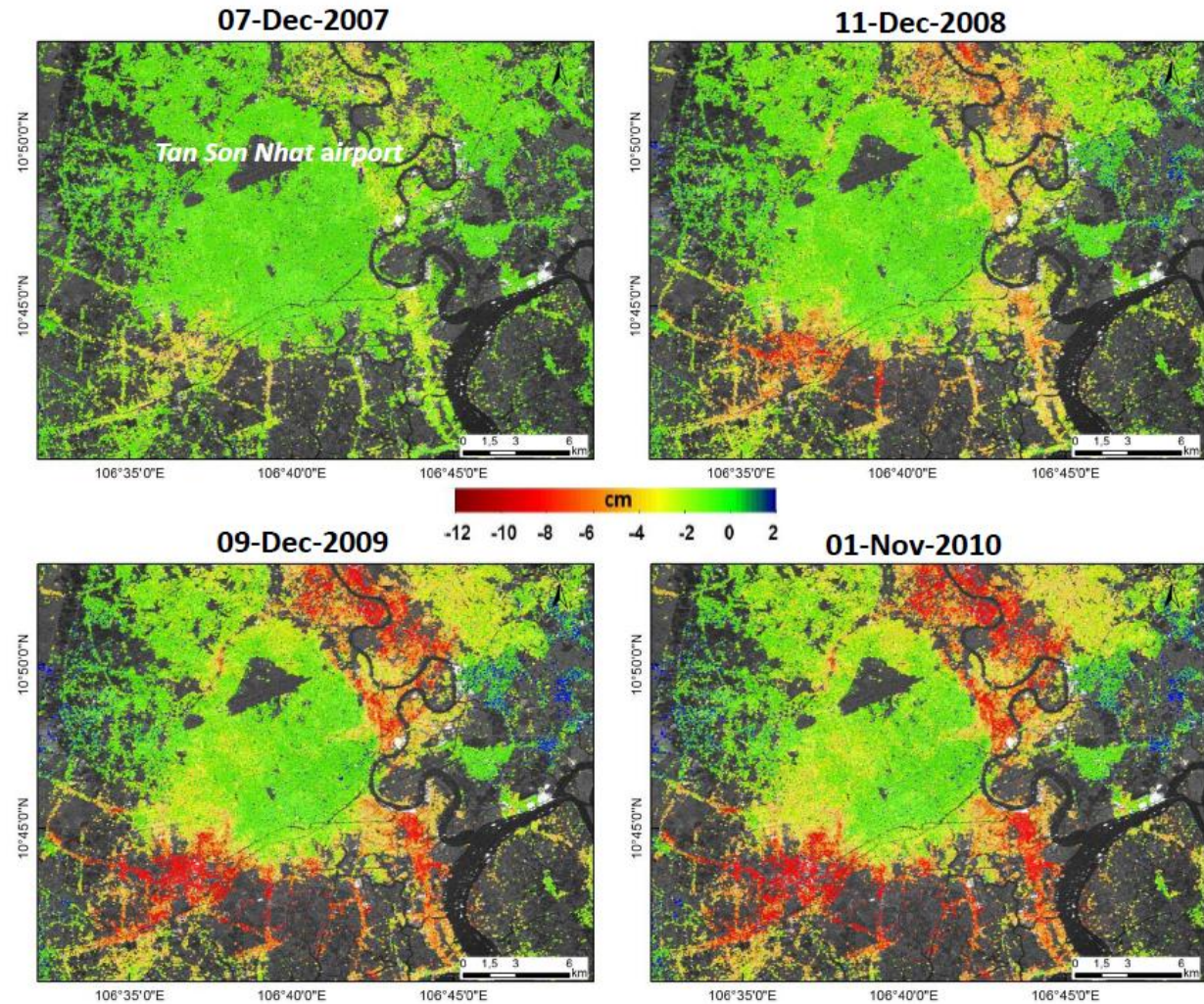
Delta-wide subsidence



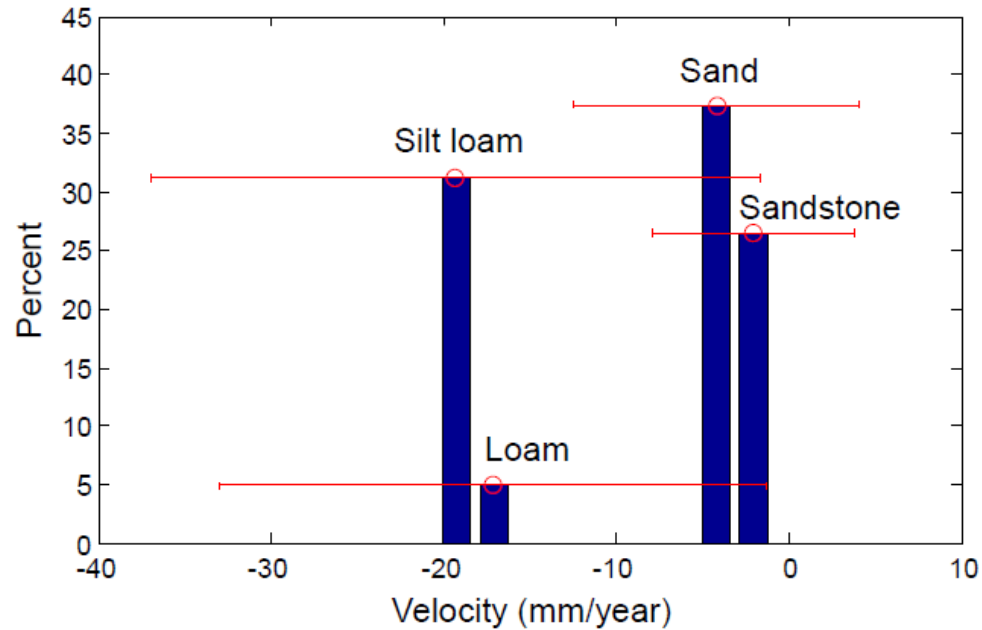
A coherent processing in one SLC coverage !

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

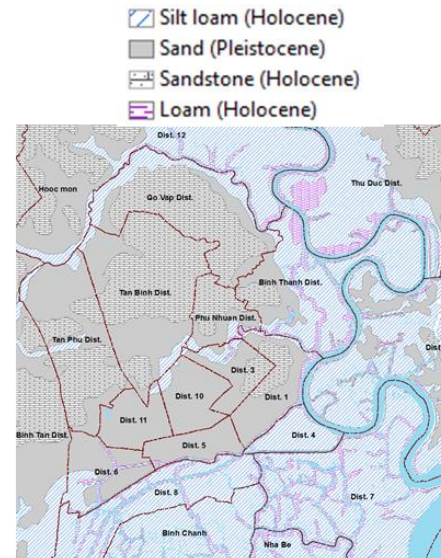


Correlation between geological factors and subsidence

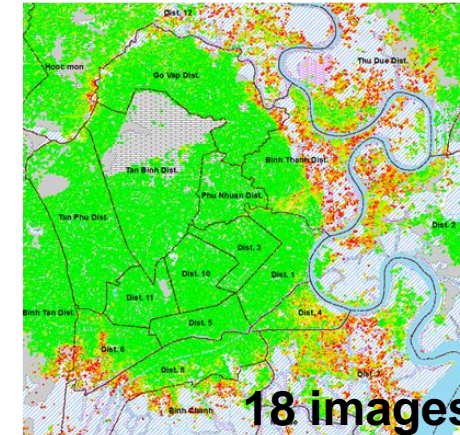


- The weak land has a high subsidence rate!
- Cosmos SkyMED vs Sentinel-1.

Sources: Dr. Hab Ho Tong Minh Dinh et



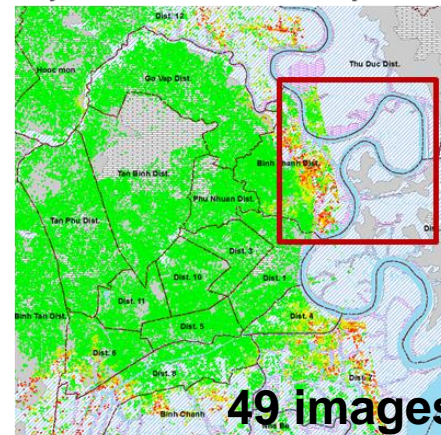
2006-2010 average velocity by L-band ALOS



18 images

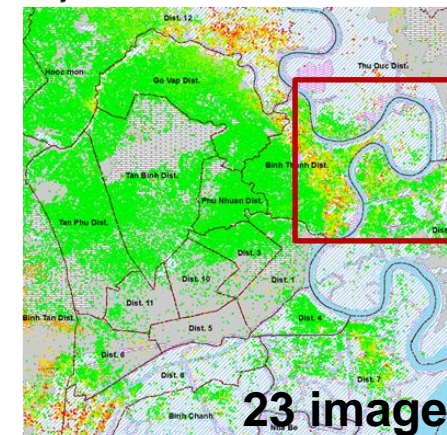


2014-2016 average velocity by X-band Cosmos SkyMED



49 images

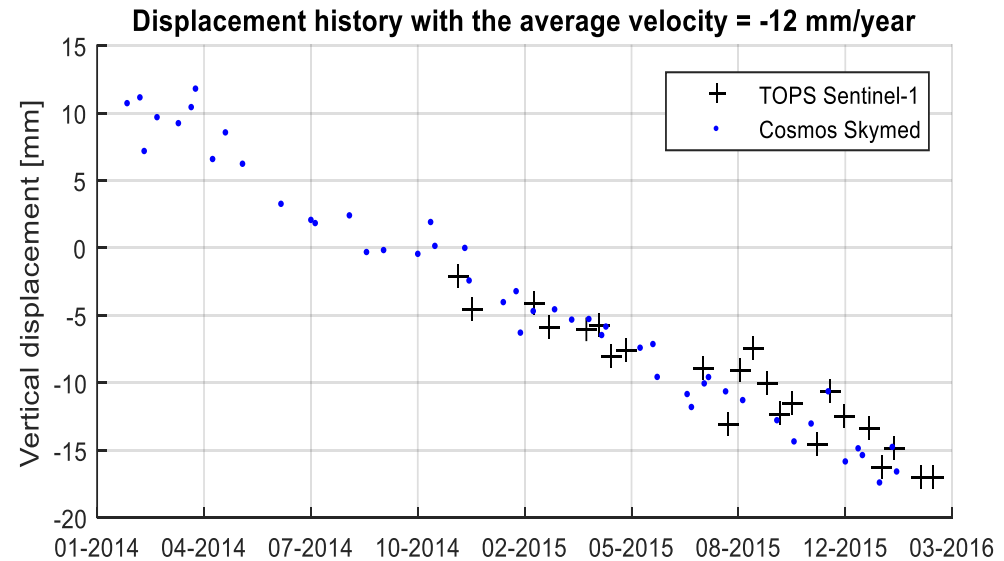
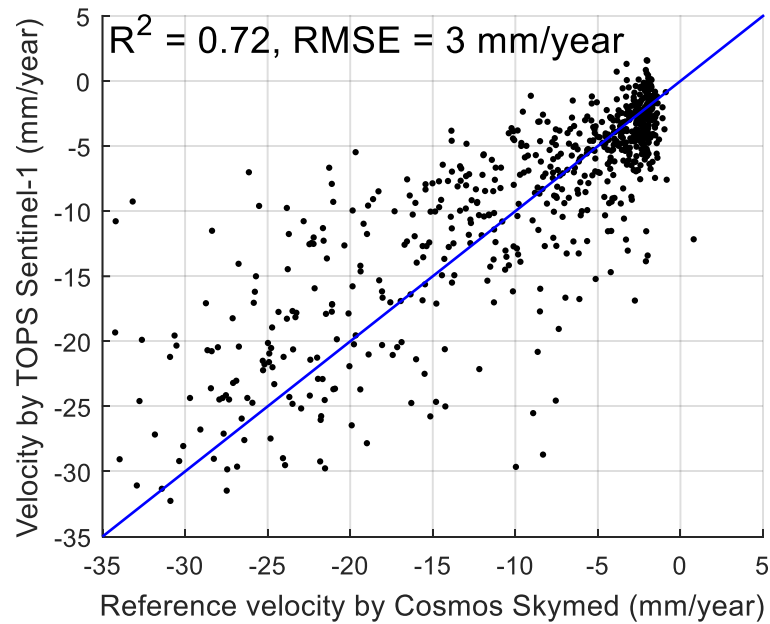
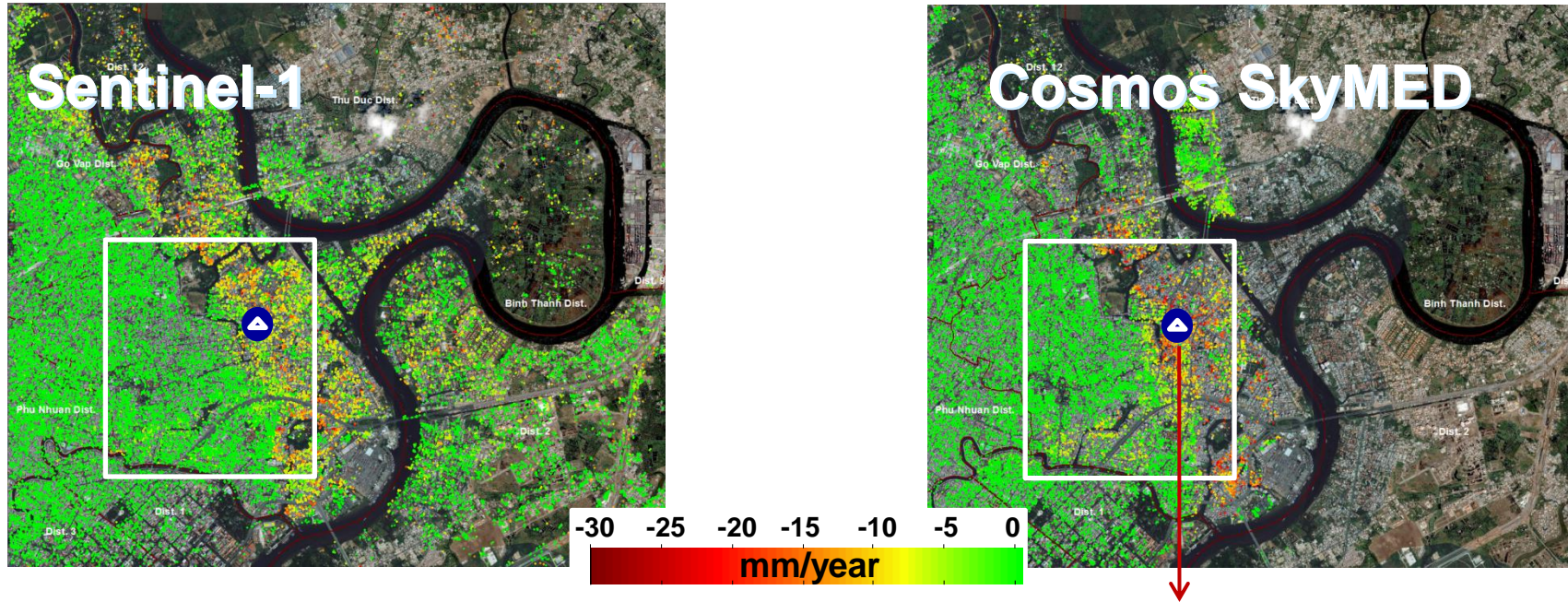
2014-2016 average velocity by C-band TOPS Sentinel-1



23 images

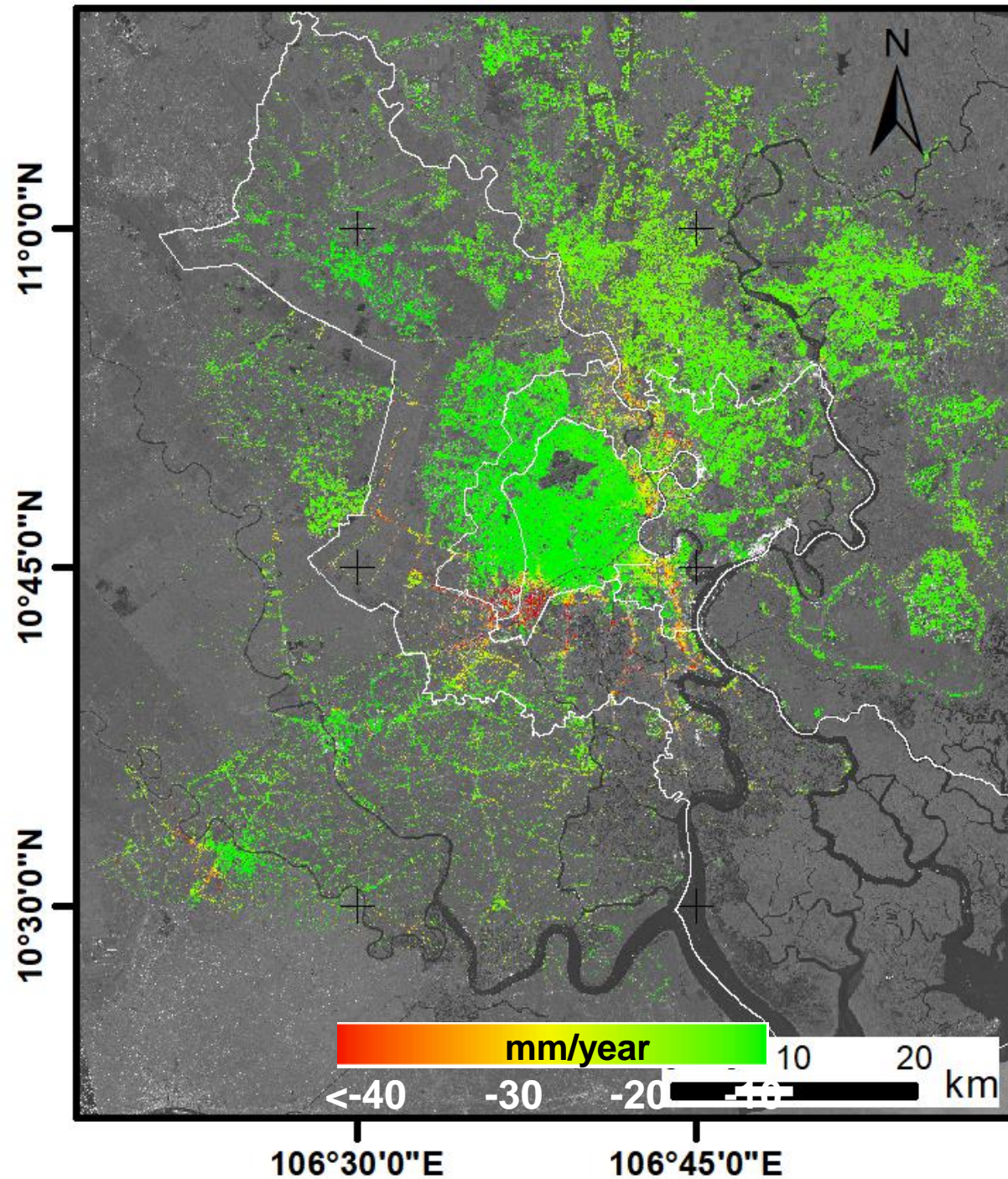


Comparison Stripmap Cosmos Skymed and TOPS Sentinel-1



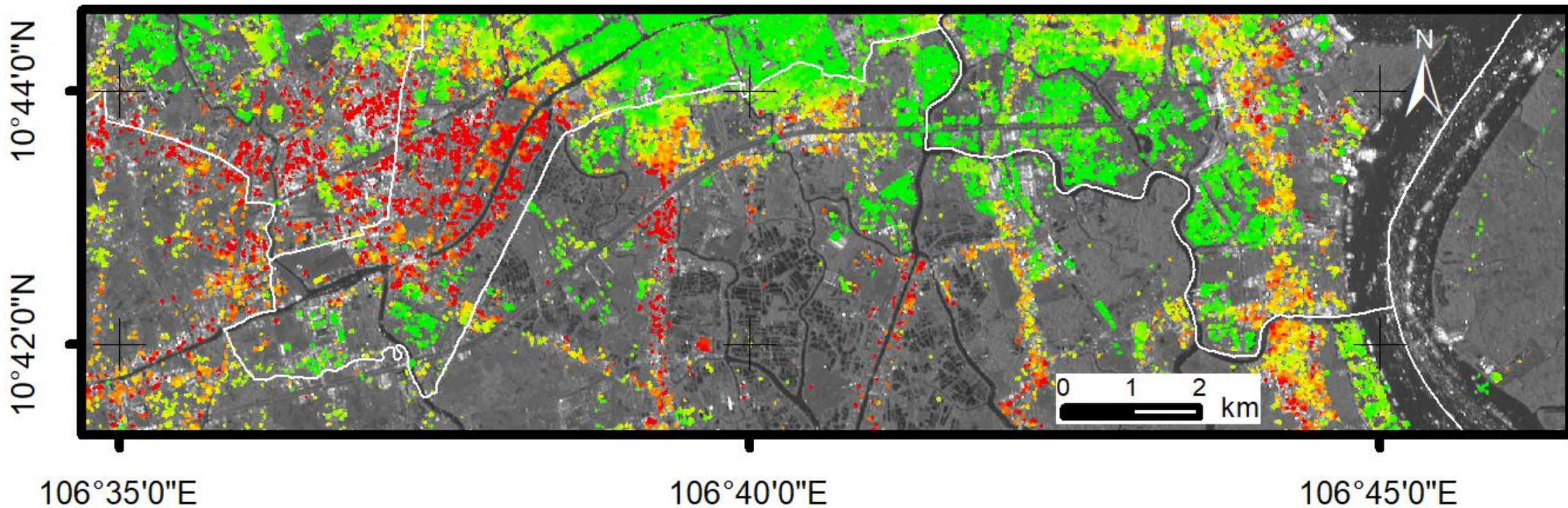


Land subsidence
velocity in HCMC in
the period 2015-2020
(Sentinel-1)



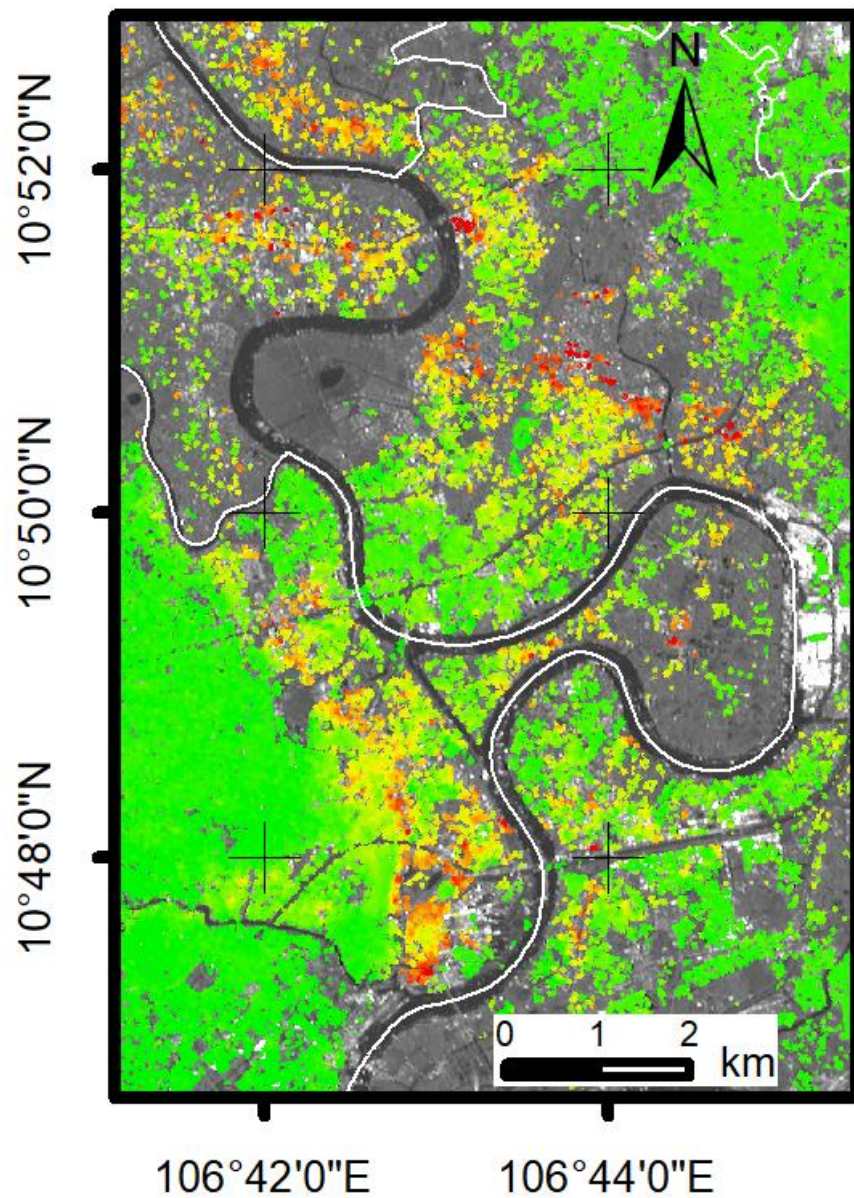


Areas with high subsidence velocity (Binh Tan and District 8)



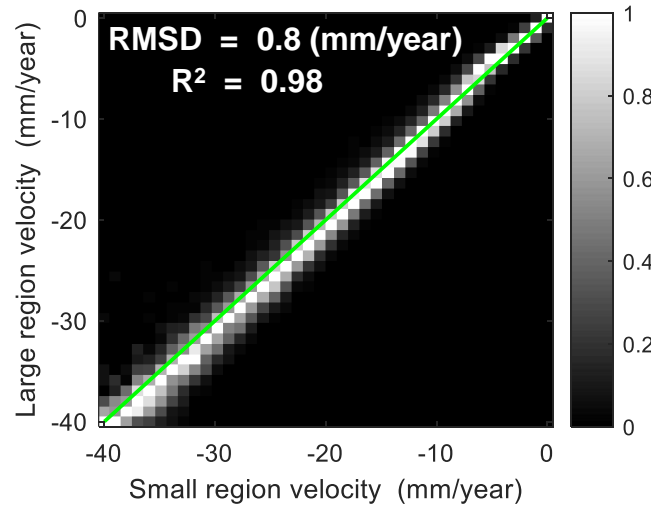
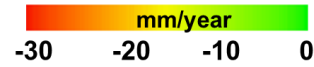
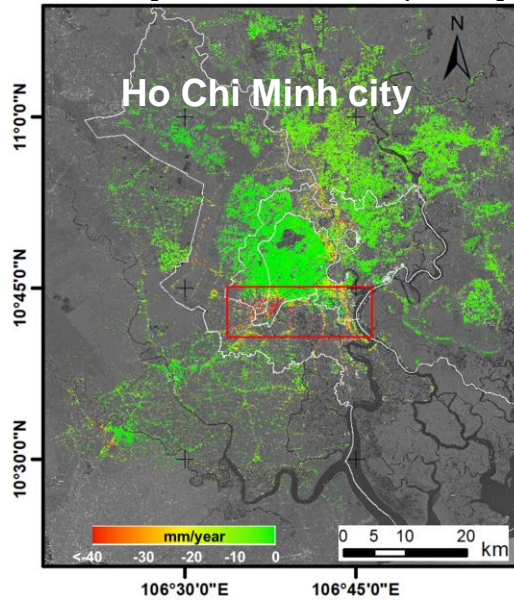


The area along the Saigon River

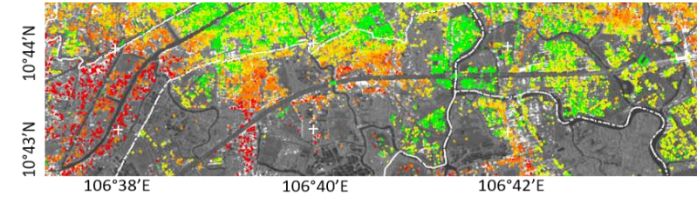


Delta-wide subsidence

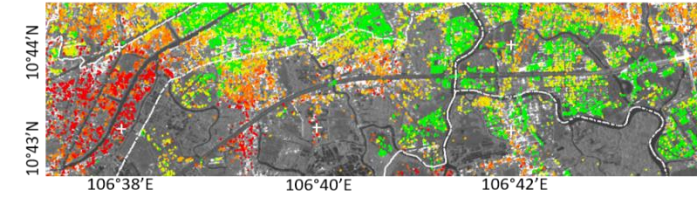
Velocity 2015-2020 (mm/year)



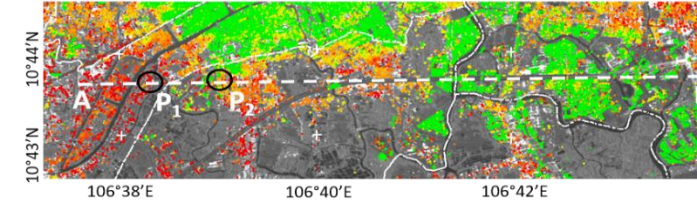
(a) Sentinel-1 A128



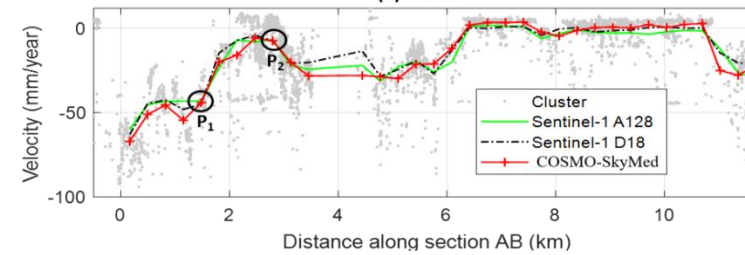
(b) Sentinel-1 D18



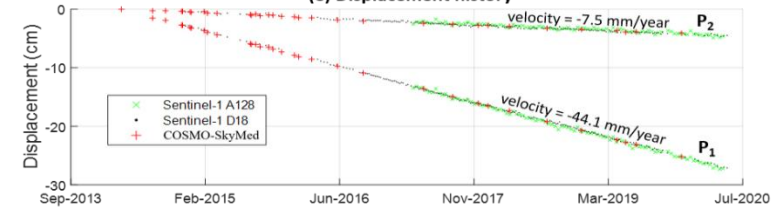
(c) COSMO-SkyMed



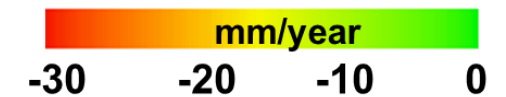
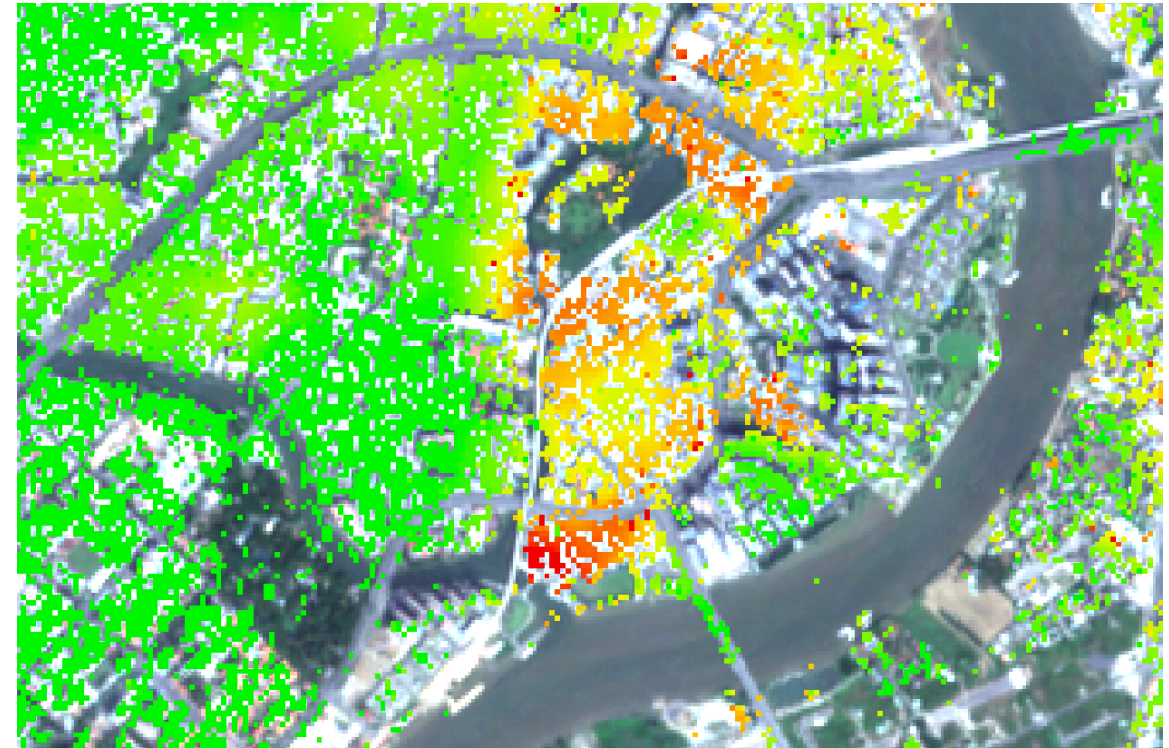
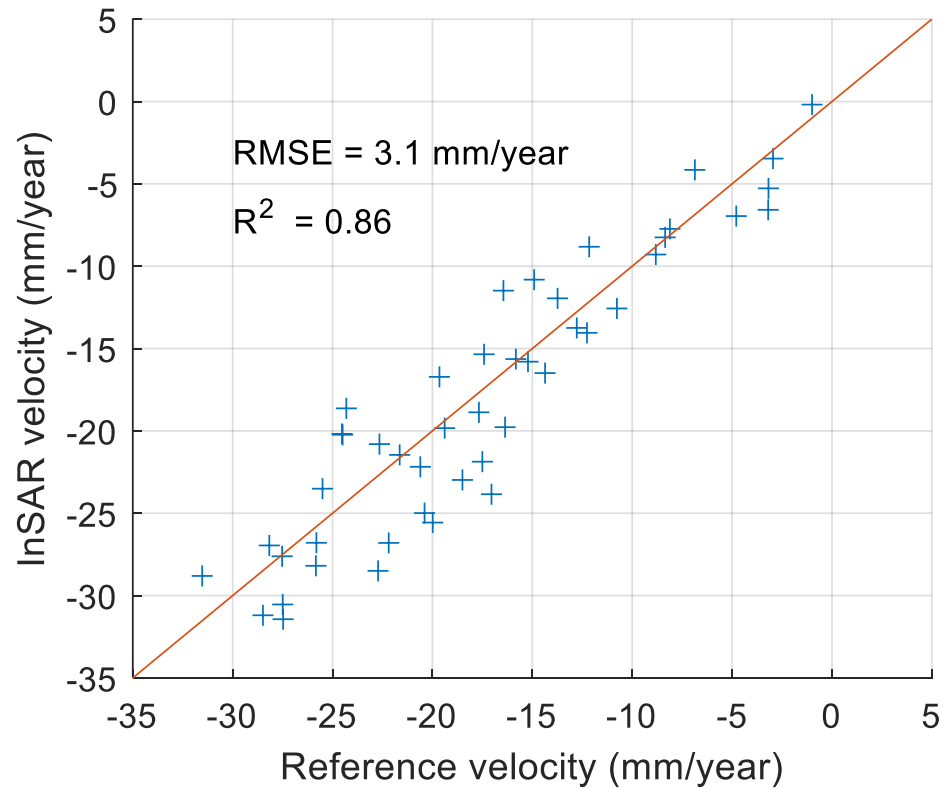
(d) Profile



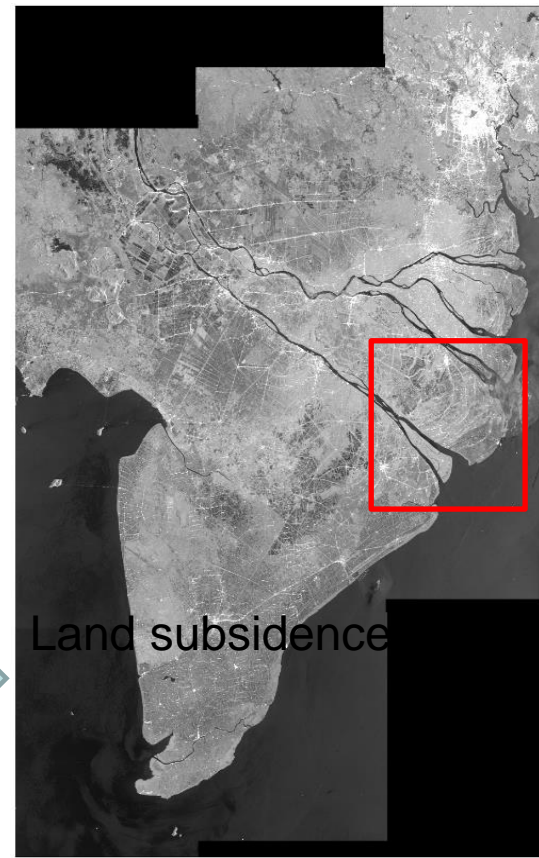
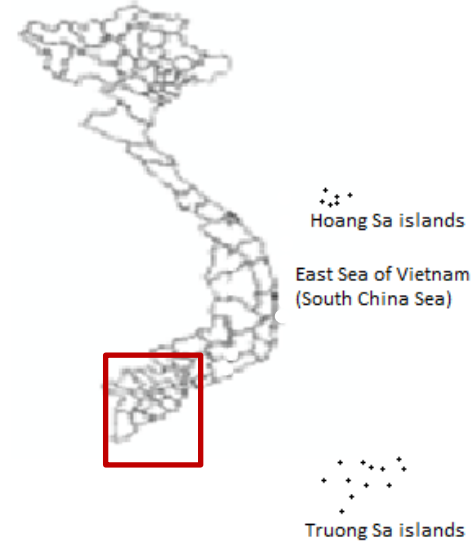
(e) Displacement history



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

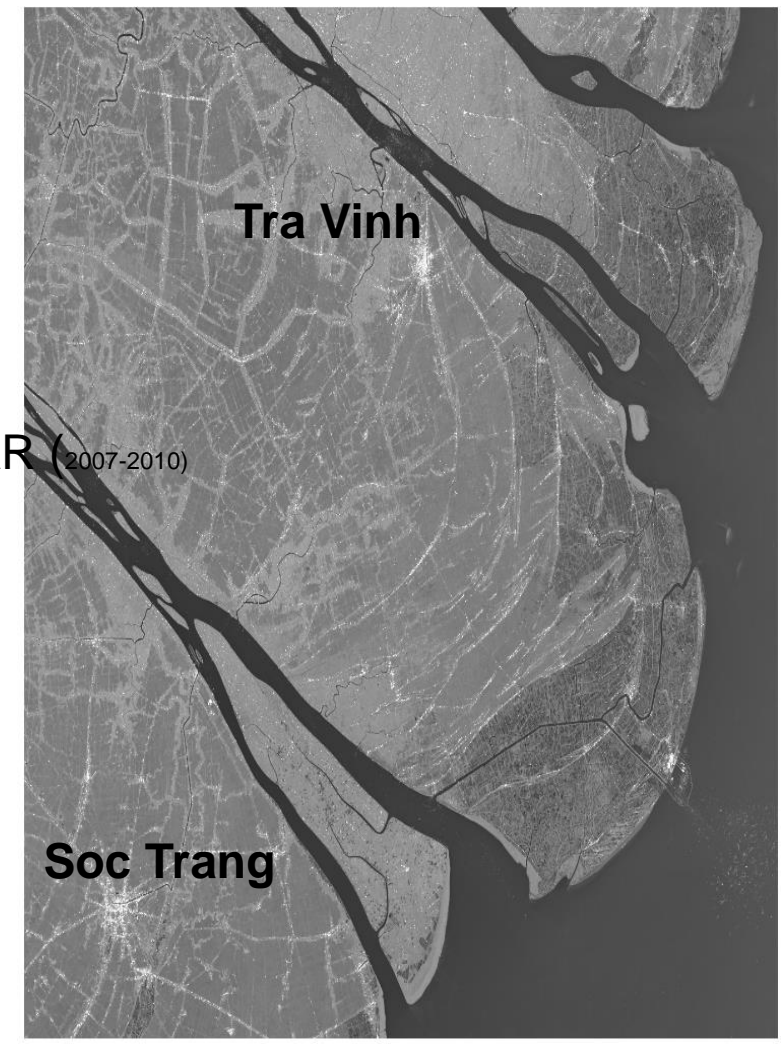


**Good agreement in vertical velocity
between reference and InSAR
velocity (2017 - 2021)**



80 km

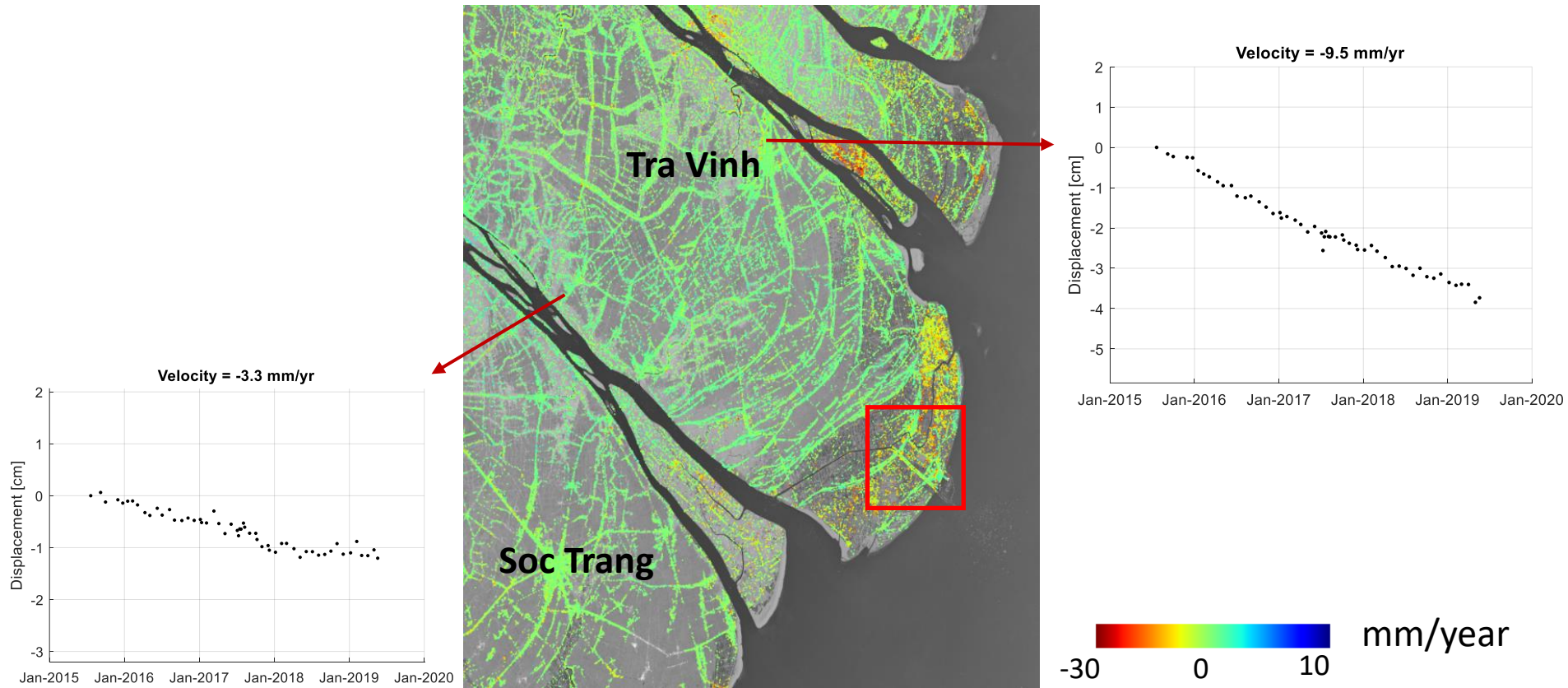
SAR intensity image



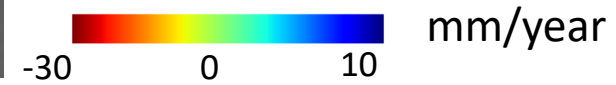
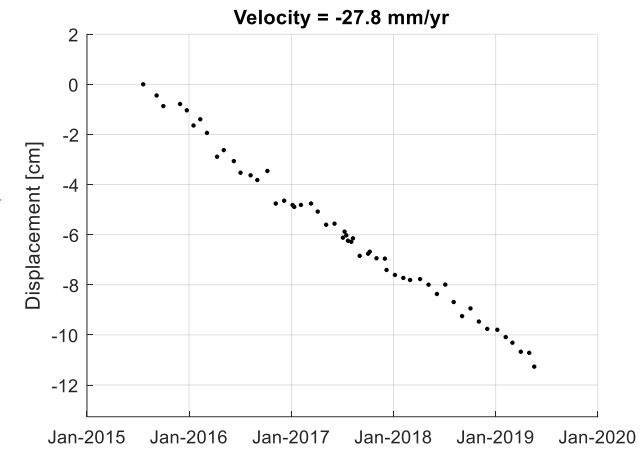
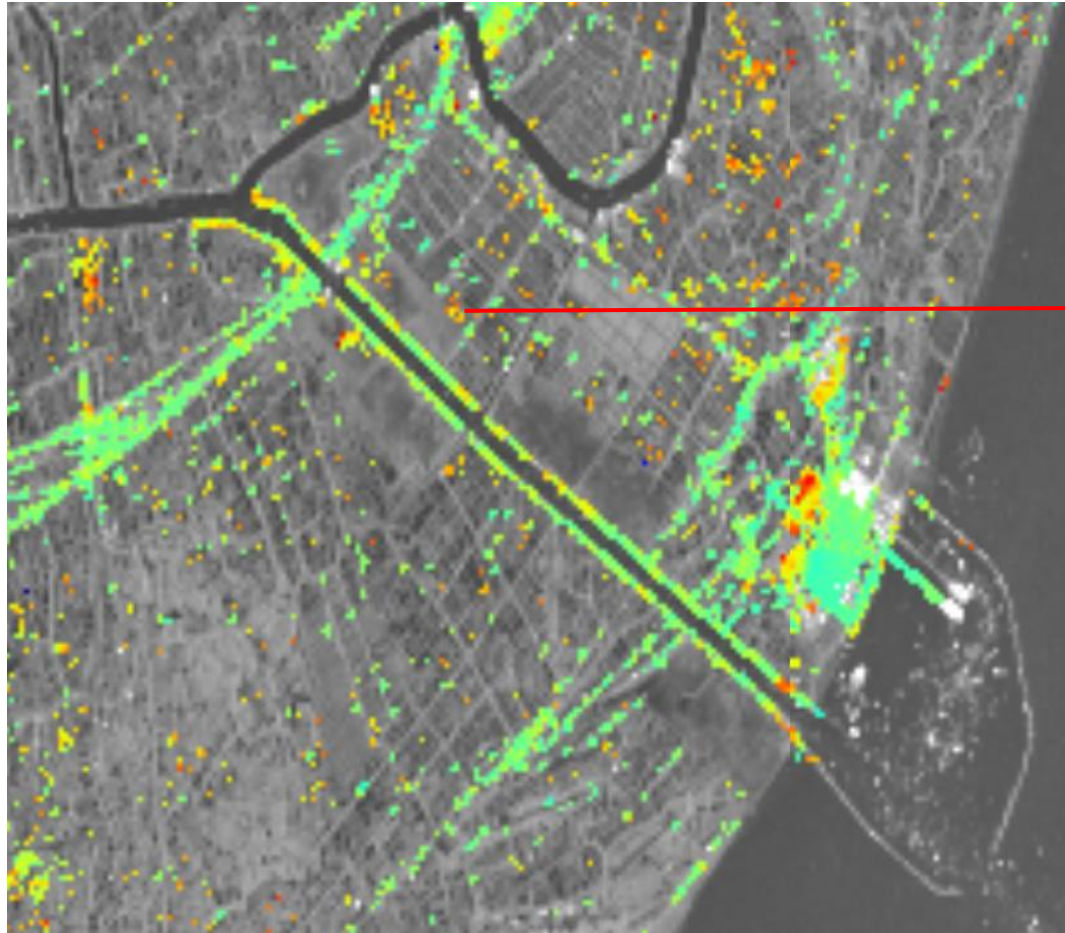
Land subsidence in Tra Vinh by InSAR (2015-2020)

80 km

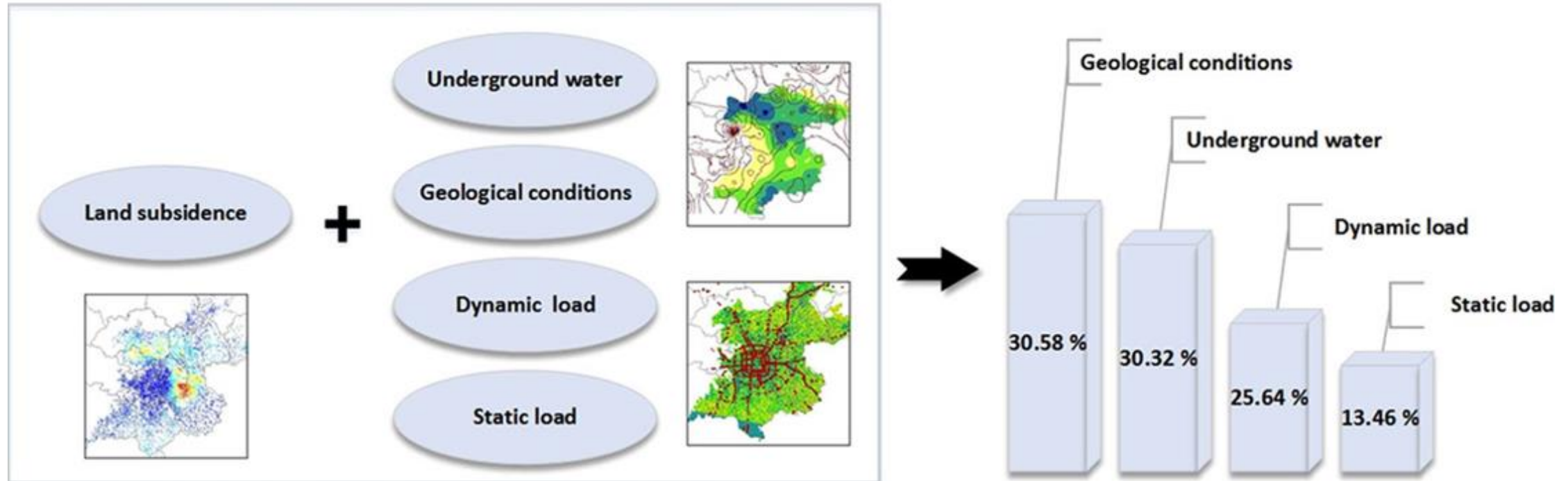
Ground subsidence velocity (mm/year)



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>

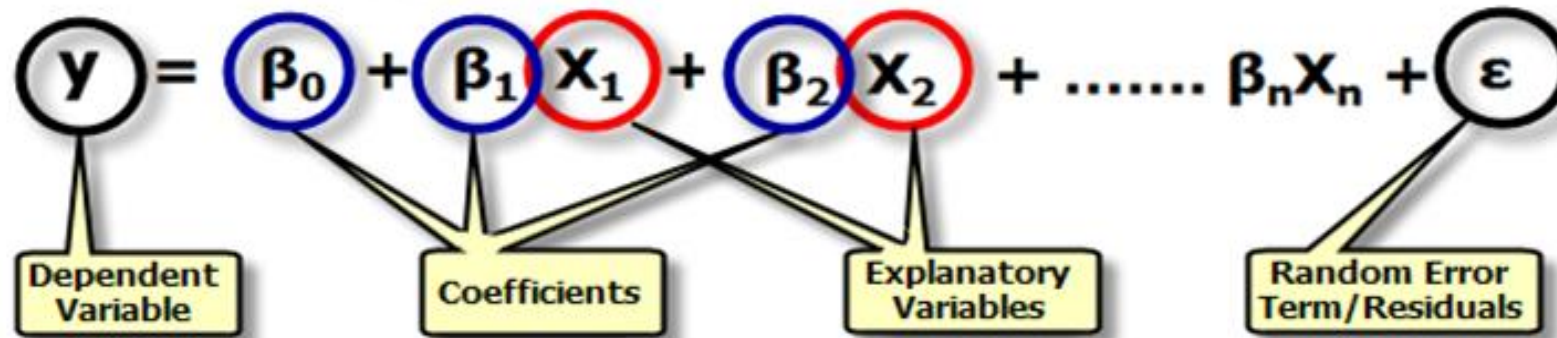


Land subsidence forecast



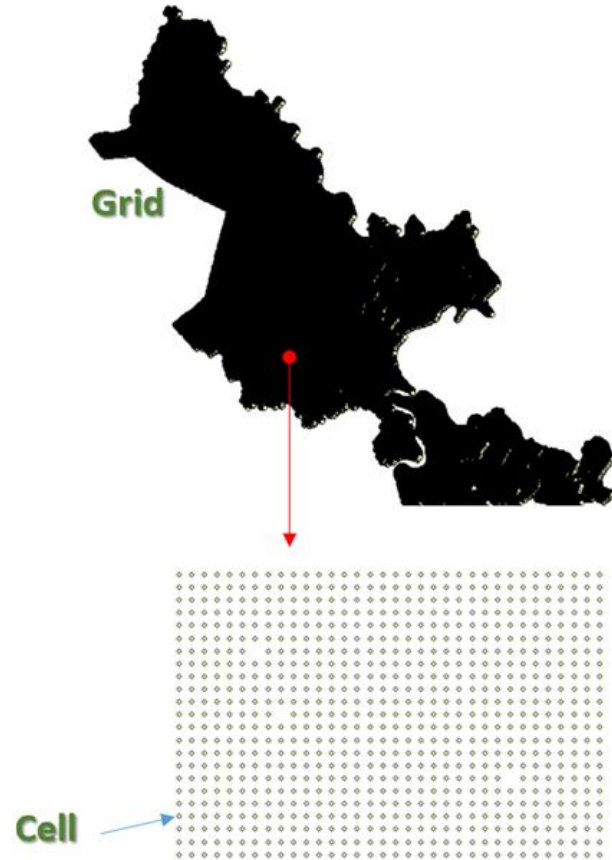
- GIS regression model + Machine learning

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



$$\text{VelocityOfCell} = W_0 + W_1 \times \text{DTXDKC} + W_2 \times \text{KCGT} + W_3 \times \text{GWT} + W_4 \times \text{Geo} + \varepsilon$$

- There are about 50.000 regression equations/cell/ year
- From year 2000 to year 2020: 20×50000 equations $\Rightarrow W(i); \varepsilon$



Dependent Variable

Explanatory Variables

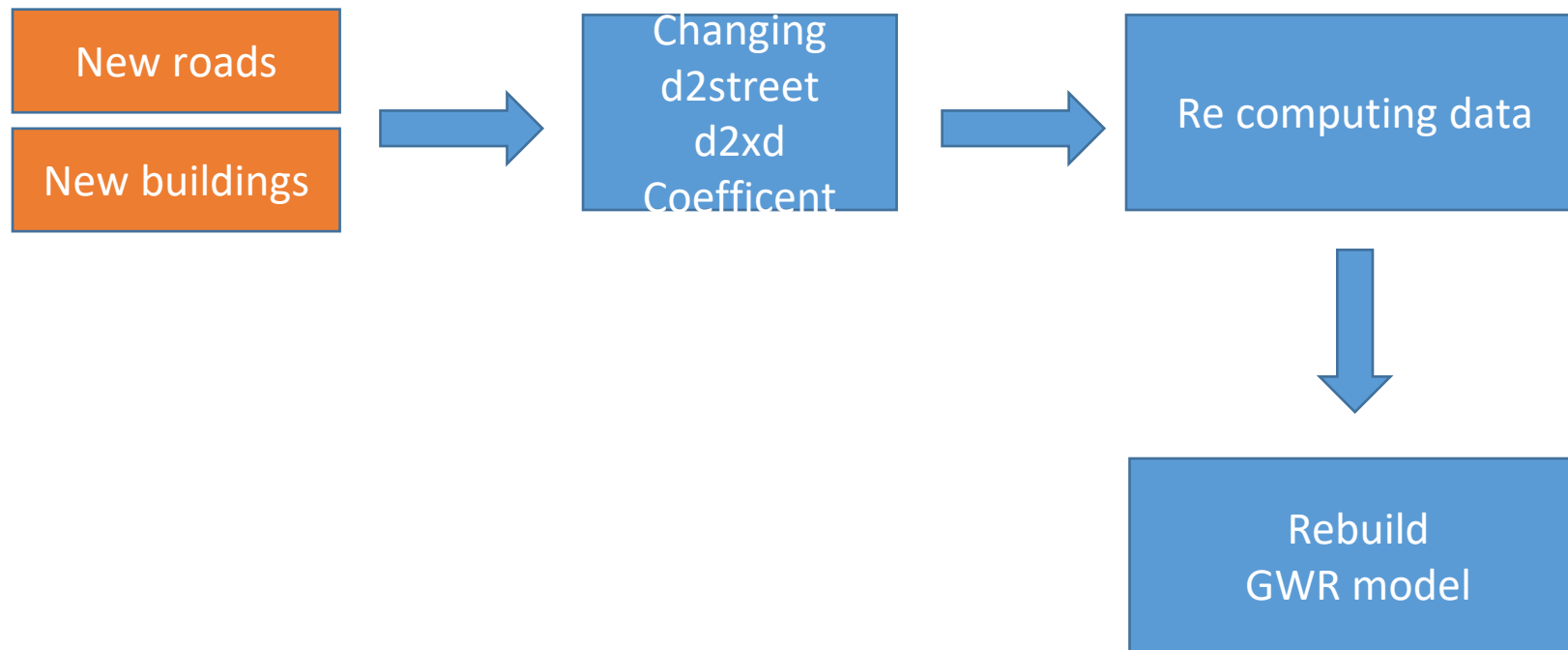
Table							
SampleData							
FID	Shape	fid_1	id	velocity	d2street	d2xd	elevation
0	Point	188	188	-3.111604	16.591471	7894	0.573
1	Point	1084	1084	-3.22888	90.057308	7798	0.68916
2	Point	1085	1085	-2.821293	144.047628	7816	0.64581
3	Point	1978	1978	-3.536514	263.593287	7667	0.4364
4	Point	1979	1979	-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

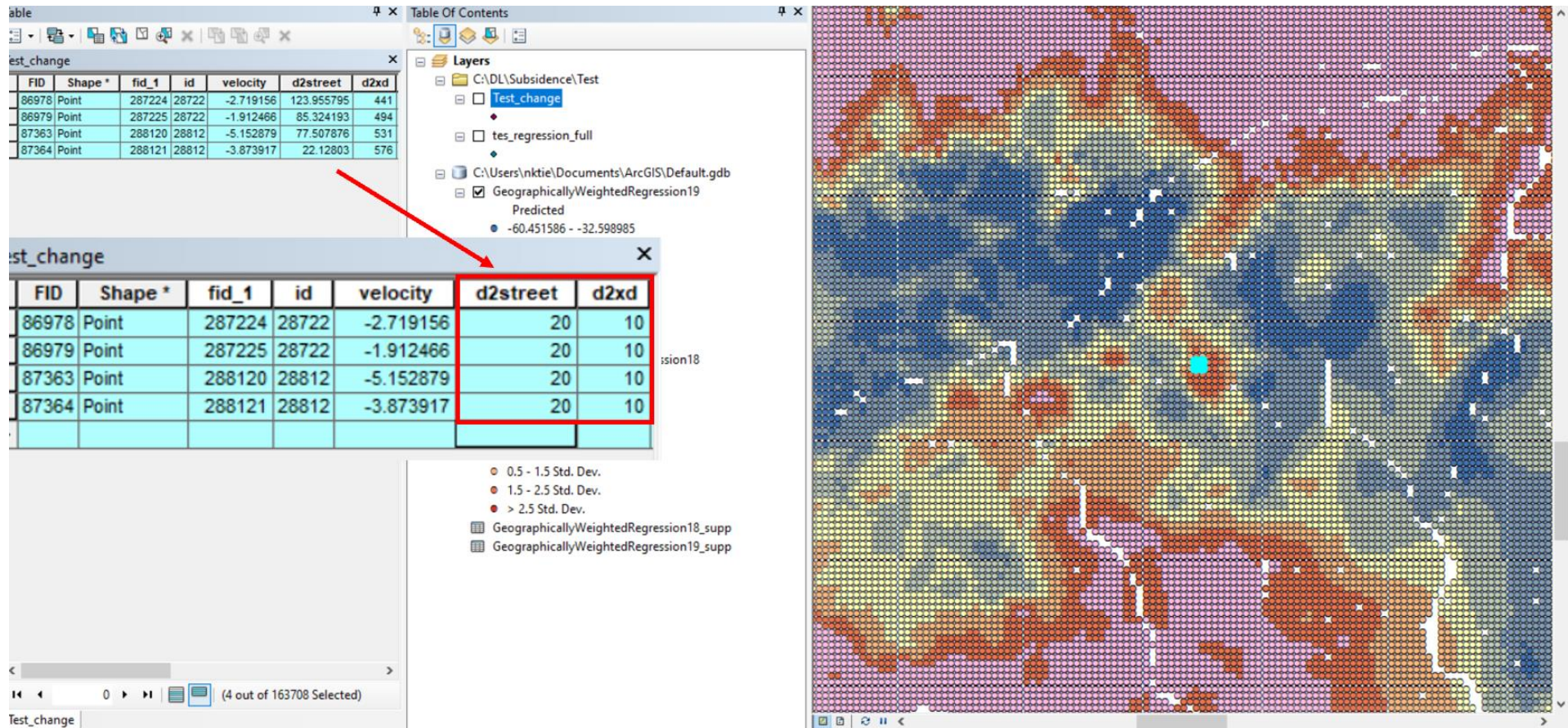
- Velocity:** land subsidence rate by year (mm/yr - pixel) calculated by InSAR
- d2street:** distance from a cell to nearest street
- d2xd:** distance from a cell to large building
- elevation:** topographic elevation of cell

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

86978

Identify

Identify from: <Top-most layer>

GeographicallyWeightedRegression21
...-2.719156

Location: 106.644802 10.707138 Decimal Degrees

Field	Value
OBJECTID	86979
Shape	Point
Observed velocity	-2.719156
Condition Number	4.725082
Local R2	0.024236
Predicted	-5.989855
Coefficient Intercept	-5.748254
Coefficient #1 d2xd	0.000782
Coefficient #2 d2street	-0.012471
Residual	3.270698
Standard Error	2.851544
Standard Error Intercept	1.146457
Standard Error Coefficient #1 d2xd	0.001889
Standard Error Coefficient #2 d2street	0.008079
Std. Residual	1.146992
Source ID	86978

Identified 1 feature

86979

Identify

Identify from: <Top-most layer>

GeographicallyWeightedRegression21
...-1.912466

Location: 106.644947 10.706310 Decimal Degrees

Field	Value
OBJECTID	86980
Shape	Point
Observed velocity	-1.912466
Condition Number	4.943168
Local R2	0.098823
Predicted	-5.323804
Coefficient Intercept	-4.787666
Coefficient #1 d2xd	0.00062
Coefficient #2 d2street	-0.027117
Residual	3.411338
Standard Error	2.827085
Standard Error Intercept	1.204949
Standard Error Coefficient #1 d2xd	0.001833
Standard Error Coefficient #2 d2street	0.007344
Std. Residual	1.206662
Source ID	86979

Identified 1 feature

87363

Identify

Identify from: <Top-most layer>

GeographicallyWeightedRegression21
...-5.152879

Location: 106.645979 10.707180 Decimal Degrees

Field	Value
OBJECTID	87364
Shape	Point
Observed velocity	-5.152879
Condition Number	5.181225
Local R2	0.075953
Predicted	-4.185385
Coefficient Intercept	-3.844096
Coefficient #1 d2xd	-0.001165
Coefficient #2 d2street	-0.016482
Residual	-0.967494
Standard Error	2.794079
Standard Error Intercept	1.274399
Standard Error Coefficient #1 d2xd	0.001805
Standard Error Coefficient #2 d2street	0.008232
Std. Residual	-0.346266
Source ID	87363

Identified 1 feature

87364

Identify

Identify from: <Top-most layer>

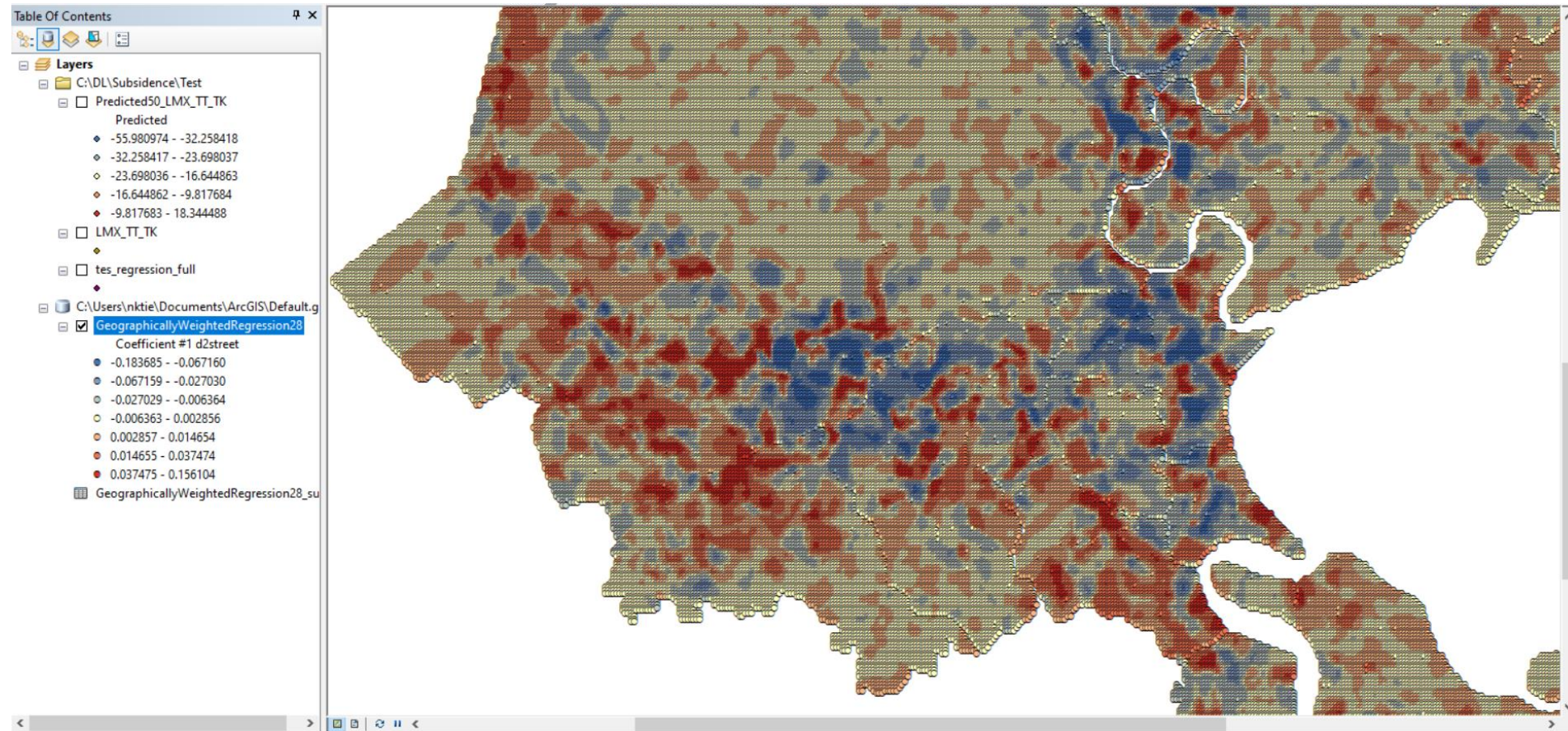
GeographicallyWeightedRegression21
...-3.873917

Location: 106.645840 10.706310 Decimal Degrees

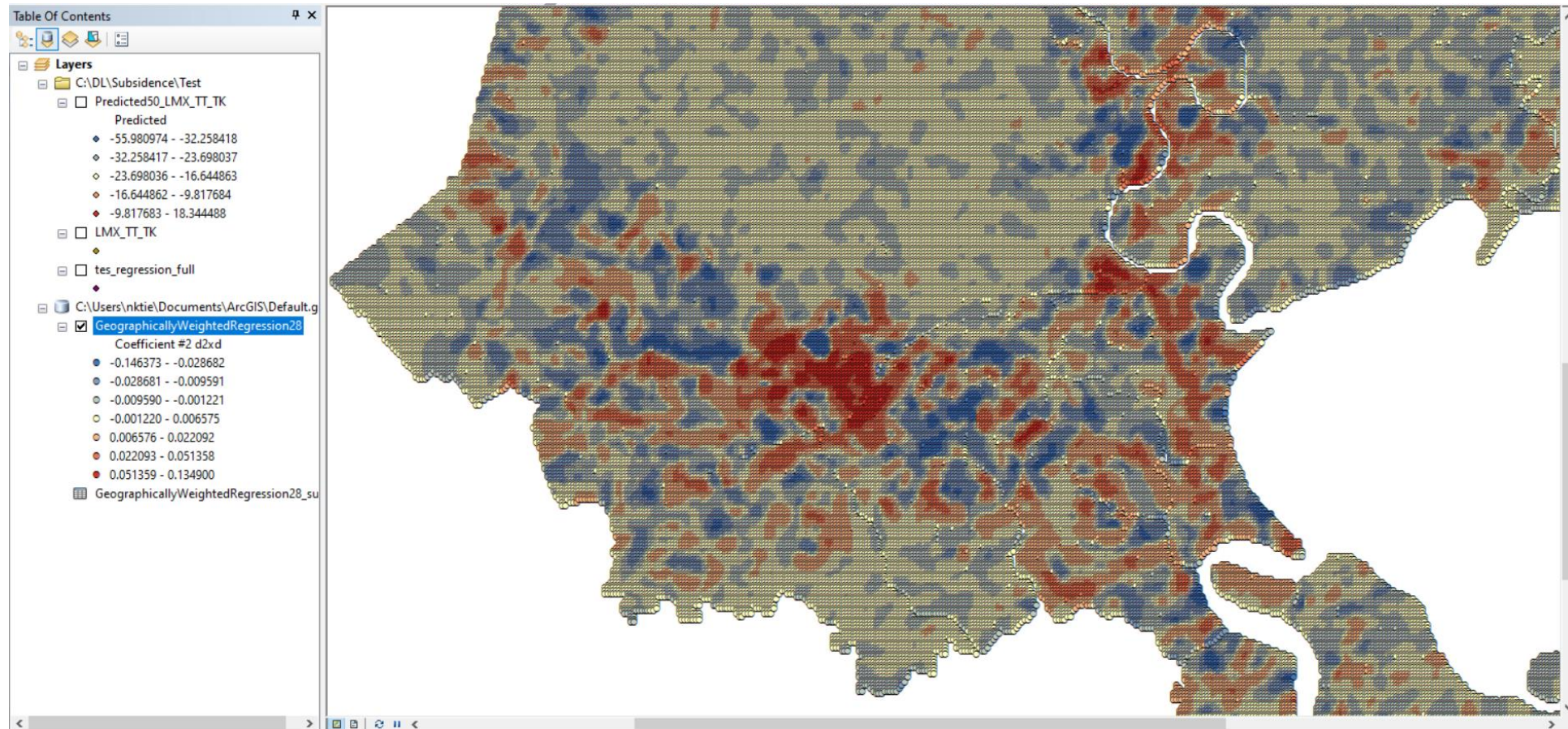
Field	Value
OBJECTID	87365
Shape	Point
Observed velocity	-3.873917
Condition Number	5.343733
Local R2	0.083809
Predicted	-4.393464
Coefficient Intercept	-4.010991
Coefficient #1 d2xd	0.000119
Coefficient #2 d2street	-0.019183
Residual	0.519547
Standard Error	2.782593
Standard Error Intercept	1.328777
Standard Error Coefficient #1 d2xd	0.001772
Standard Error Coefficient #2 d2street	0.008132
Std. Residual	0.186713
Source ID	87364

Identified 1 feature

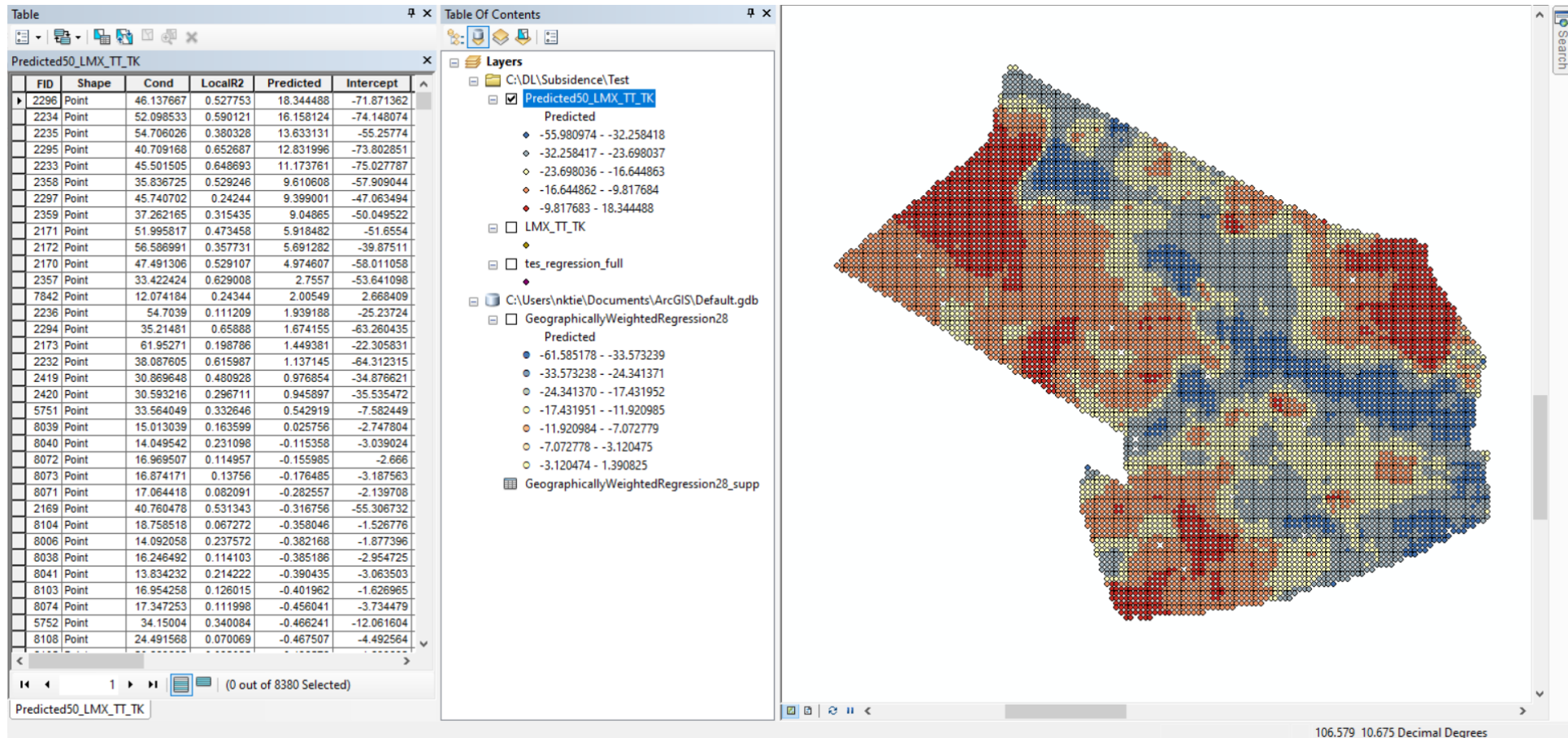
Distribution map of the impact of traffic construction changes on land subsidence D2STREET:



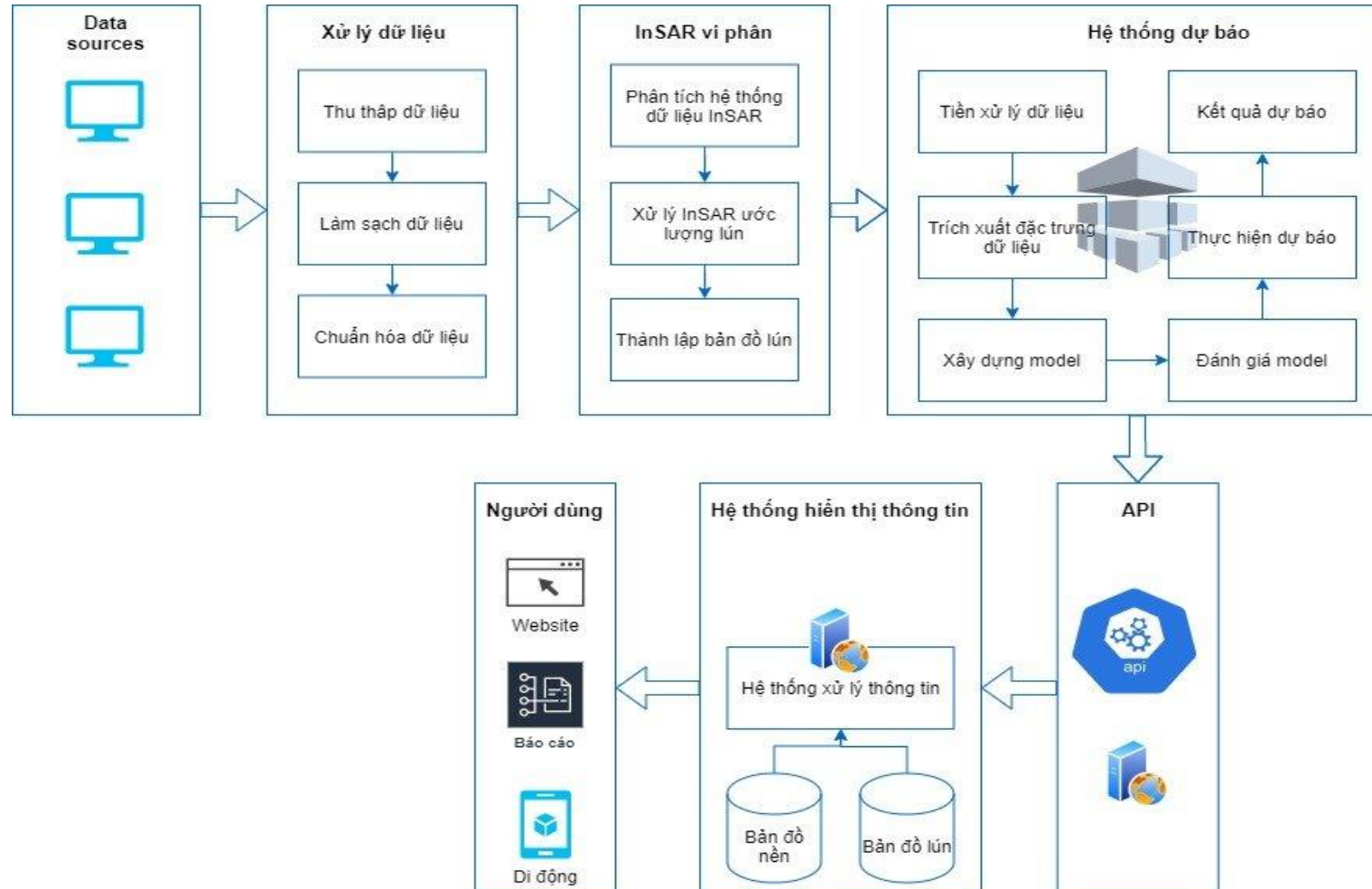
Distribution map of the influence of construction changes on land subsidence D2XD:



The map simulates subsidence when the distance from 1 cell (1 hectare) to the road is 50m : ($d_{Street} = 50\text{ m}$)



Land subsidence forecast system





Some recent typical publications

1. **Chon Le Trung**, Hồ Tổng Minh Định, Huỳnh Quyền, Bùi Trọng Vinh, Trần Văn Hưng, 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).

*Thank
you*



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