→ EARTH OBSERVATION FOR SUSTAINABLE DEVELOPMENT

Disaster Risk Reduction

Analysis of the PSI results on Central Sulawesi (ex-ante & ex-post)

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disaster risk reduction
eo4sd

PSI analysis on Central Sulawesi

(ex-ante & ex-post Earthquake of 28 September 2018)

Grount Motion Analysis overview

1) Ex-ante PS/DS ground motion map

- Number or Images: **58**
- Temporal resolution: ***25 April 2015 – 7 june 2018***
- Sensor: **Sentinel-1** (spatial resolution: 5 m x 20 m)

2) Ex-post PS/DS ground motion map

- Number or Images: **31**
- Temporal resolution: 05 October 2018 – 15 April 2018
- Sensor: **Sentinel-1** (spatial resolution: 5 m x 20 m)

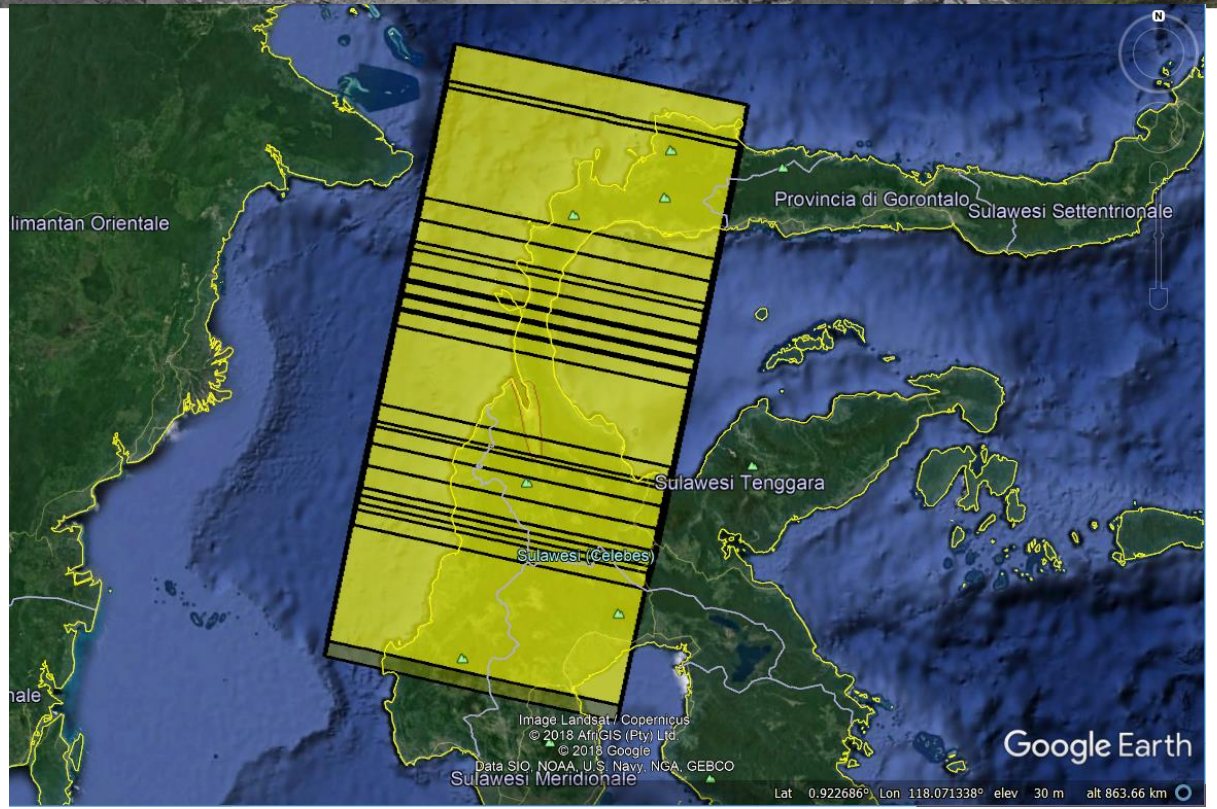
Area of Interest (AOI)

Area: 792 Km^2

1) Ex-Ante PS/DS ground motion map

Input data

- Datastack: **Descending orbit**
- Number of Images: **58**
- Temporal resolution: ***25 April 2015***
  7 june 2018
- Sensor: **Sentinel-1**
  (Spatial Resolution: 5 m x 20 m)
- DEM: SRTM 30 meters



1) Ex-Ante PS/DS ground motion map

Rheticus® Displacement data Processing based on SPINUA Algorithm

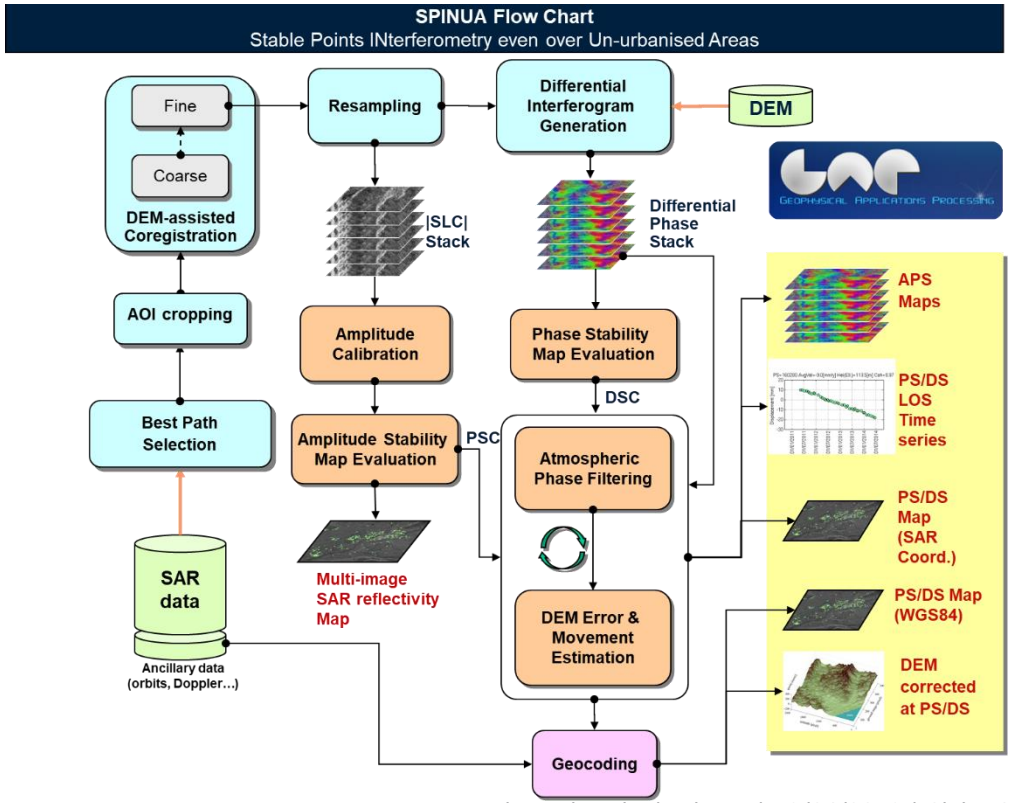
Output:

- Supermaster date: **12 June 2017**

- **PS/DS ground motion maps:**

- ID of PS/DS (CODE)
- LAT/LON of PS/DS (°)
- LOS Displacement time series (DLYYYYMMDD) (mm/year)
- LOS Average velocity of Displacement (V_LOS) (mm/year)
- Standard Deviation of V_LOS (V_LOS_STD)(mm/year)
- Incidence angle of the LOS (INC_ANG) (°)
- Heading Angle of LOS (HEAD_ANG)(°)
- Altitude of PS/DS Scatterers (H_GEO) (m)
- Altitude Standard Deviation(H_STDDEV) (m)
- Coherence of PS/DS (COH)
- DEM error (H_AUX_DEM)

- **PS/DS time series of calibrated amplitude:**
- Amplitude time series (AMYYYYMMDD)



1) Ex-Ante PS/DS ground motion map

Ground Motion statics (04/15 – 06/18):

Sensor: Sentinel-1
Orbit: Descending

- PS

Number of PS: 246759

V_LOS statistics:
'MAX': 15.0 mm/year,
'MEAN': 0 mm/year,
'MIN': -30.5 mm/year,

V_LOS_STD < 2 mm/year

Coherence Min: 0.8

- DS

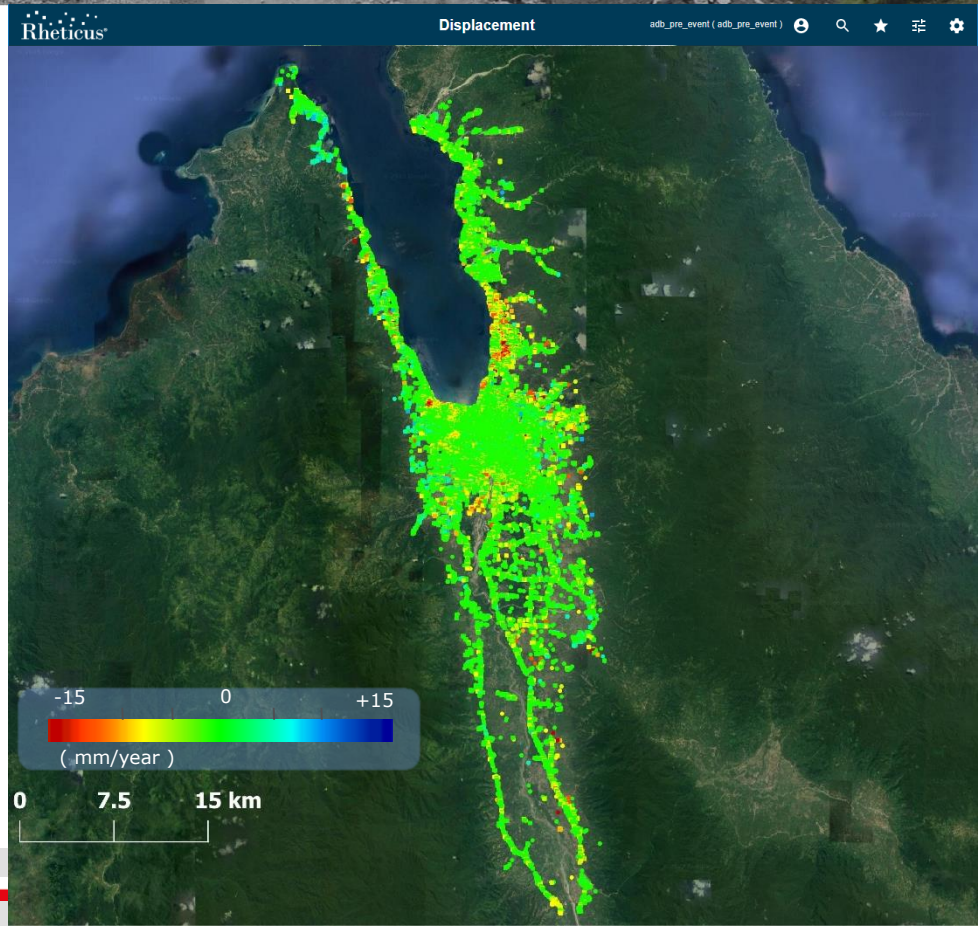
Number of DS: 26318

V_LOS statistics :
'MAX': 10.5 mm/year,
'MEAN': -0.7 mm/year,,
'MIN': -36.0 mm/year,

V_LOS_STD < 2 mm/year

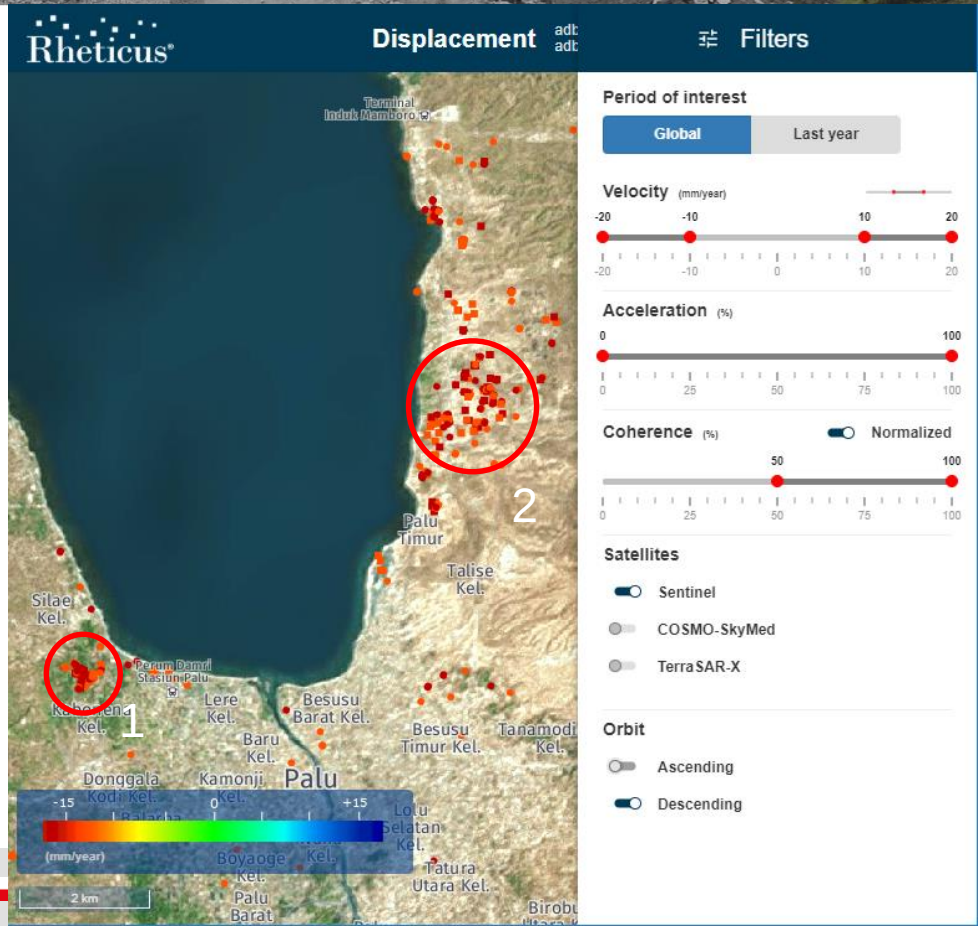
Coherence Min: 0.8

The ground motion map considering the period before the earthquake of 28 September 2018 revealed a general stability of the area.



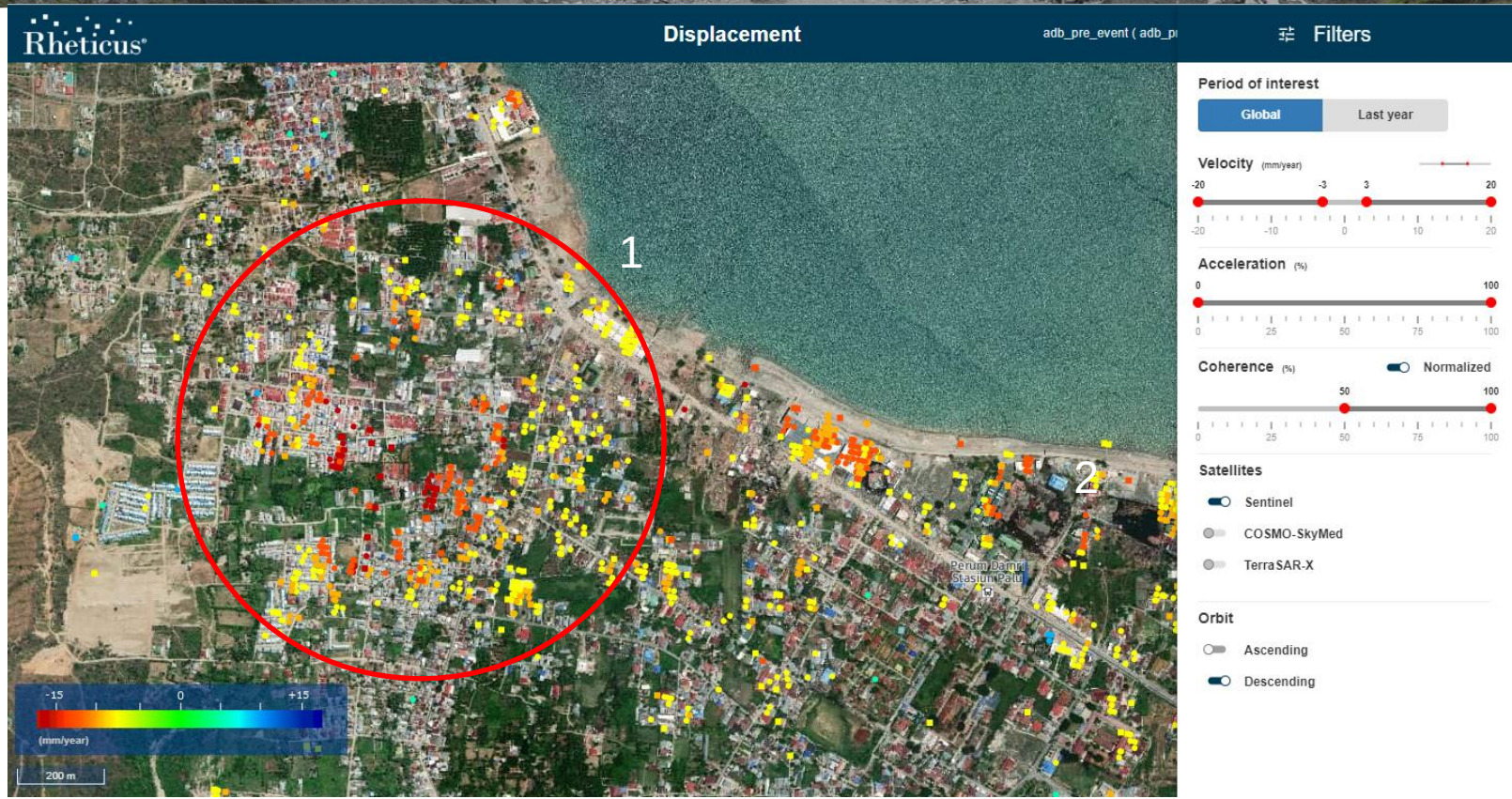
1) Ex-Ante PS/DS ground motion map

Using the Rheticus® Displacement filters and visualizing only the PS/DS characterized by the |**V_LOS|>1 cm/year**
two main ground motion phenomena has been detected as highlighted by the red circles in the image.



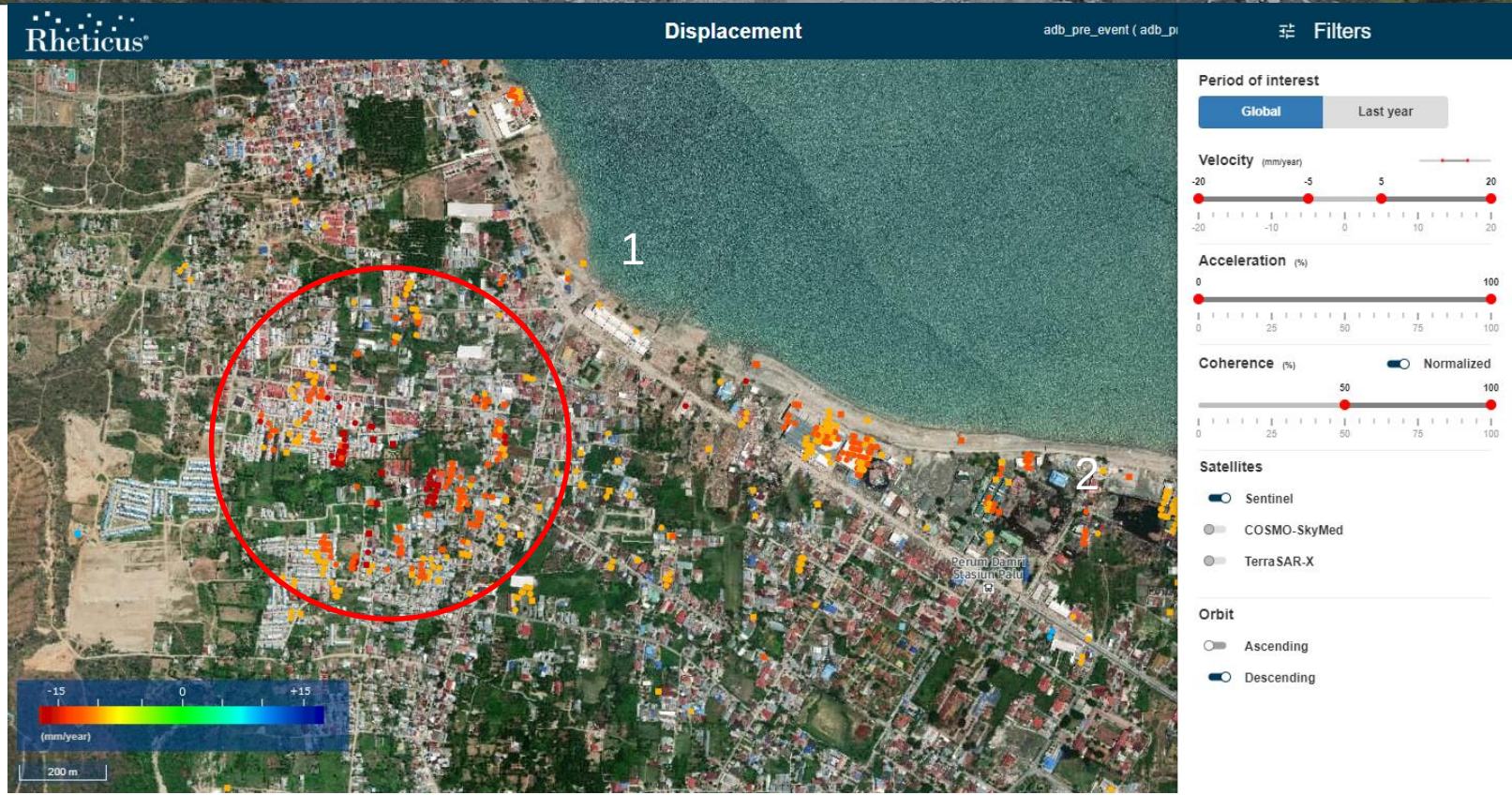
1) Ex-Ante PS/DS ground motion map

|V_LOS|
>3 mm/year



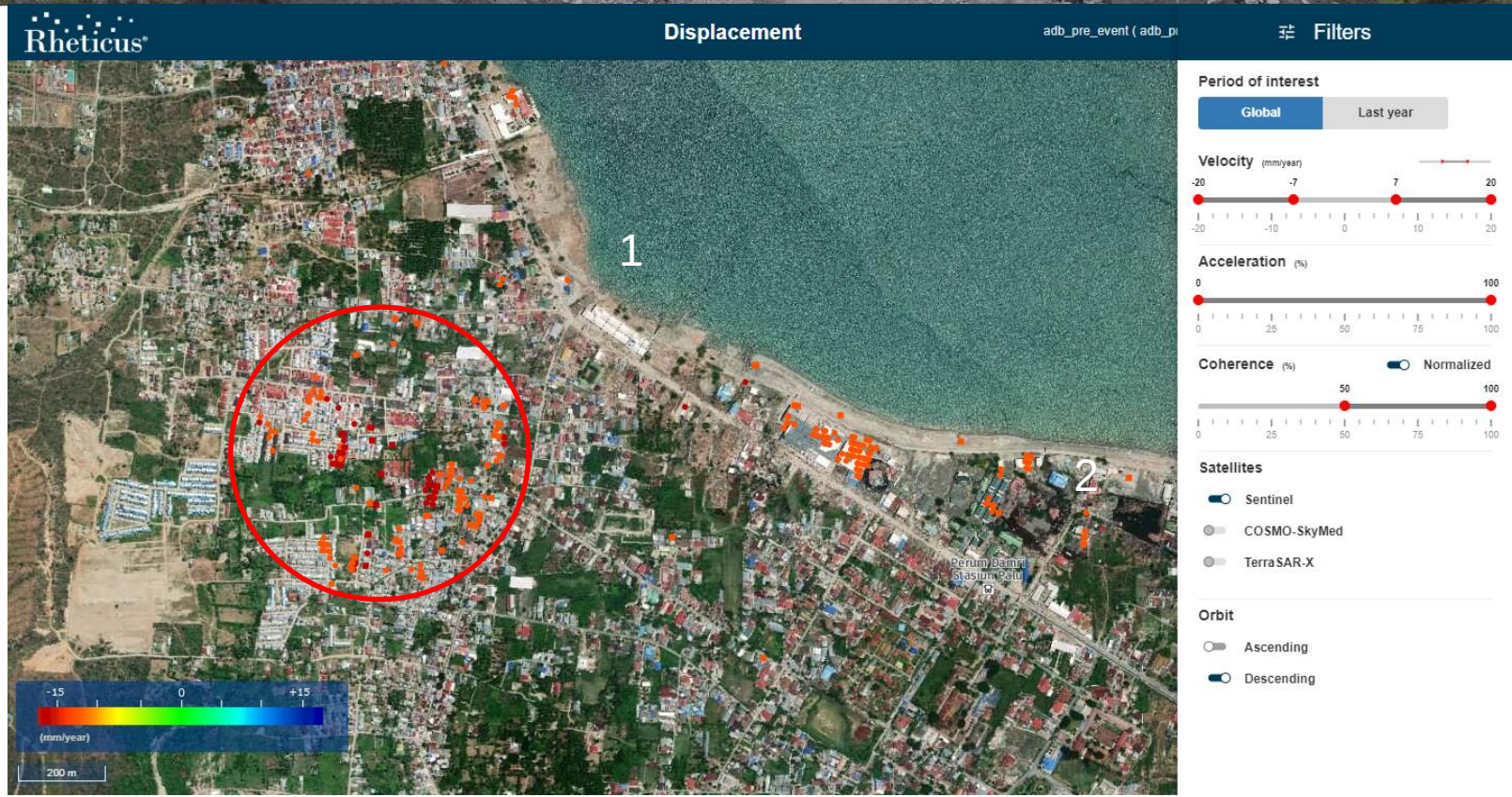
1) Ex-Ante PS/DS ground motion map

|V_LOS|
>5 mm/year



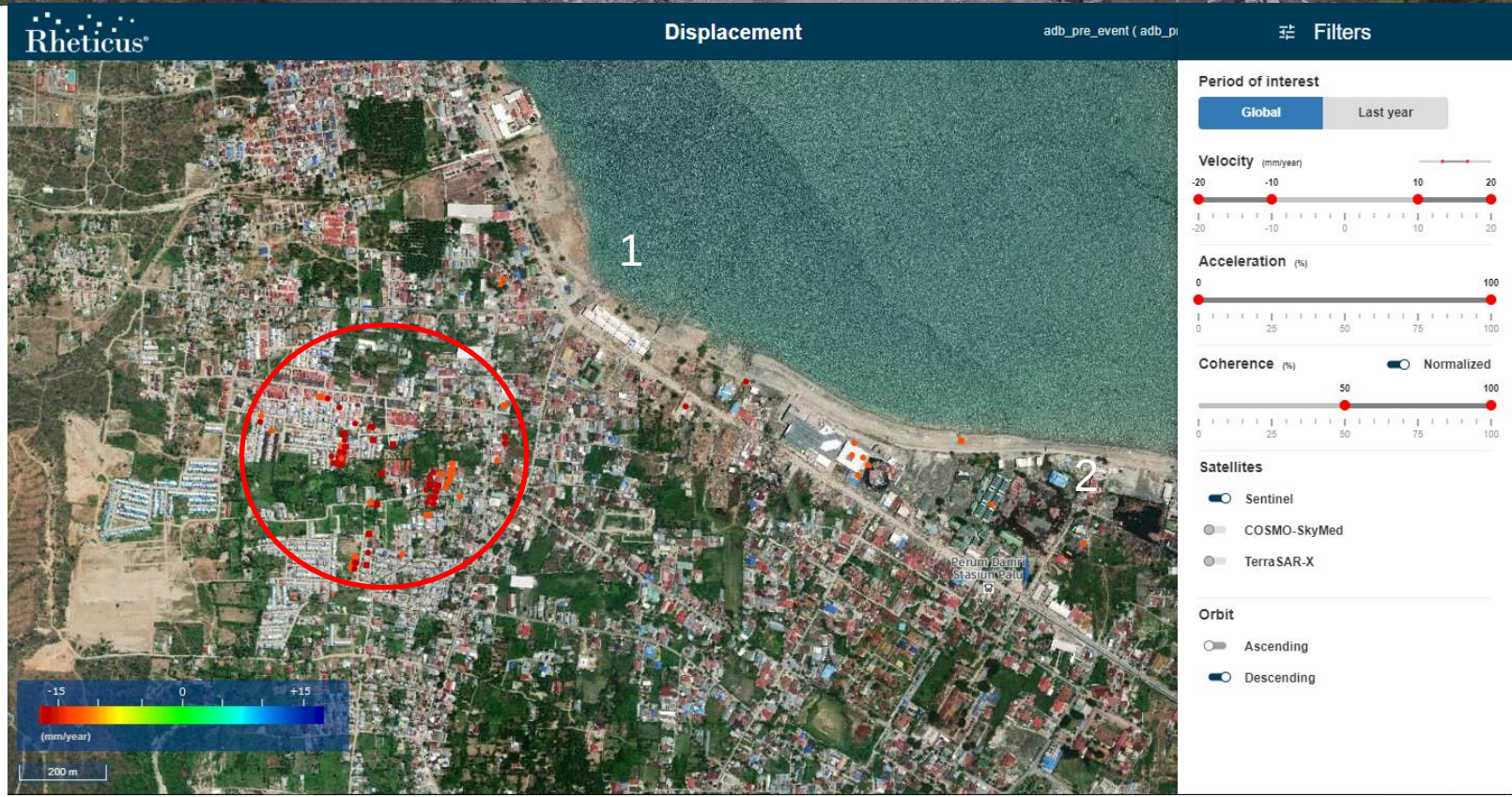
1) Ex-Ante PS/DS ground motion map

|V_LOS|
>7 mm/year



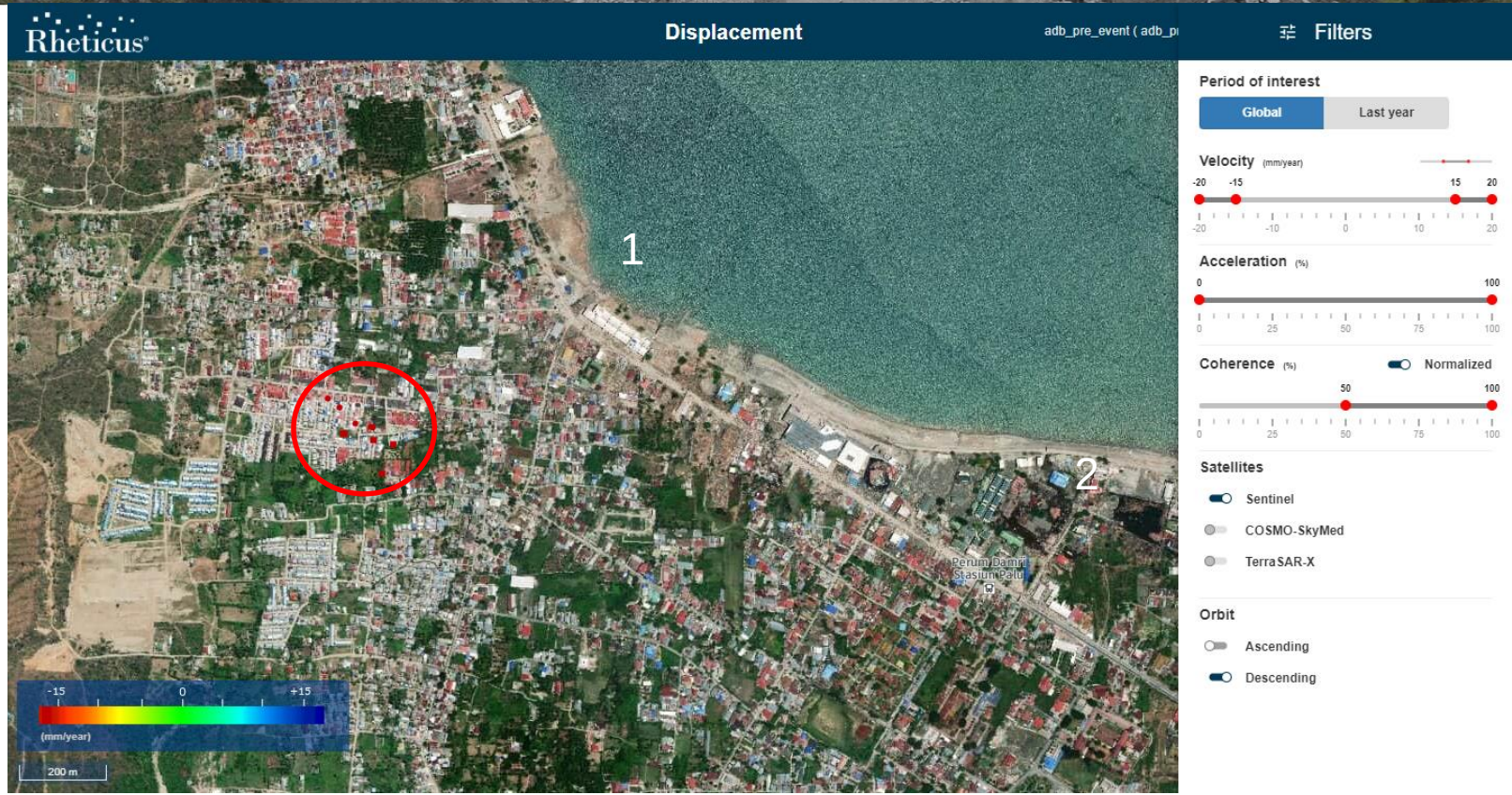
1) Ex-Ante PS/DS ground motion map

|V_LOS|
>10 mm/year



1) Ex-Ante PS/DS ground motion map

|V_LOS|
>15 mm/year



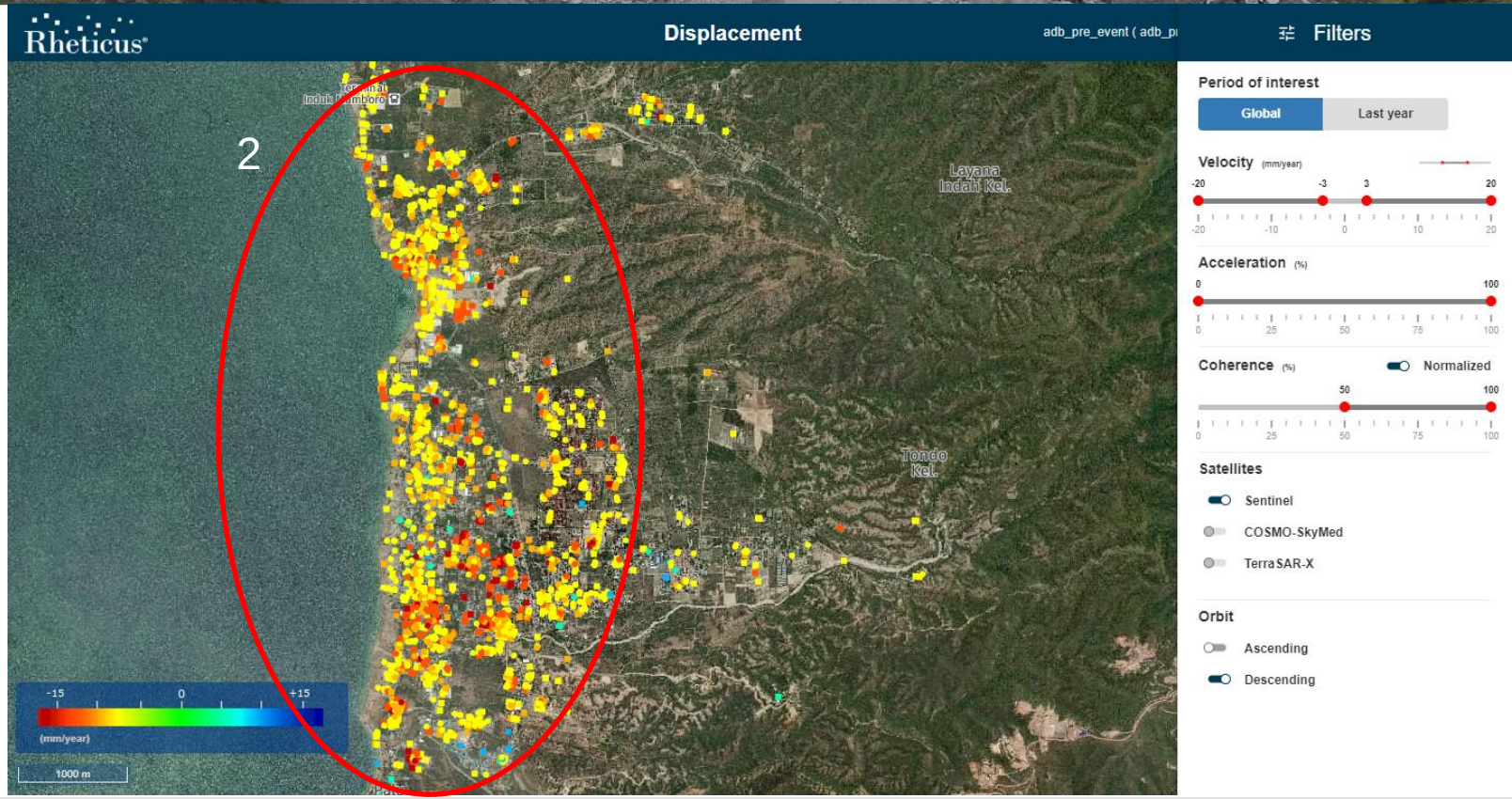
1) Ex-Ante PS/DS ground motion map

|V_LOS|
>20 mm/year

V_LOS MAX:
-27 mm/year

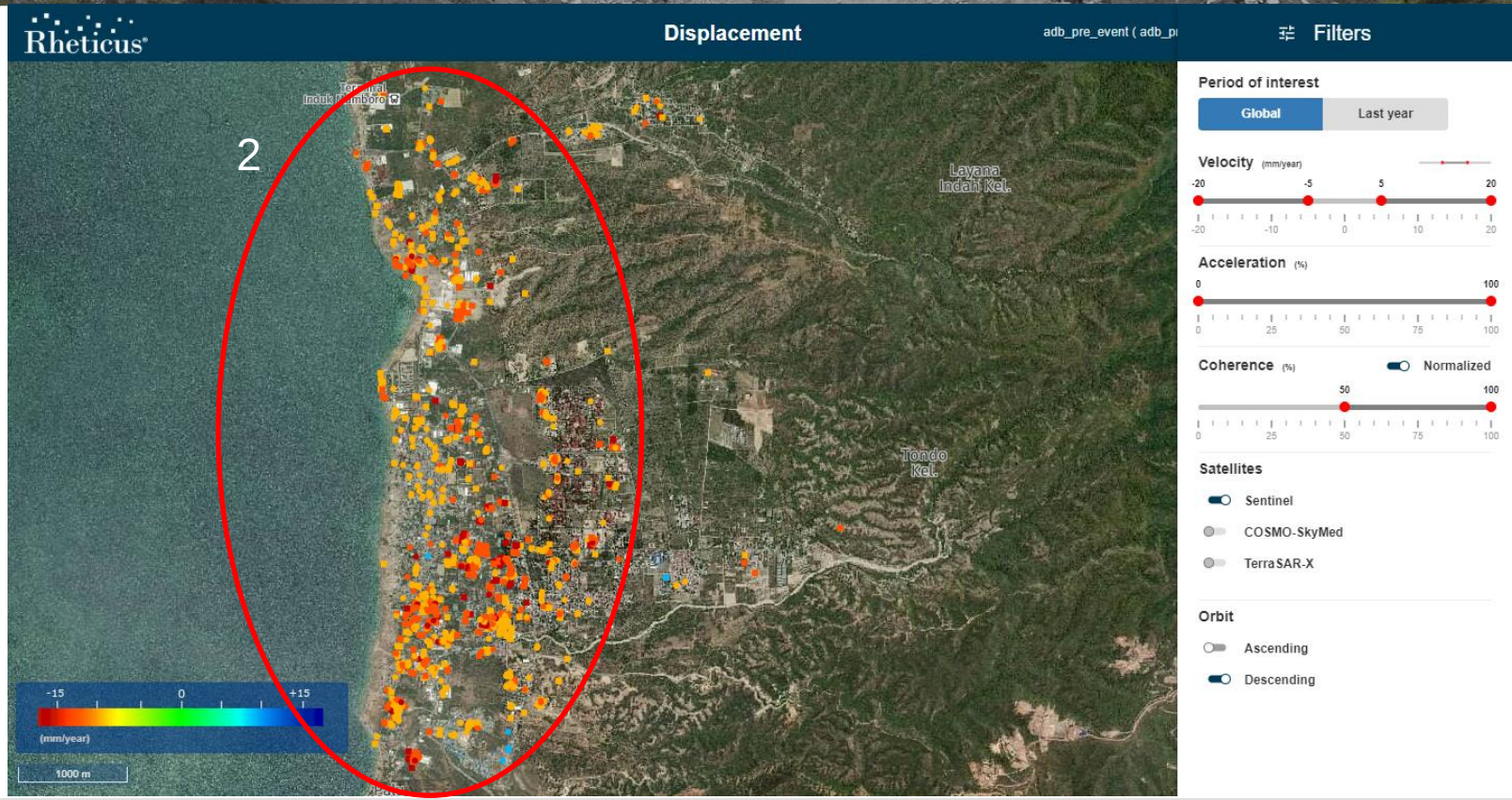
1) Ex-Ante PS/DS ground motion map

|V_LOS|
>3 mm/year



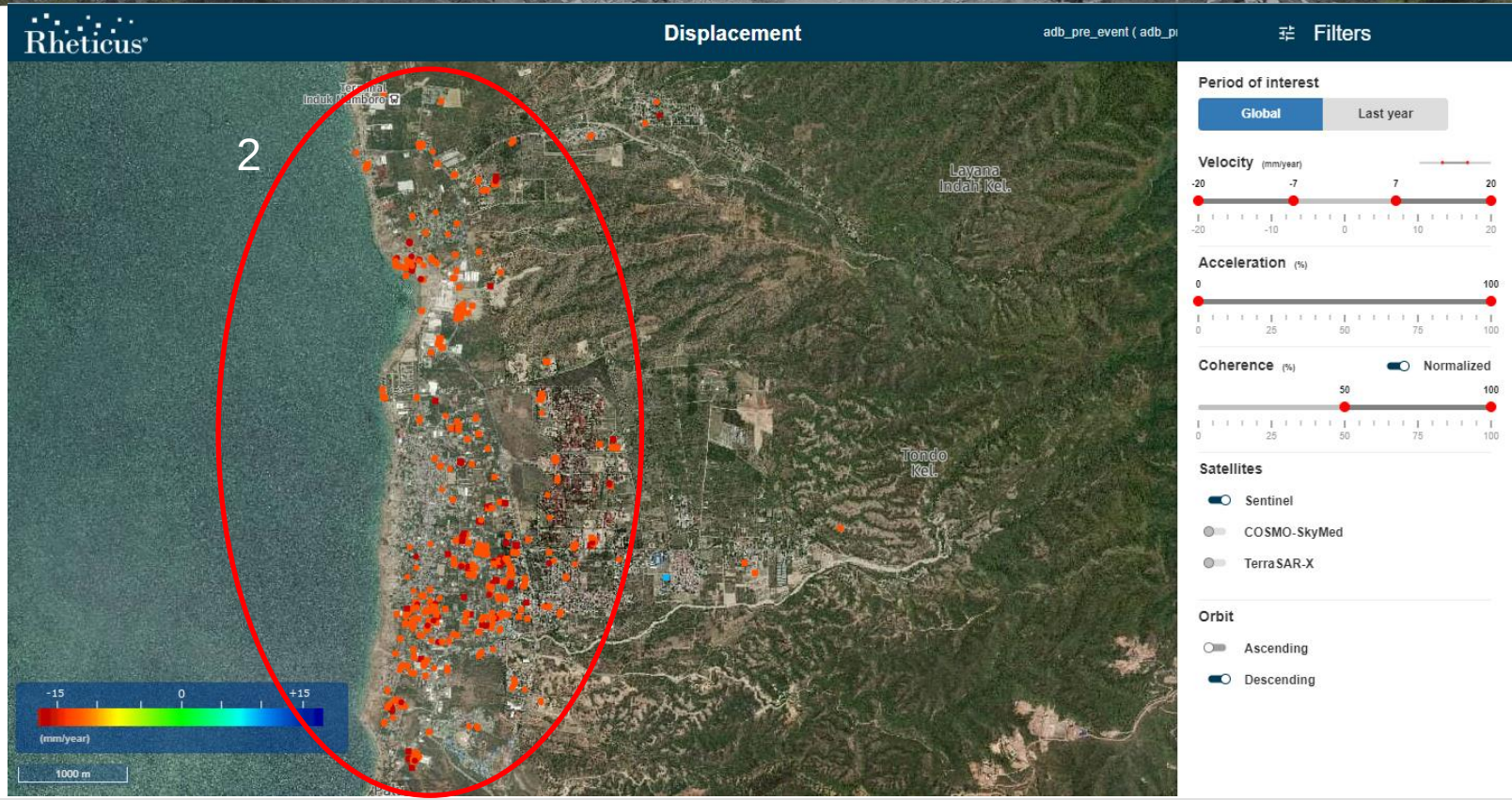
1) Ex-Ante PS/DS ground motion map

|V_LOS|
>5 mm/year



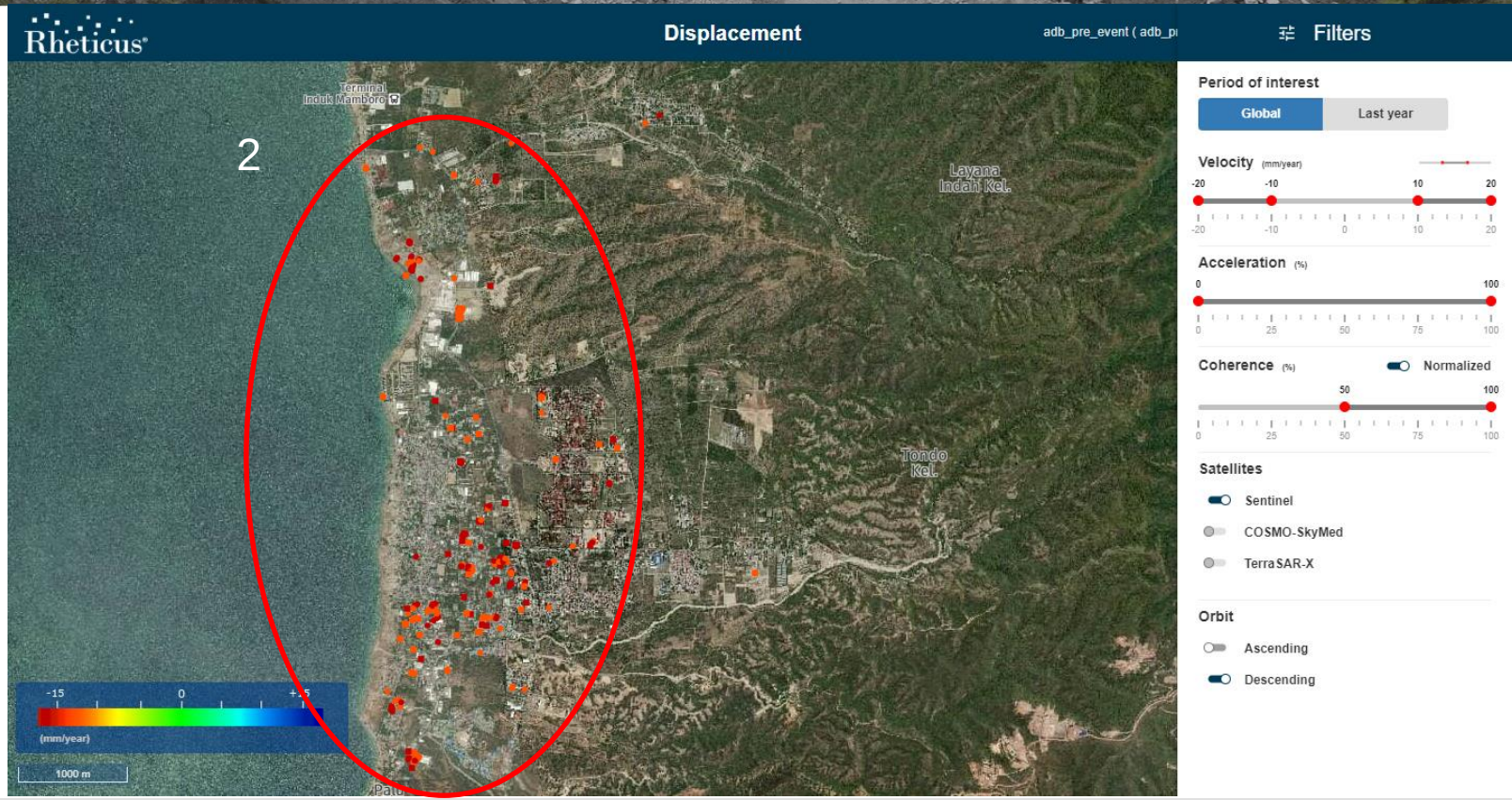
1) Ex-Ante PS/DS ground motion map

|V_LOS|
>7 mm/year



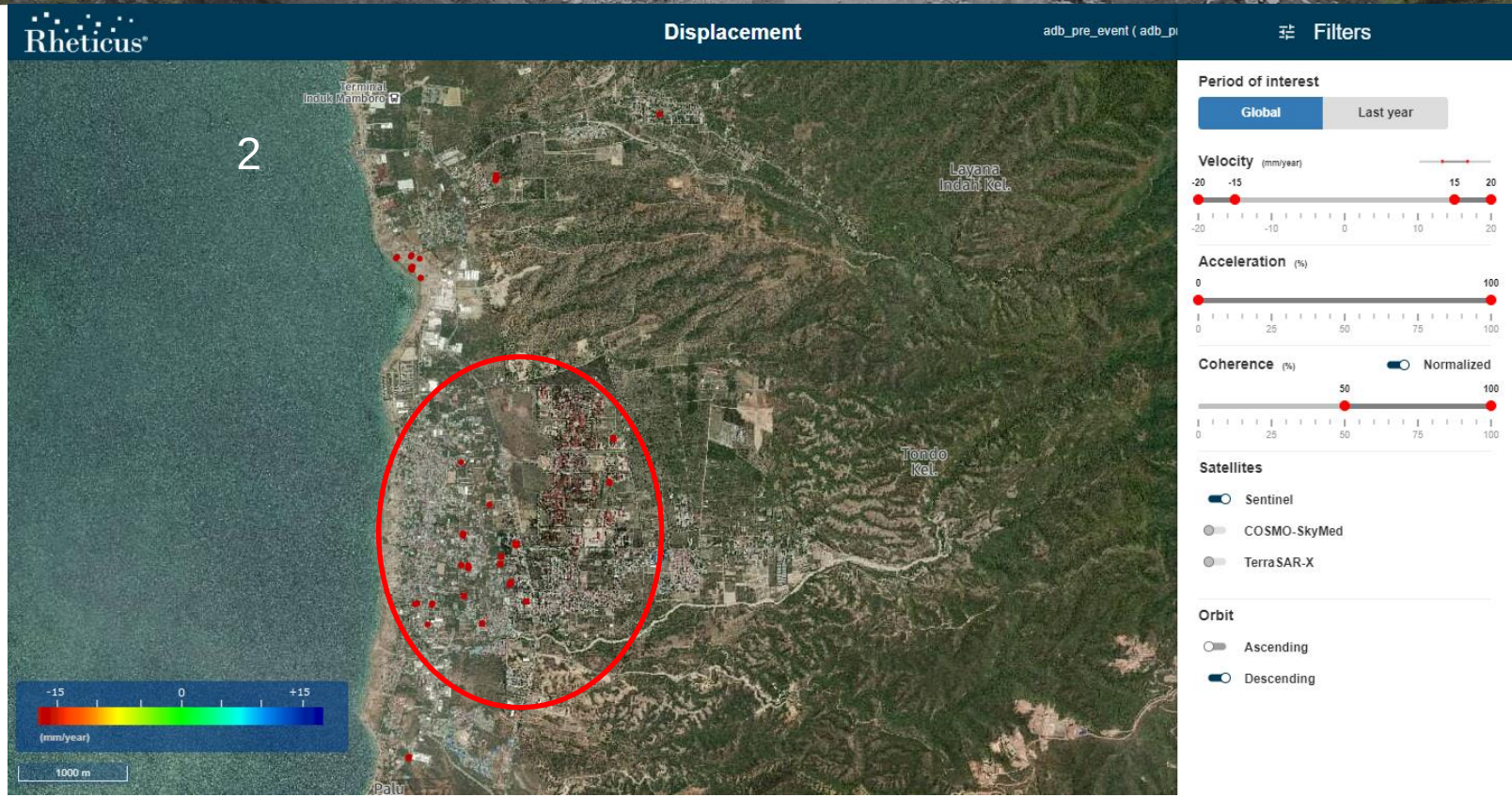
1) Ex-Ante PS/DS ground motion map

|V_LOS|
>10 mm/year



1) Ex-Ante PS/DS ground motion map

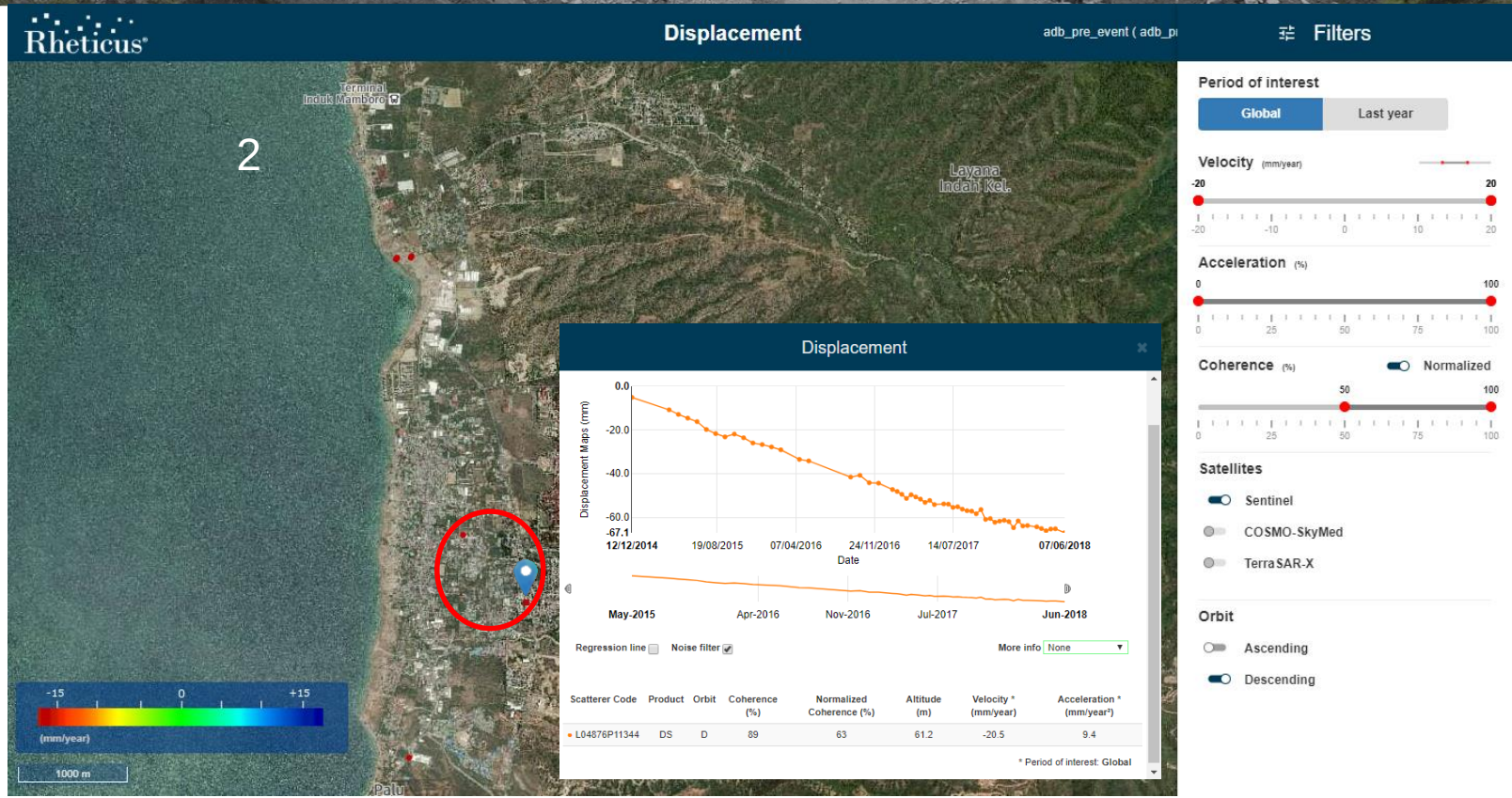
|V_LOS|
>15 mm/year



1) Ex-Ante PS/DS ground motion map

|V_LOS|
>20 mm/year

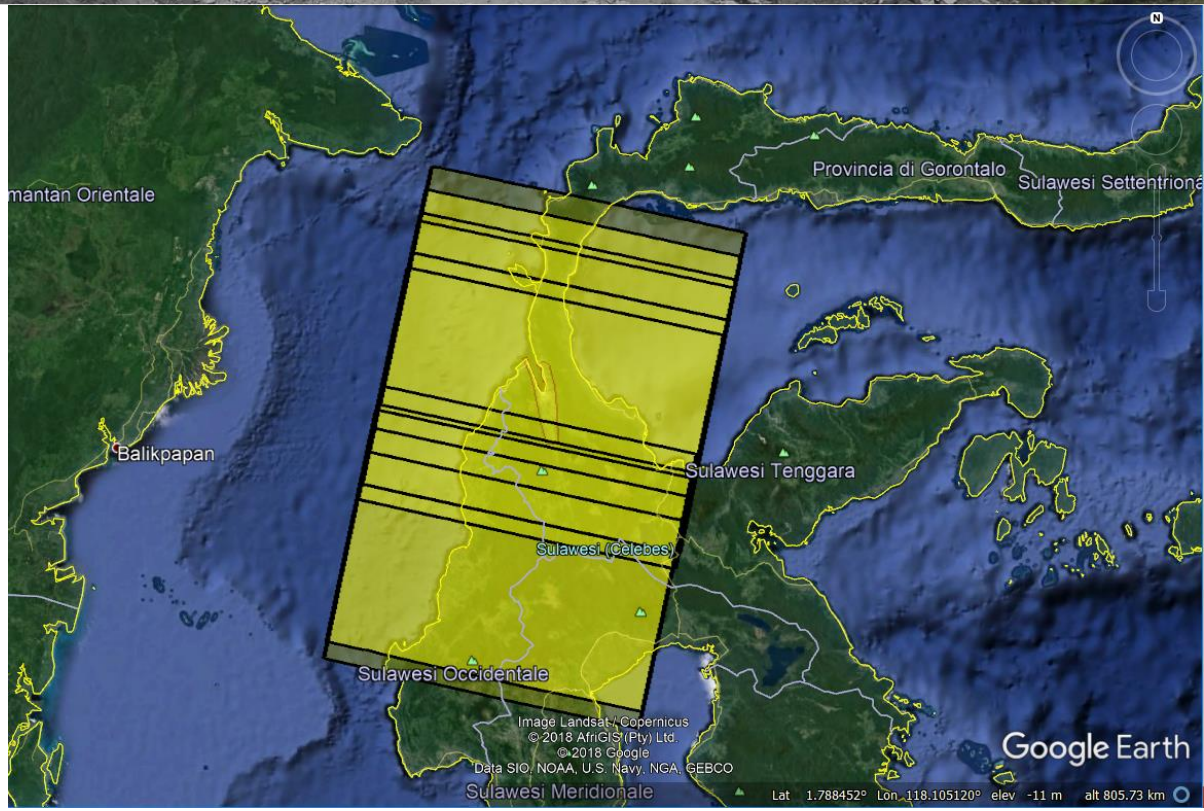
V_LOS MAX:
-20.5 mm/year



2) Ex-Post PS/DS ground motion map

Input data

- Datastack: **Descending orbit**
- Number of Images: **31**
- Temporal resolution: ***05 October 2018***
  15 April 2019
- Sensor: **Sentinel-1**
  (Spatial Resolution: 5 m x 20 m)
- DEM: SRTM 30 meters



2) Ex-Post PS/DS ground motion map

Rheticus® Displacement data Processing based on SPINUA Algorithm

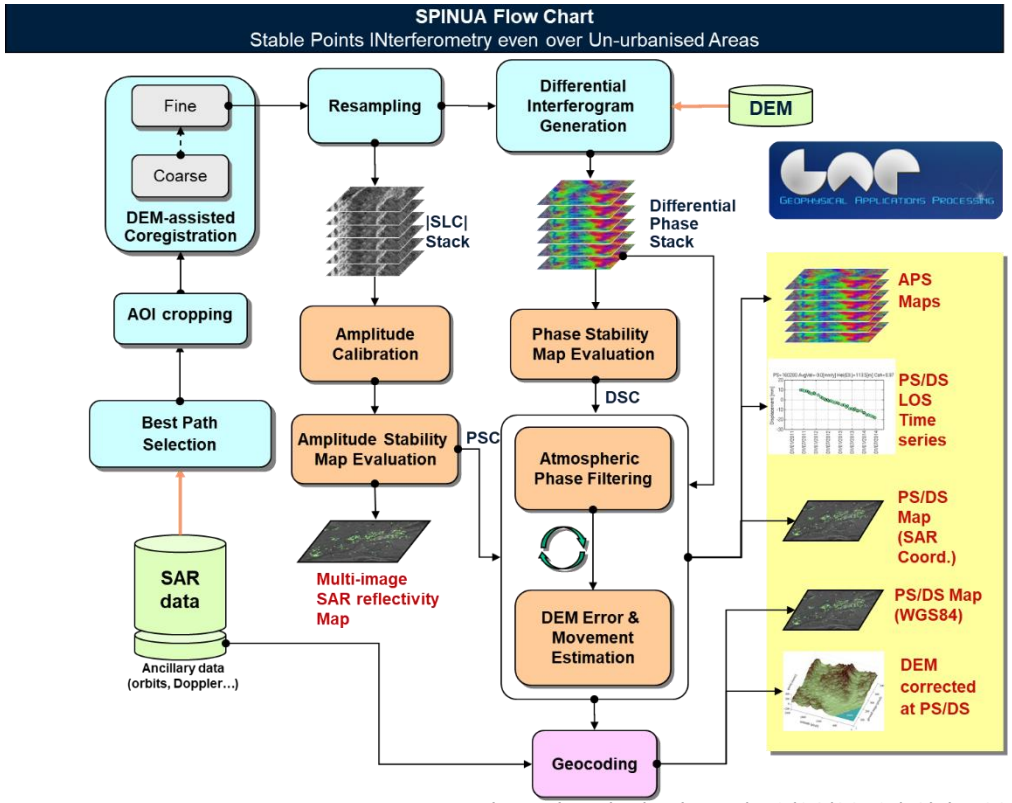
Output:

- Supermaster date: **27-JAN-2019**

- **PS/DS ground motion maps:**

- ID of PS/DS (CODE)
- LAT/LON of PS/DS (°)
- LOS Displacement time series (DLYYYYMMDD) (mm/year)
- LOS Average velocity of Displacement (V_LOS) (mm/year)
- Standard Deviation of V_LOS (V_LOS_STD)(mm/year)
- Incidence angle of the LOS (INC_ANG) (°)
- Heading Angle of LOS (HEAD_ANG)(°)
- Altitude of PS/DS Scatterers (H_GEO) (m)
- Altitude Standard Deviation(H_STDDEV) (m)
- Coherence of PS/DS (COH)
- DEM error (H_AUX_DEM)

- **PS/DS time series of calibrated amplitude:**
- Amplitude time series (AMYYYYMMDD)



2) Ex-Post PS/DS ground motion map

Ground Motion statics (10/18 – 04/19):

Sensor: Sentinel-1
Orbit: Descending

- PS

Number of PS: 514907

V_LOS statistics **(mm/year)**:
'MAX': 161.5,
'MEAN': -15.8,
'MIN': -204.0,
MAX_V_LOS_STD < 15
AVG_V_LOS_STD = 2.7

Coherence Min: 0.75

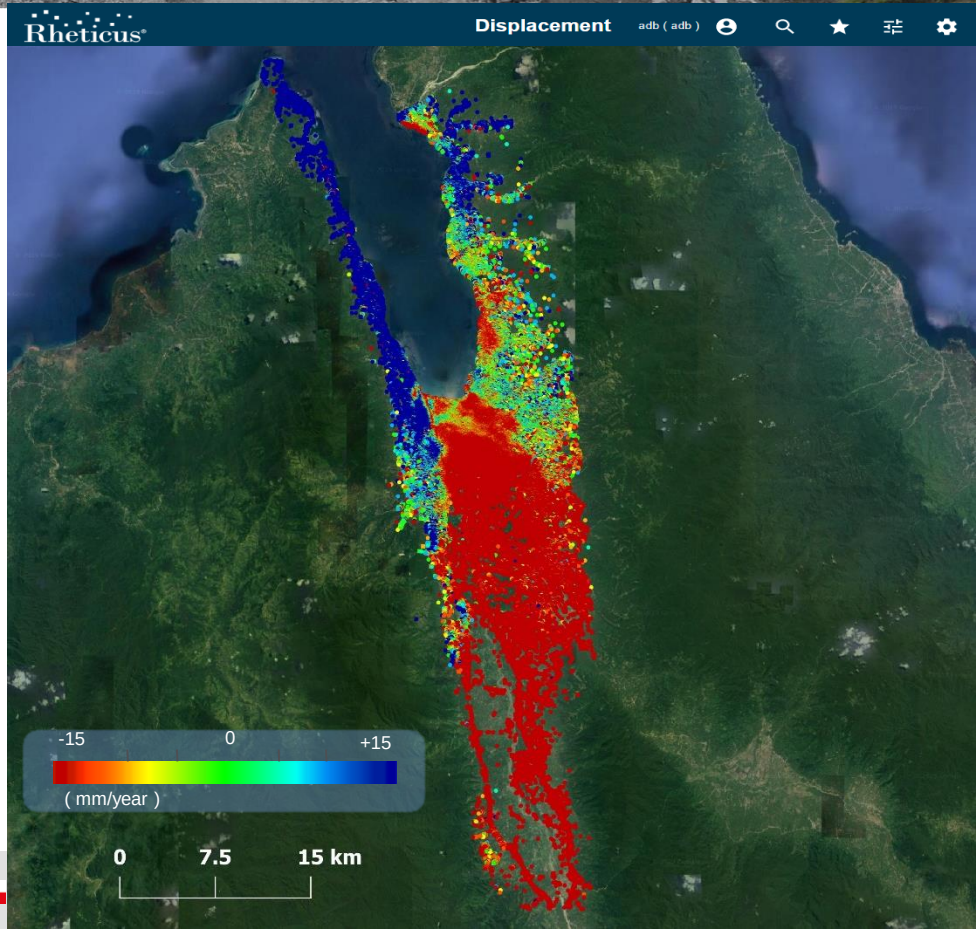
- DS

Number of DS: 36728

V_LOS statistics (**mm/year**):
'MAX': 86.5,
'MEAN': -15.9,
'MIN': -204.0**,**
MAX_V_LOS_STD < 11
AVG_V_LOS_STD = 1.5

Coherence Min: 0.75

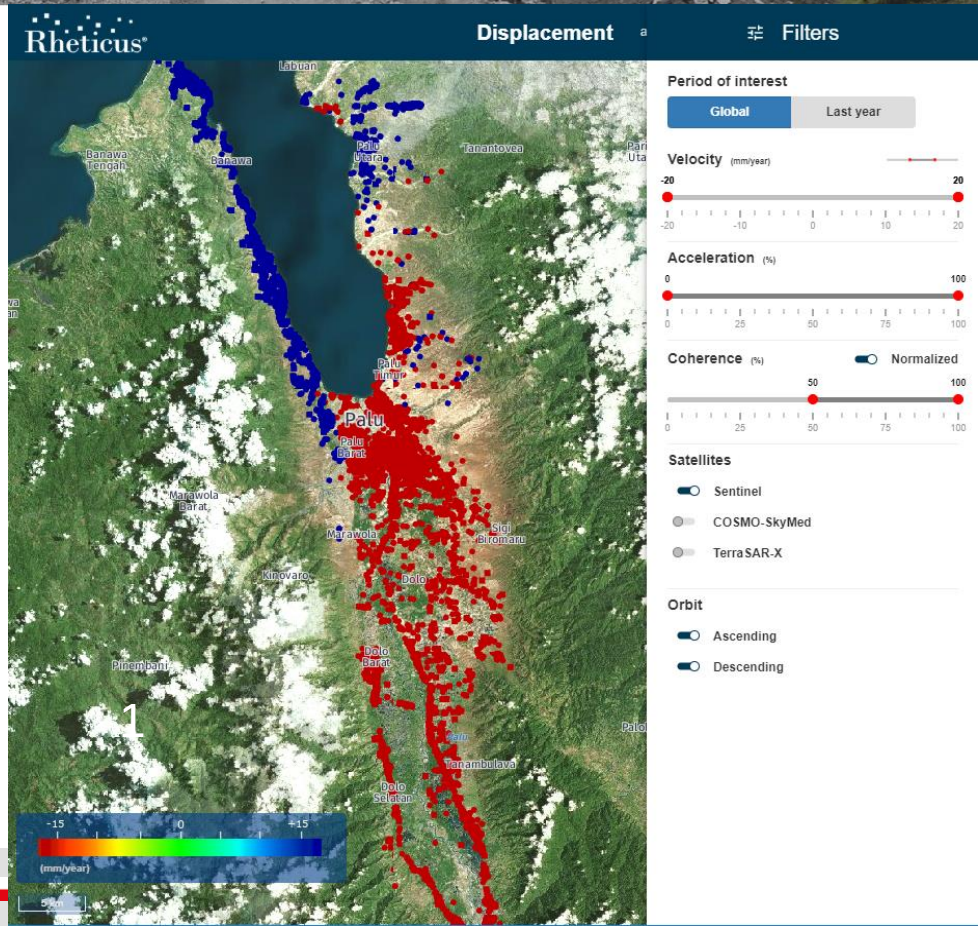
The ground motion map obtained after the earthquake of 28 September 2018 revealed that the area is still affected by ground motion.



2) Ex-Post PS/DS ground motion map

Using the Rheticus® Displacement filters and visualizing only the PS/DS characterized by the **|V_LOS|>2 cm/year** it is possible to identify the area characterized by the higher magnitude of the post-earthquake ground motion.

It is interesting to note the different ground motion behaviour between the West side of seismic fault (ground motion toward the satellite LOS) and the East side (ground motion away with respect to the satellite LOS).



2) Ex-Post PS/DS ground motion map

VLOS_statistics considering the three different area characterized by a different average ground motion behaviour:

- **Average positive velocity (Up LOS ground motion): Blue polygon**
- Average stability: Green polygon
- Average negative velocity (Down LOS ground motion): Red polygon

- PS

Number of PS: 97355

V_LOS statistics **(mm/year)**:
'MAX': 161.5,
'MEAN': 22.3,
'MIN': - 151.0,
AVG_V_LOS_STD = 2.8

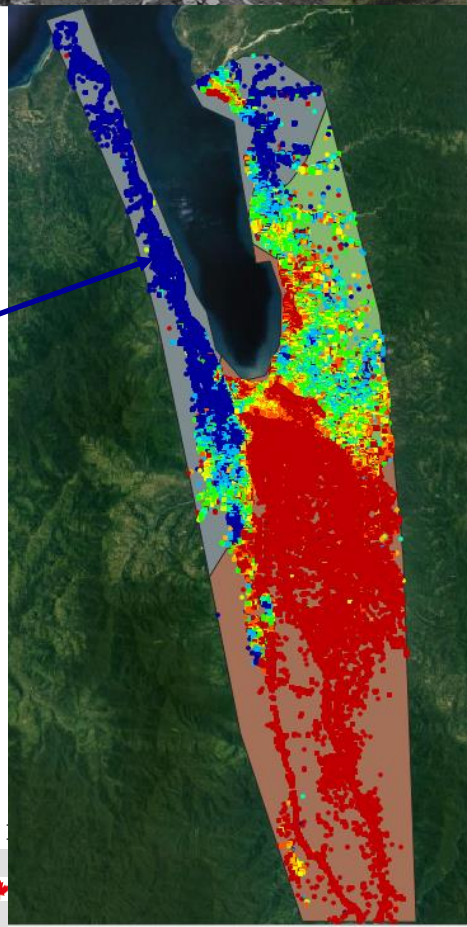
Coherence Min: 0.75

- DS

Number of DS: 7838

V_LOS statistics (**mm/year**):
'MAX': 86.5,
'MEAN': 21.4,
'MIN': -47.5,
AVG_V_LOS_STD = 1.6

Coherence Min: 0.75



2) Ex-Post PS/DS ground motion map

VLOS_statistics considering the three different area characterized by a different average ground motion behaviour:

- Average positive velocity (Up LOS ground motion): Blue polygon
- **Average stability: Green polygon**
- Average negative velocity (Down LOS ground motion): Red polygon

- PS

Number of PS: 116223

V_LOS statistics (**mm/year**):
'MAX': 119.5,
'MEAN': -1.5,
'MIN': - 169.5,
AVG_V_LOS_STD = 2.7

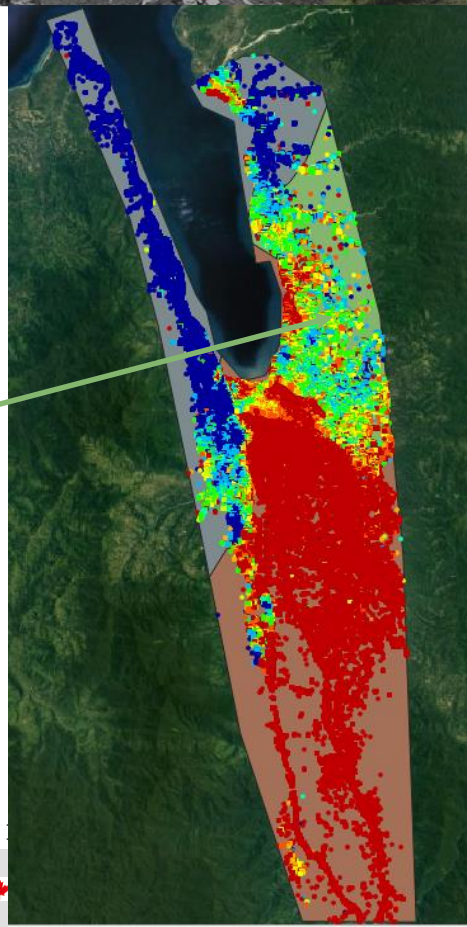
Coherence Min: 0.75

- DS

Number of DS: 8507

V_LOS statistics (**mm/year**):
'MAX': 25.0,
'MEAN': **-0.8**,
'MIN': -58.0,
AVG_V_LOS_STD = 1.4

Coherence Min: 0.75



2) Ex-Post PS/DS ground motion map

VLOS_statistics considering the three different area characterized by a different average ground motion behaviour:

- Average positive velocity (Up LOS ground motion): **Blue polygon**
- Average stability: Green polygon
- **Average negative velocity (Down LOS ground motion): Red polygon**

- PS

Number of PS: 302446

V_LOS statistics **(mm/year)**:
'MAX': 156.0,
'MEAN': -33.5,
'MIN': - 204.0,
AVG_V_LOS_STD = 2.7

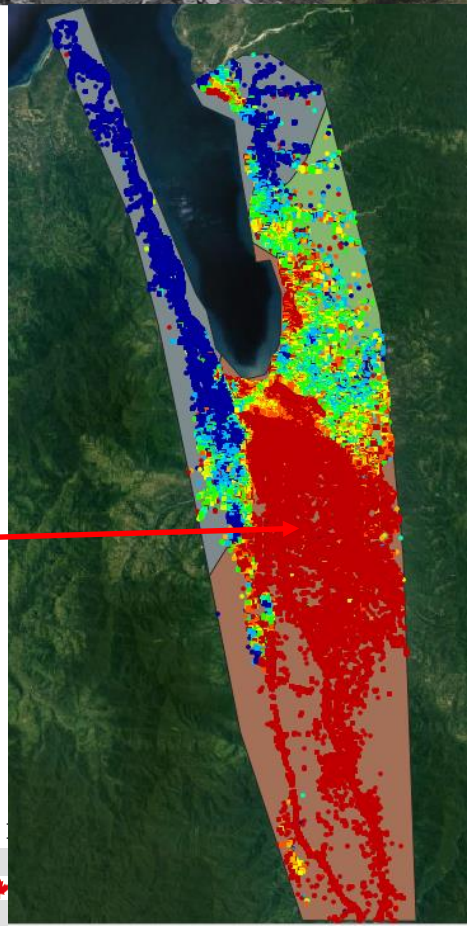
Coherence Min: 0.75

- DS

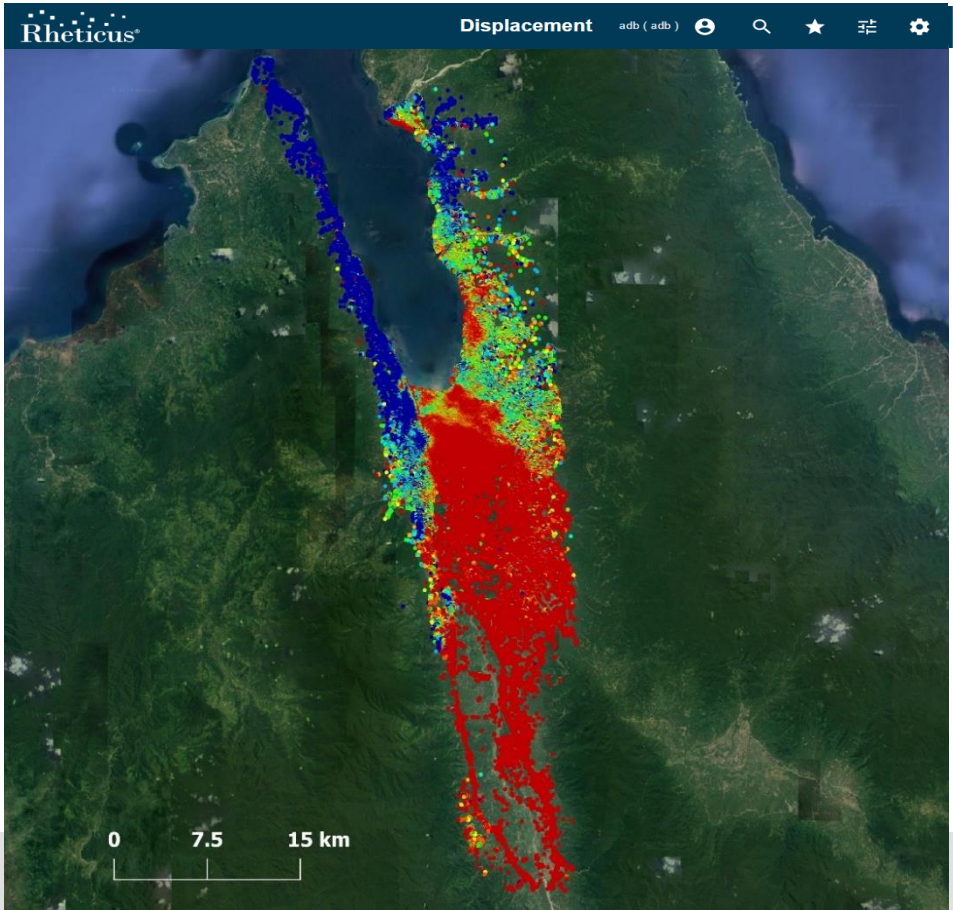
Number of DS: 20447

V_LOS statistics (**mm/year**):
'MAX': 36.0,
'MEAN': -36.4,
'MIN': -204.0,
AVG_V_LOS_STD = 5

Coherence Min: 0.75



Palu PS/DS ground motion map (pre VS post earthquake 28/09/2018)

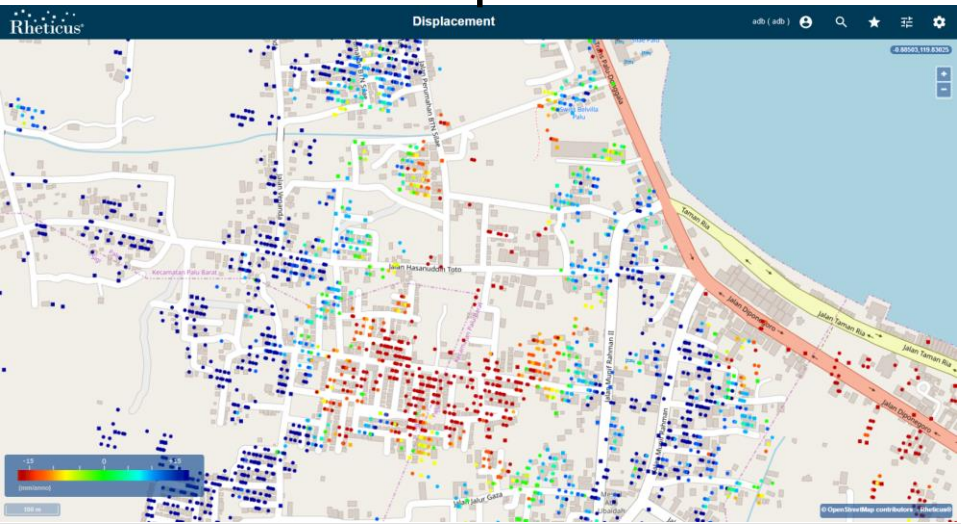


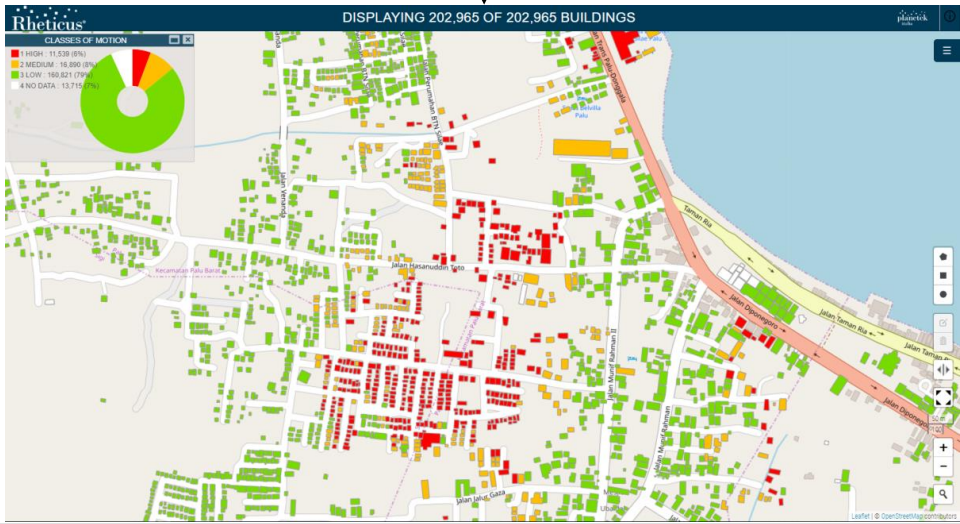
Rheticus® Building – Vertical application for the buildings monitoring

Rheticus® Building provides updated levels of concern on each building based on the measurements of displacement of the building itself and of the nearby areas performed by means of the Rheticus® Displacement ground motion measurements.

FROM THE DISPLACEMENT MEASUREMENTS

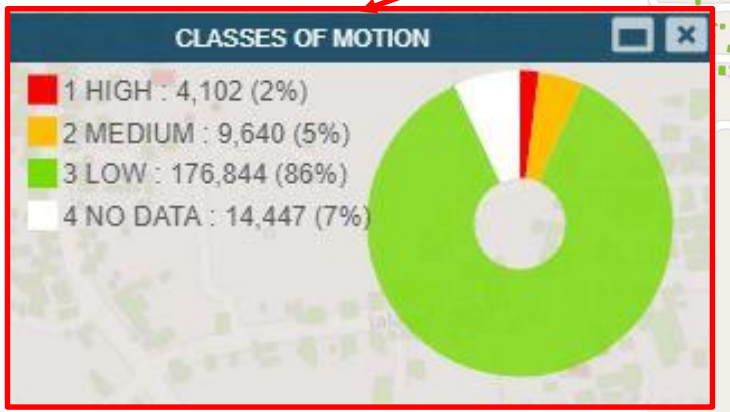
TO THE BULDING STABILITY LAYER

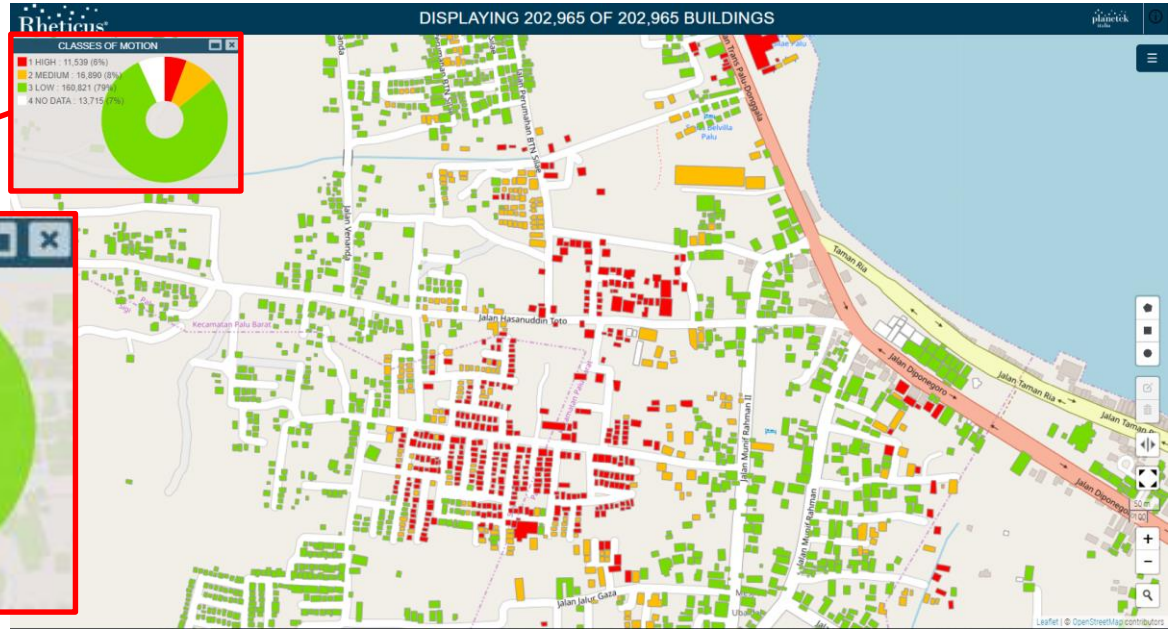




The status of each measured building is represented by 3 classes/colours that correspond to a decreasing level of concern:

The parameters used to classify the level of concern are based on the statistical model that combines the **velocity, acceleration and coherence of PS/DS Scatterers in order to highlight the buildings that are affected by differential motions.**





Rheticus® Building overview

1) Ex-ante Rheticus® building stability layer

Input data:
- Ex-Ante PS/DS ground motion map (Sentinel-1 / *25 April 2015 – 7 june 2018*)
- Open-Street map buildings over the AOI

Output:
- Ex-Ante Rheticus® Building Stability layer

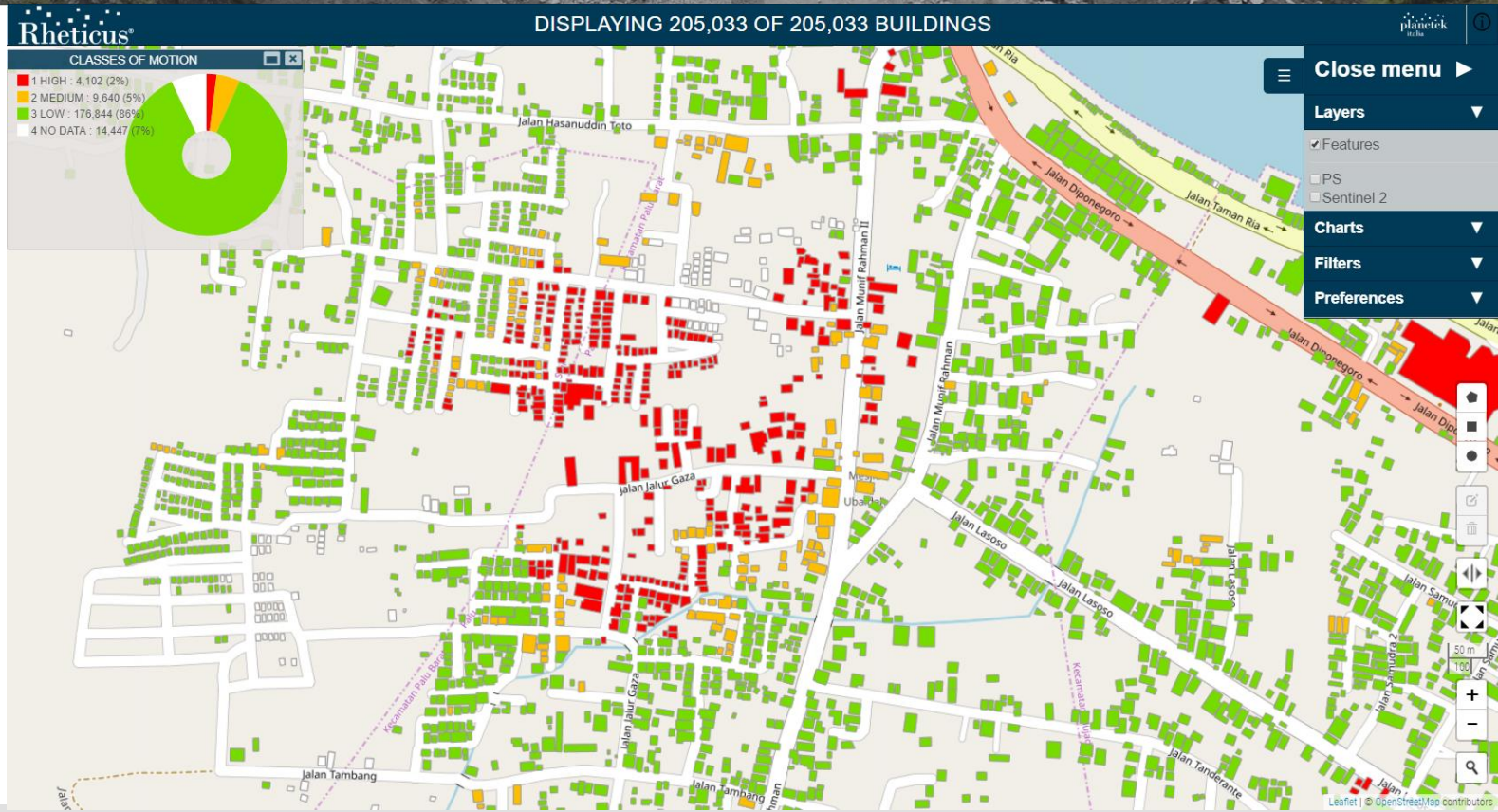
2) Ex-post Rheticus® building stability layer

Input data:
- Ex-post PS/DS ground motion map (Sentinel-1 / *05 October 2018 – 15 April 2019)*
- Open-Street map buildings over the AOI **(Note: the destroyed buildings according to the Copernicus EMS were not considered for the classification)**

Output:
- Ex-Post Rheticus® Building stability layer

1) Ex-Ante Rheticus® Building Stability layer

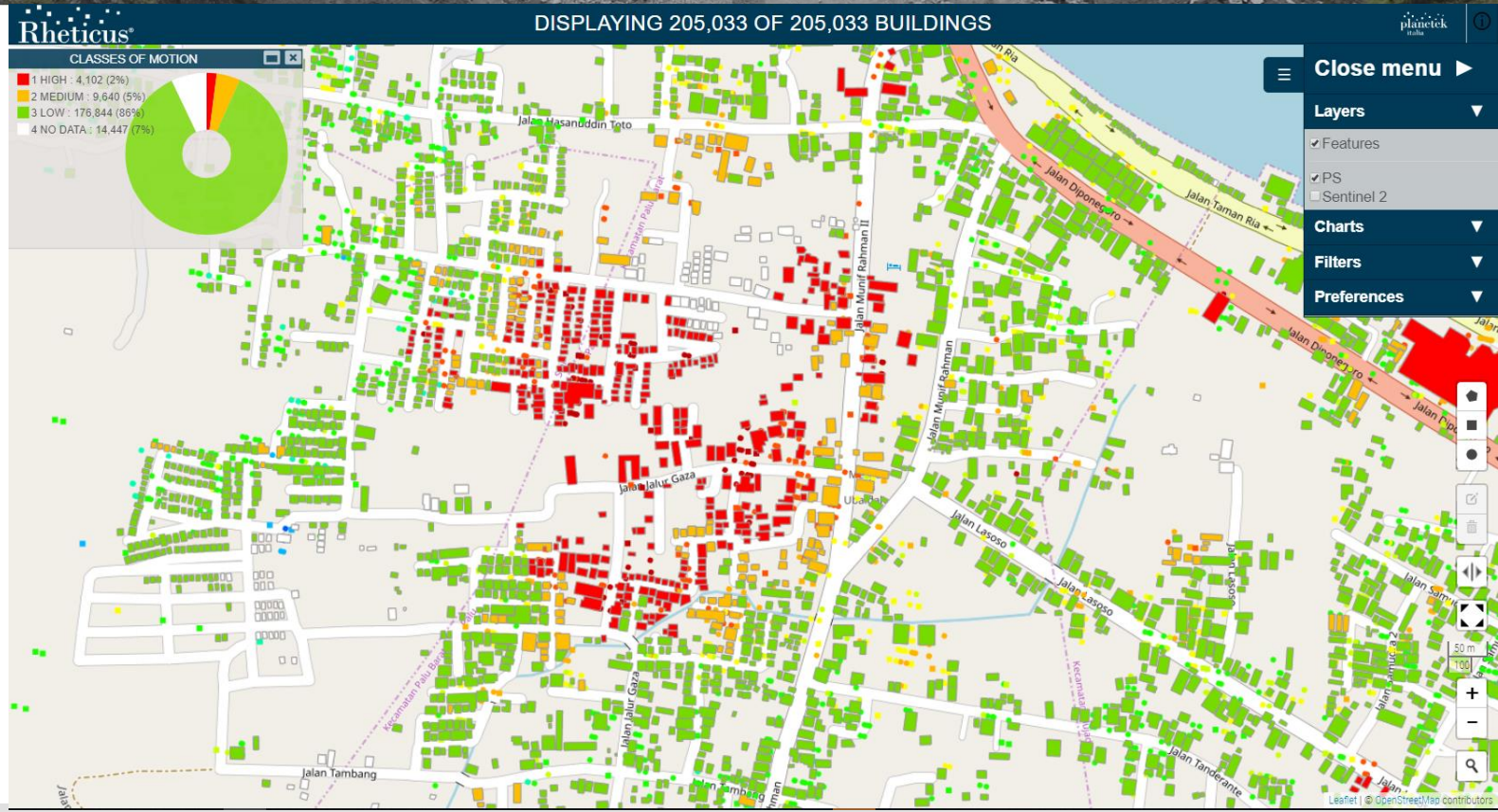
Example over the area on the west side affected by subsidence.



1) Ex-Ante Rheticus® Building Stability layer

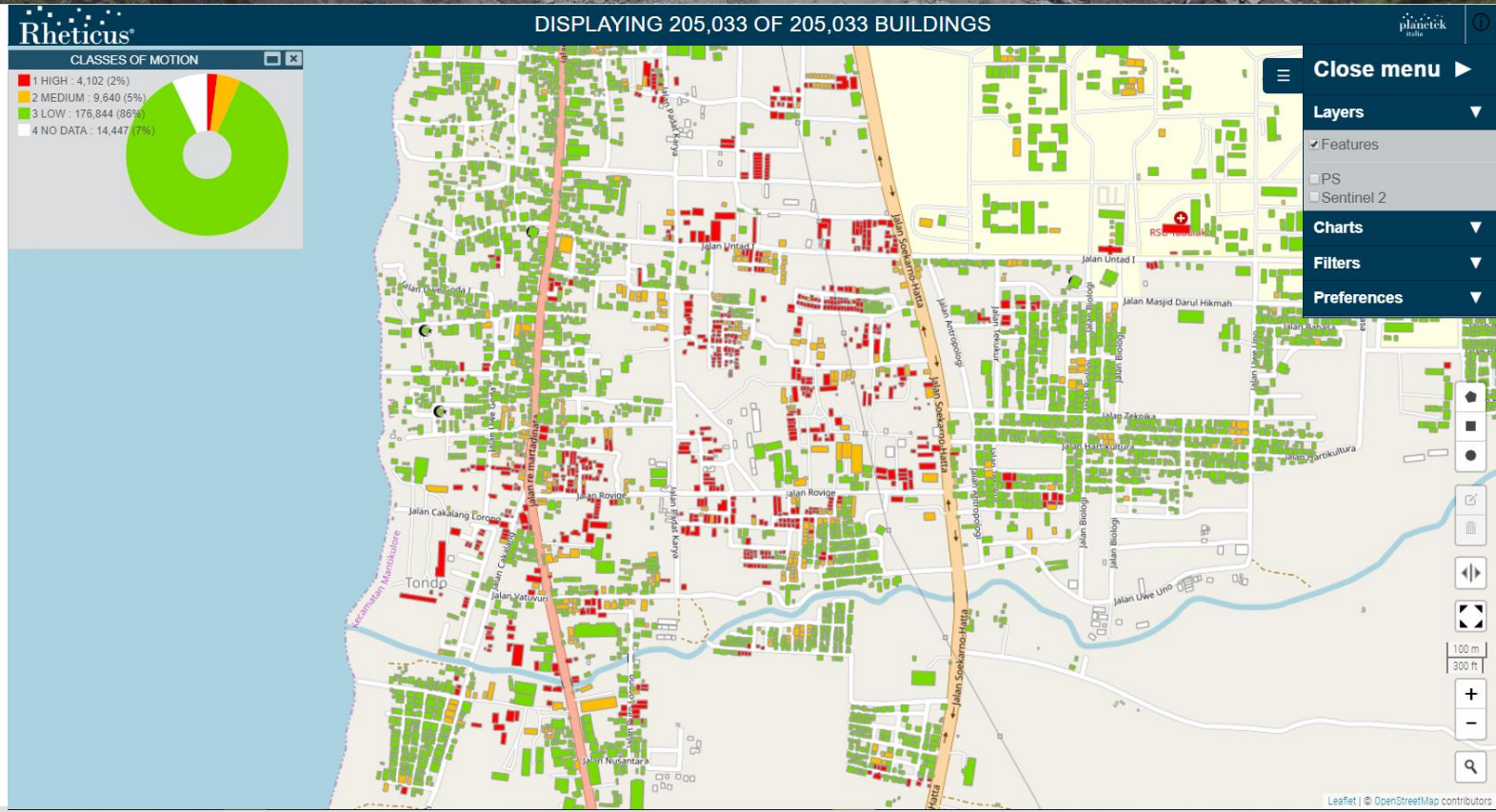
Example over the area on the west side affected by subsidence.

Overlay with the PS/DS map



1) Ex-Ante Rheticus® Building Stability layer

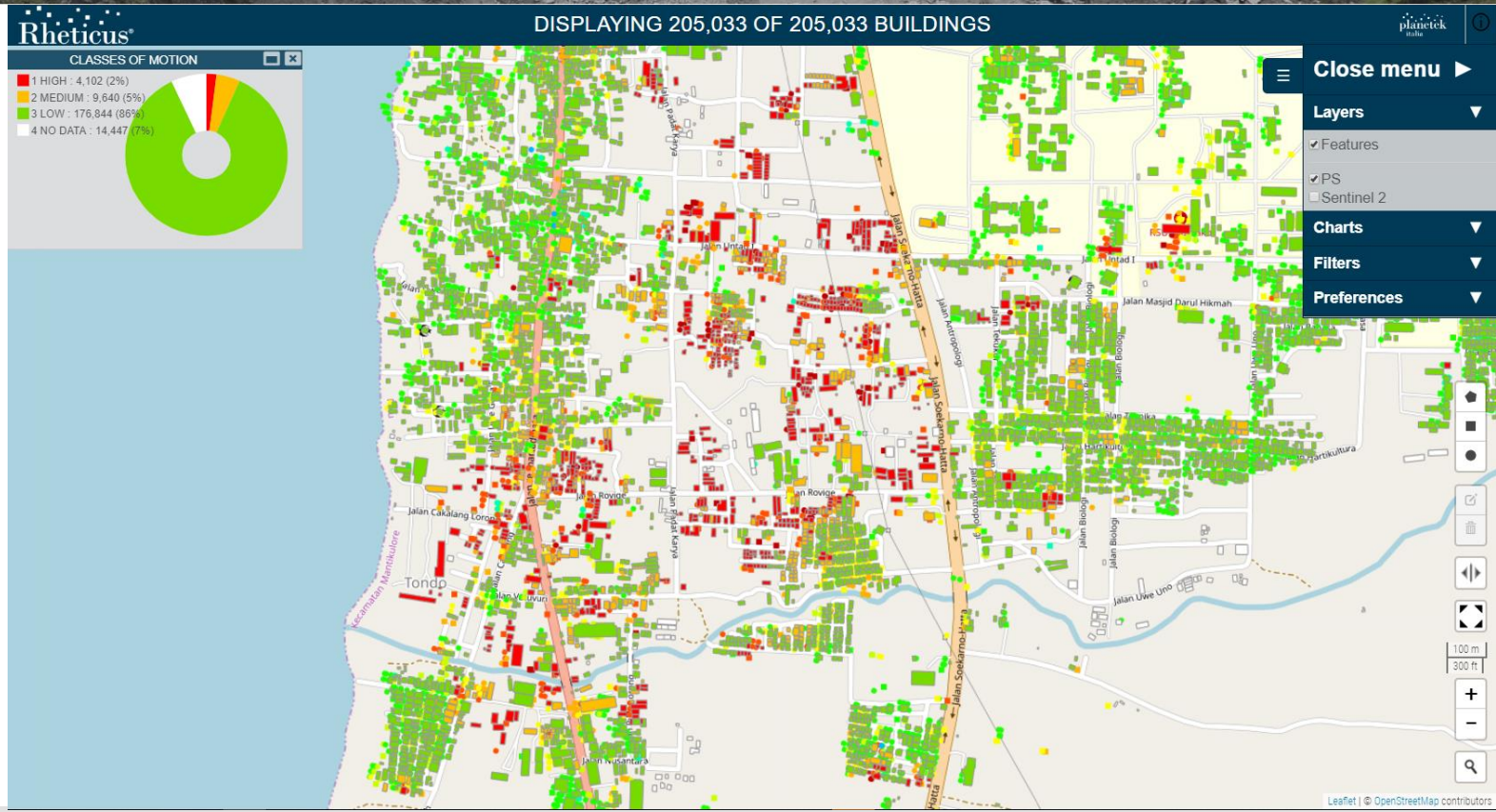
Example over the area affected by diffused ground motion on the north-east side of Palu



1) Ex-Ante Rheticus® Building Stability layer

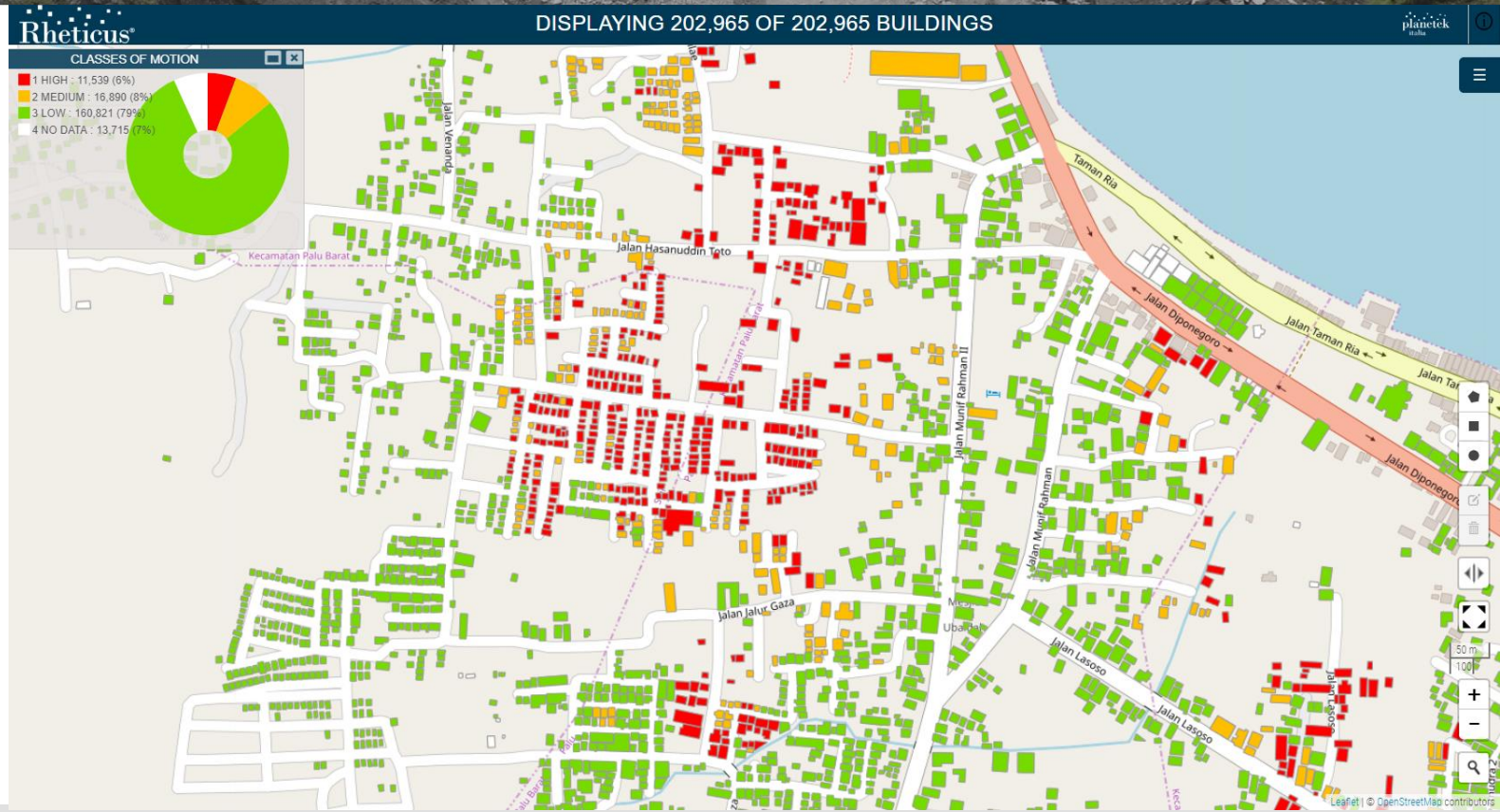
Example over the area affected by diffused ground motion on the north-east side of Palu

Overlay with the PS/DS map



2) Ex-Post Rheticus® Building Stability layer

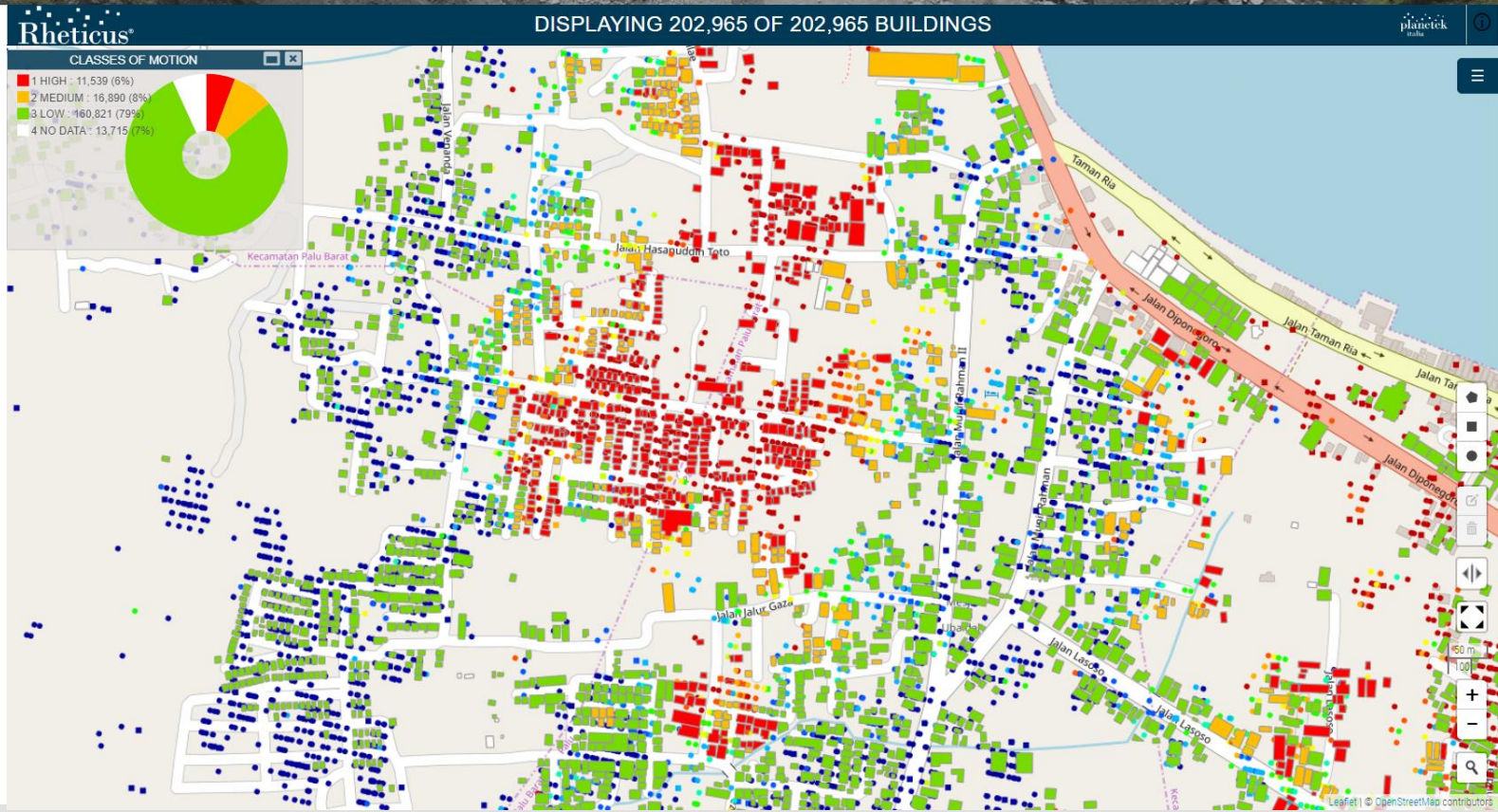
Example over the area on the west side affected by subsidence. The phenomena is still active in the post-seismic period.



2) Ex-Post Rheticus® Building Stability layer

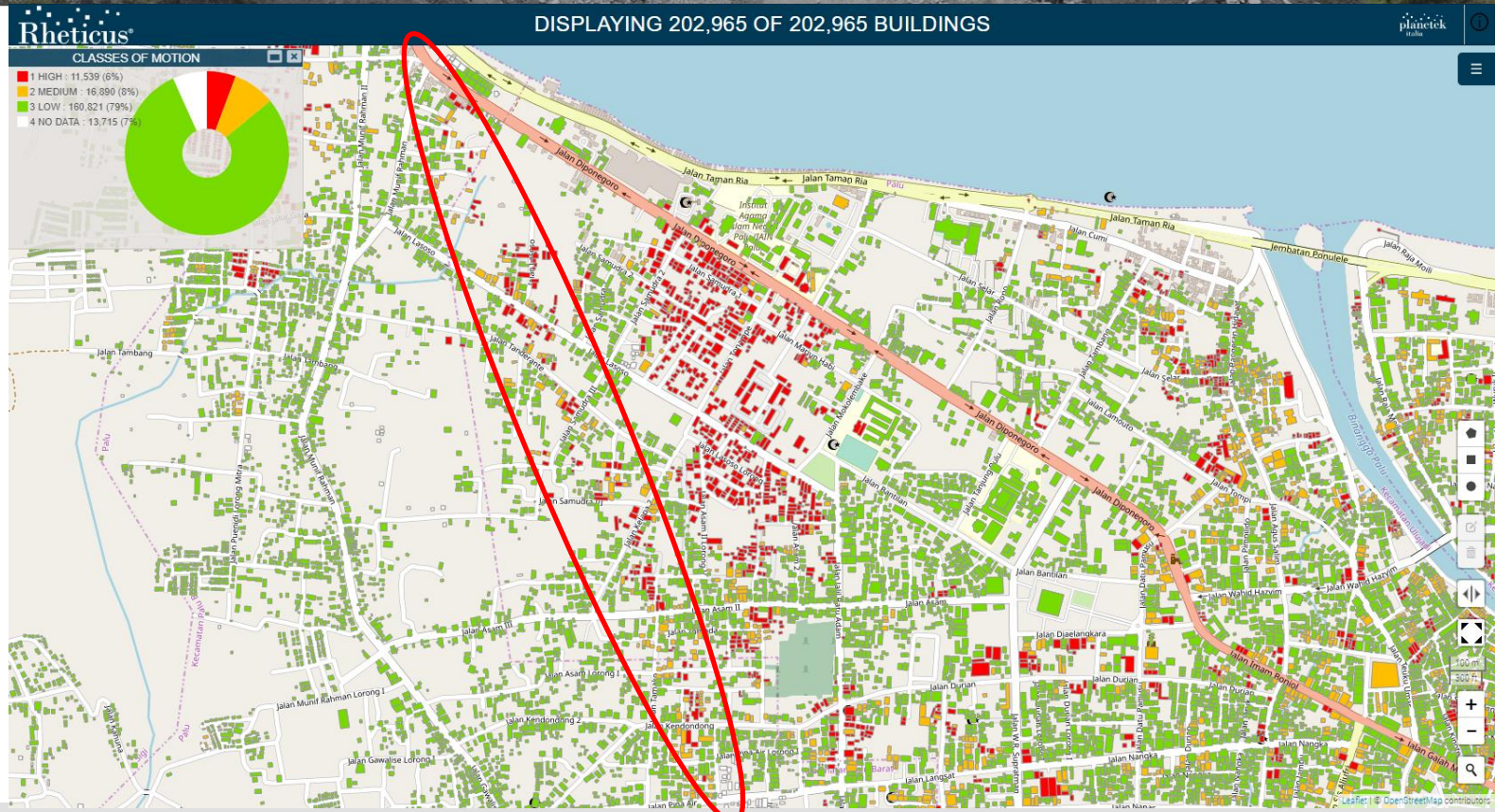
Example over the area on the west side affected by subsidence.

The differential ground motion between the area still affected by subsidence and the surrounding area affected by homogeneous post-seismic motion (positive LOS velocity) is clearly highlighted.



2) Ex-Post Rheticus® Building Stability layer

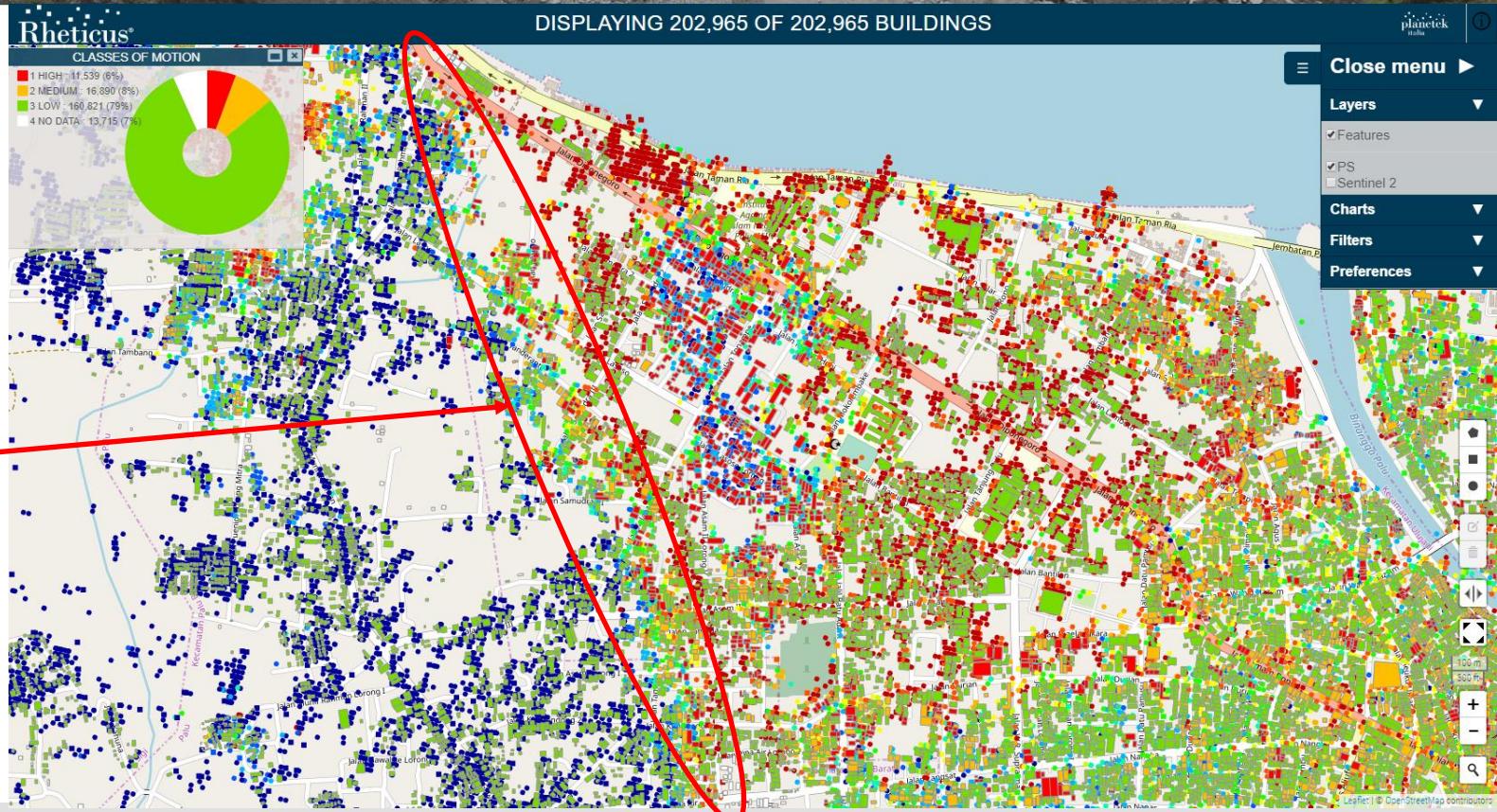
Example over the area close to the seismic fault (highlighted with the red circle).



2) Ex-Post Rheticus® Building Stability layer

Example over the area close to the seismic fault (highlighted with the red circle).

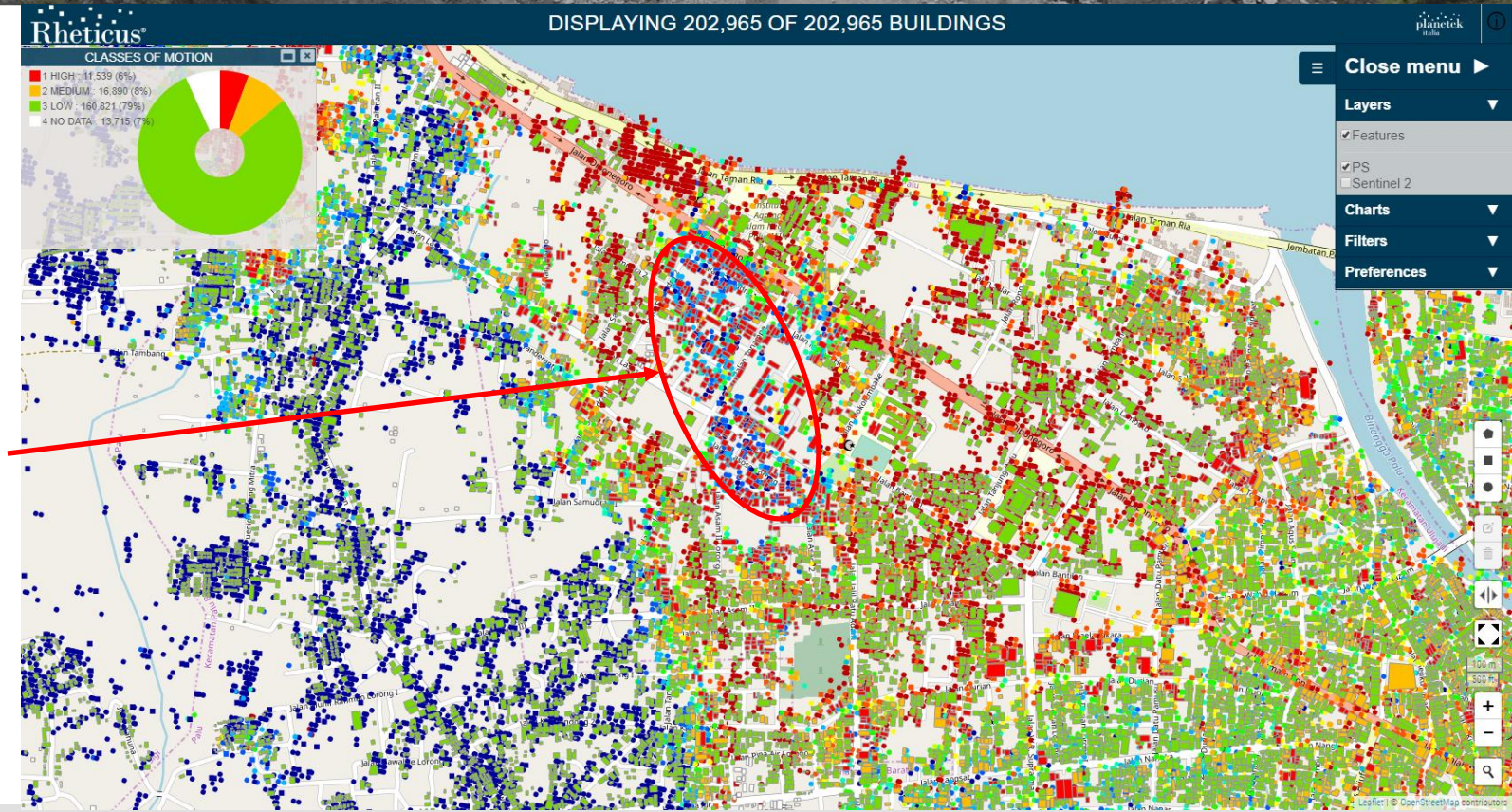
It is interesting to see the correlation between the buildings classified as red and the differential motion highlighted by the PS/DS map close to the seismic fault.



2) Ex-Post Rheticus® Building Stability layer

Example over the area close to the seismic fault (highlighted with the red circle).

Localised area affected by differential movements (positive LOS velocity) with respect to the surrounding area characterized by subsidence.



Let’s keep in touch

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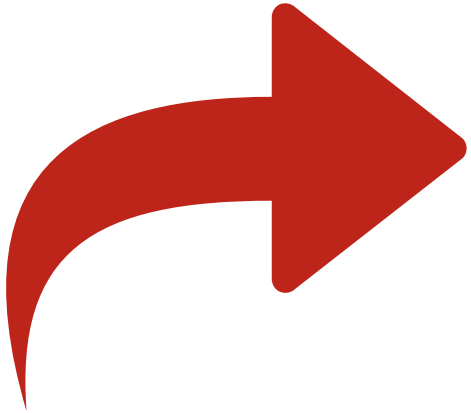

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