UNIVERSITÀ DEGLI STUDI DI PADOVA

# Prevention of Potential Catastrophes Depending on Interferometric Radar Technique and Artificial Intelligence

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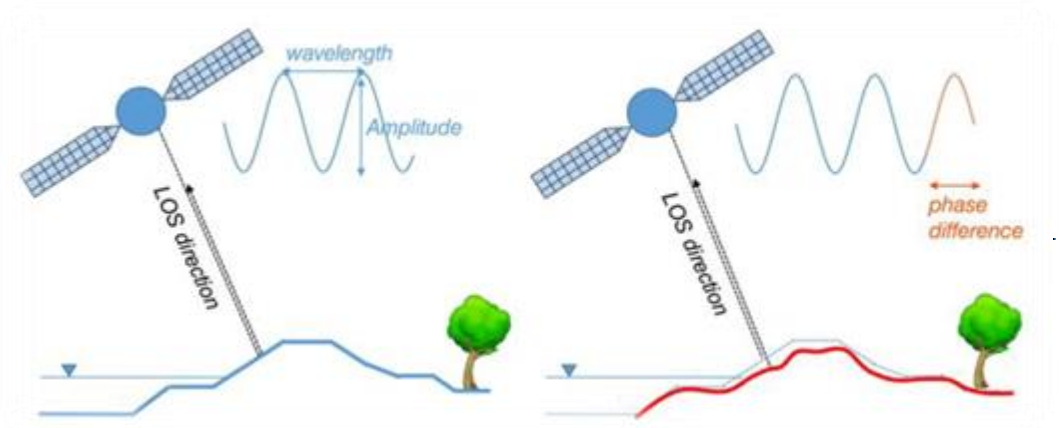
Meeting - 06/09/2021

# INTRODUCTION

InSAR (Interferometric Synthetic Aperture Radar) is an efficient tool to monitor surface motions of millimeters depending on the phase difference concept

The phase differences are the changes in range along the Line of Sight of a satellite (LoS)




$$\phi = -\frac{4\pi}{\lambda}\delta_{\mathrm{LoS}}$$

$$\phi = (\psi_P - \psi_Q)_{t_2} - (\psi_P - \psi_Q)_{t_1}.$$

# SENTINEL1



**Sentinel-1 is a multi-pass system with both a high spatial and temporal resolution**

**Thus Sentinel-1 can detect and monitor the displacements of the earth's surface related to landslides which can be relatively small in space and variable in time**

# MAIN OBJECTIVE



**Using Intelligent algorithms in developing a methodology that can automatically analyze large InSar data packets and identify areas where infrastructure are at risk of displacement due to ground movement**

# WHY IS IT IMPORTANT?

**Such a benefit we can get by transcending the following obstacles**

- The high amount InSAR data and expert knowledge to get the results
- Using complex software environments as future time series analysis will become longer
- Considering the geological conditions of the studied area
- Defining the appropriate DInSAR approach and a stable reference point for the selected workflow
- Estimating the atmospheric contribution

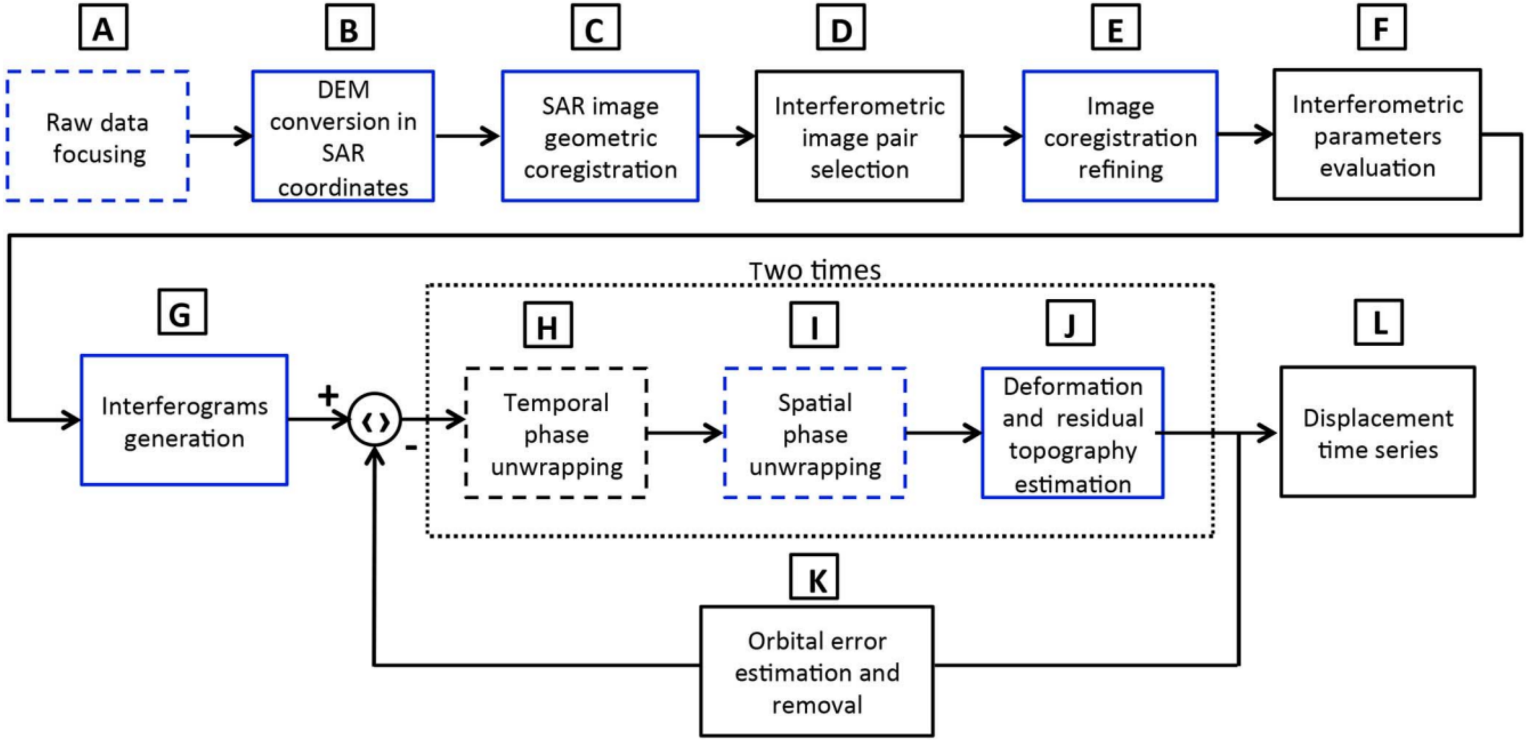
# P-SBAS TECHNIQUE

**The theoretical and empirical aspects should be considered for each case study to decide which DInSAR approach to use and avoid certain limitations**

**Theoretically, the SBAS approach provides a higher density of measurement points than the PS approach**

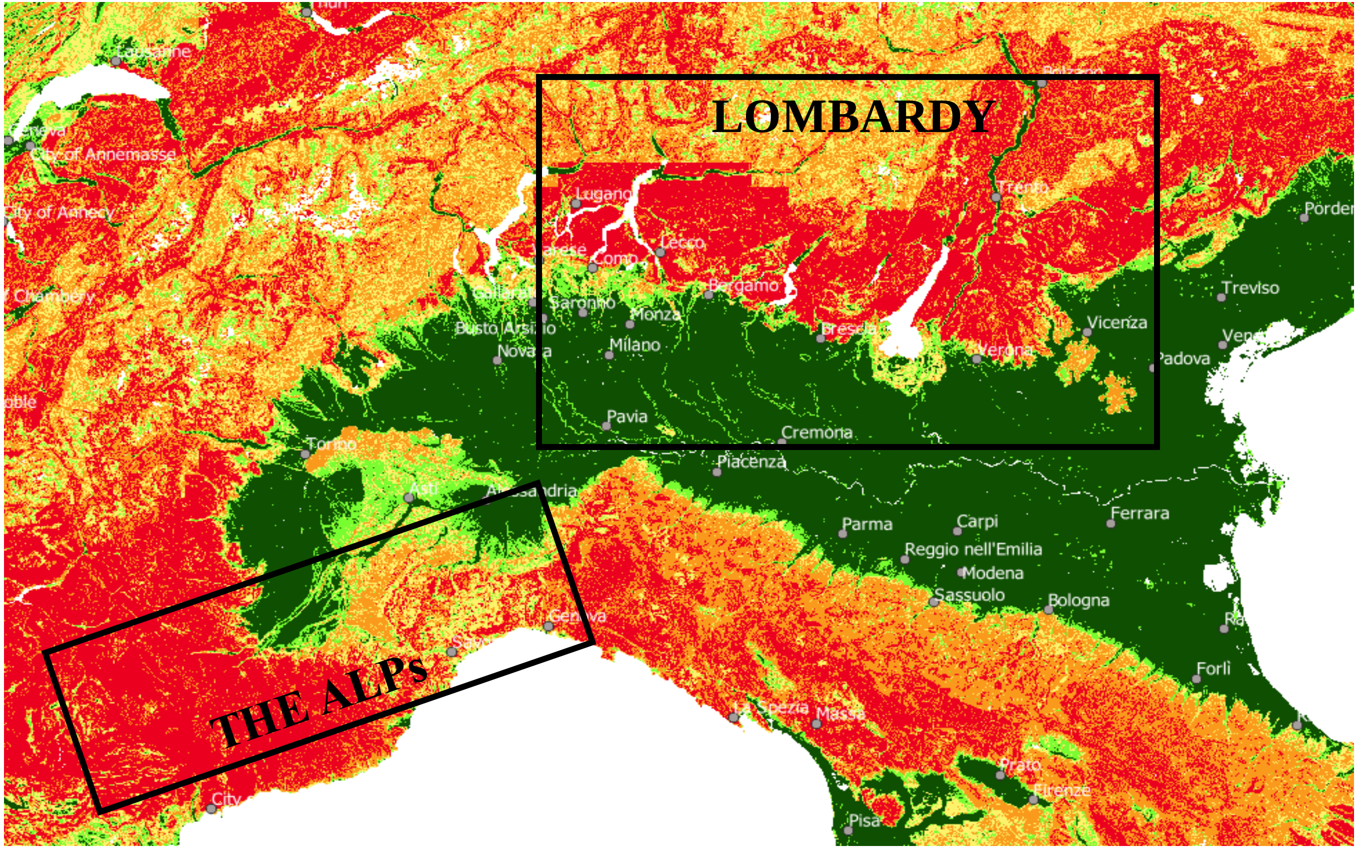
➡ **P-SBAS processing chain runs many steps in parallel by exploiting different bursts as inputs**

# P-SBAS TECHNIQUE




**P-SBAS workflow: Black and blue blocks represent sequential and parallel (from a process-level perspective) processing steps, respectively Dashed line blocks represent multithreading programmed processing steps**

# DATASETS


LOMBARDY
THE ALPs
Lugano
Lecco
Como
Bergamo
Saronno
Monza
Busto Arsizio
Milano
Brescia
Verona
Vicenza
Trento
Treviso
Padova
Pavia
Cremona
Piacenza
Torino
Asti
Parma
Carpi
Reggio nell'Emilia
Modena
Sassuolo
Bologna
Ferrara
Forlì
Massa
Prato
Firenze
Pisa
City of Annemasse
City of Annecy
Chambery
Lausanne

# THE METHODOLOGY

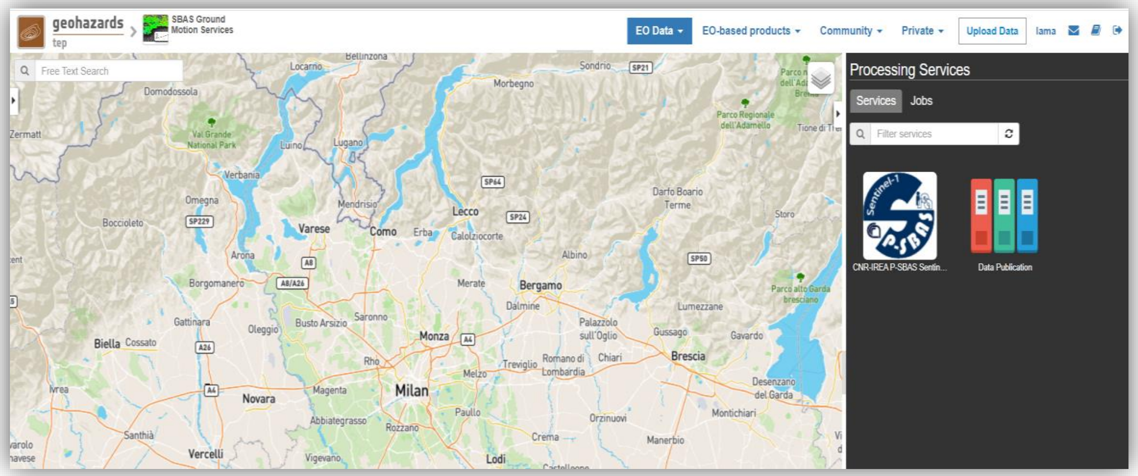
**1. The entire interferograms and time series processing chains have been processed automatically using PSBAS technique provided by the GEP platform**

# 1.The Methodology (Geohazards TEP)

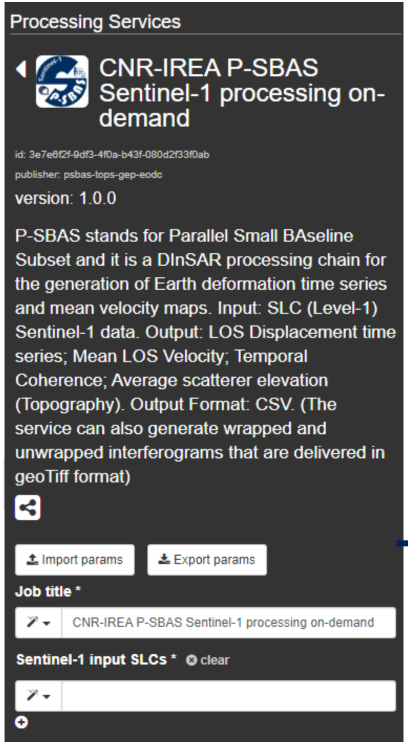
Sponsorship

By: NoR esa

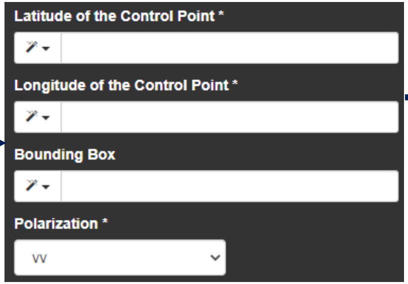
G-TEP is a cloud computing environment that provides an extensive collection of computing resources and storage that can be effectively exploited through the P-SBAS processing chain to carry out interferometric analyses at a vast scale in reduced time frames

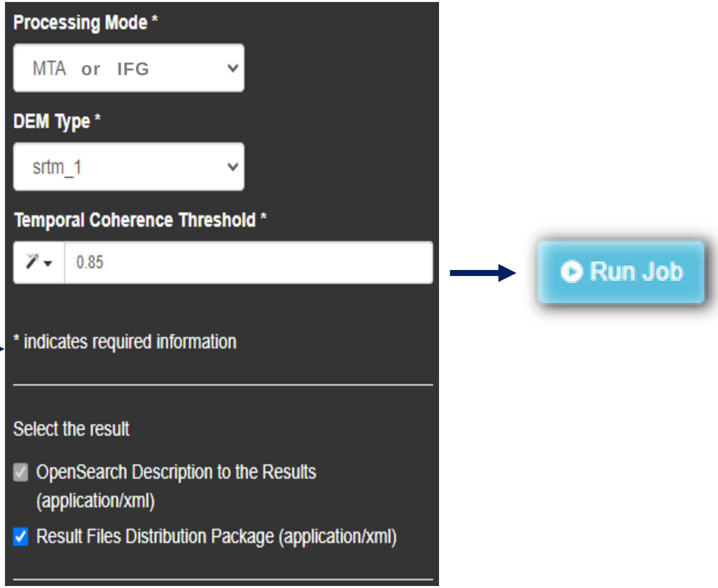


# 1.The Methodology (Geohazards TEP)



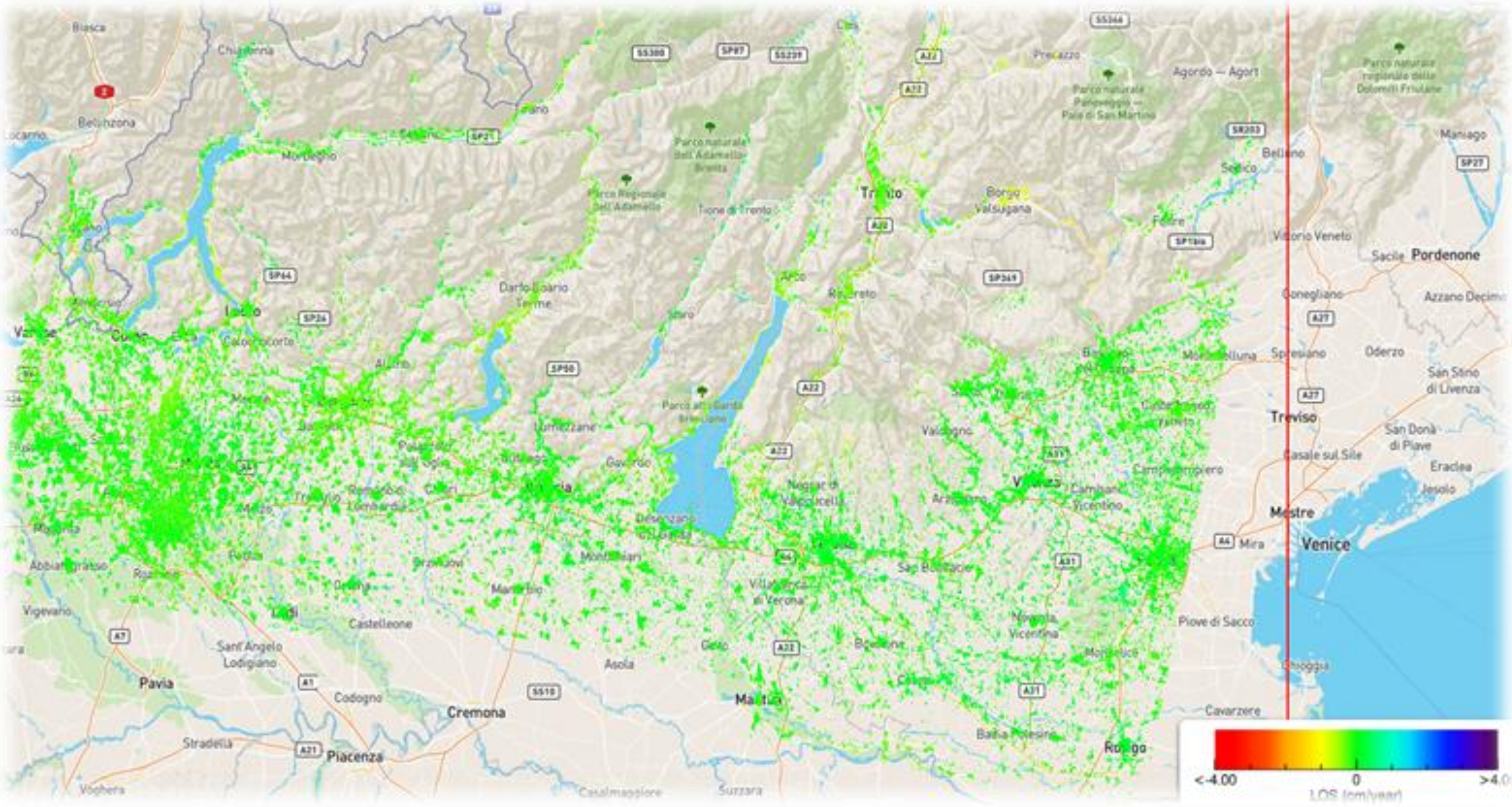

Selecting suitable SAR images is a key step since the criteria adopted for the selection of these images have a strong impact on the quality of the results



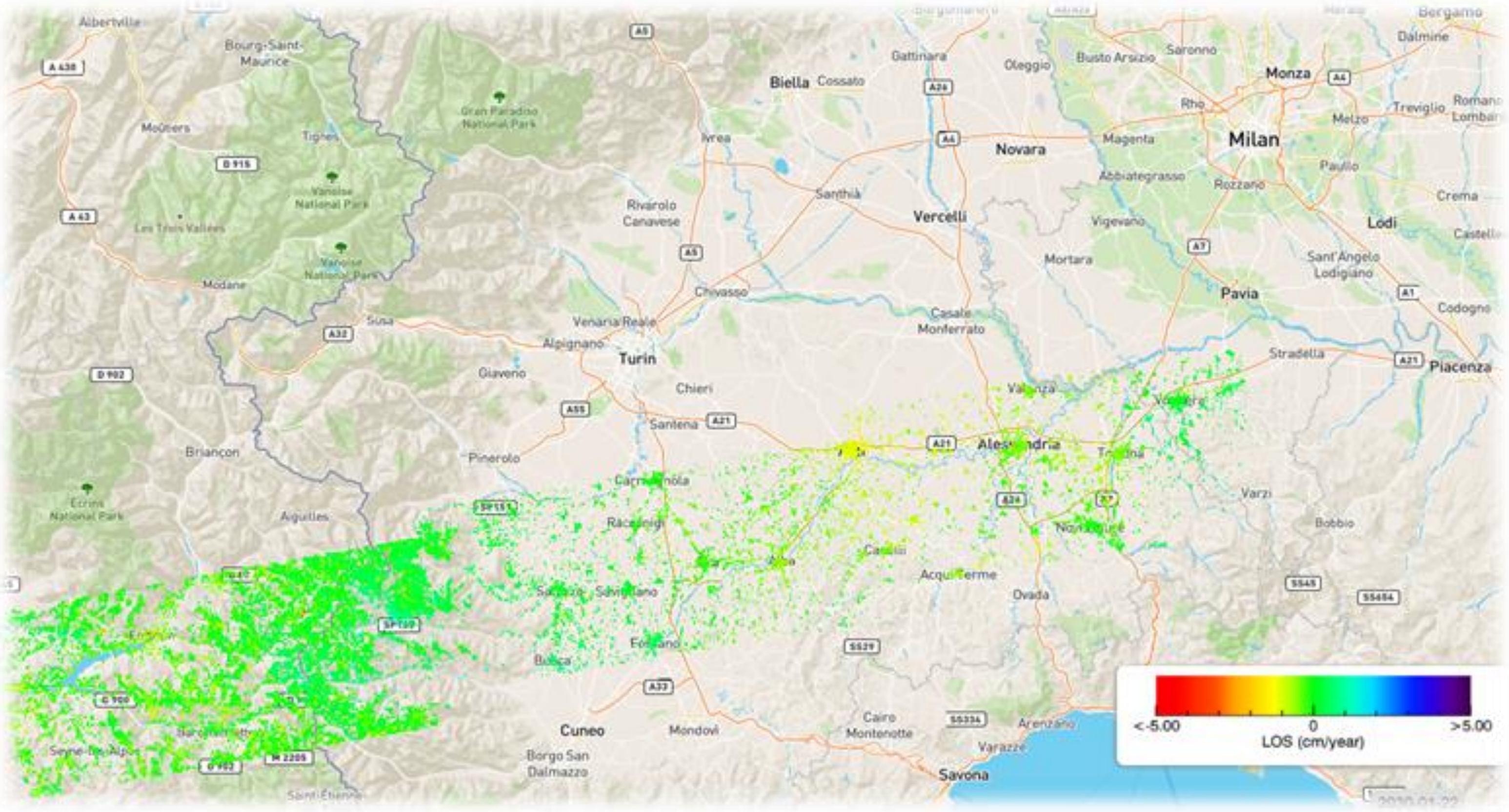
# 1.Results of Time-Series Analysis

MILAN



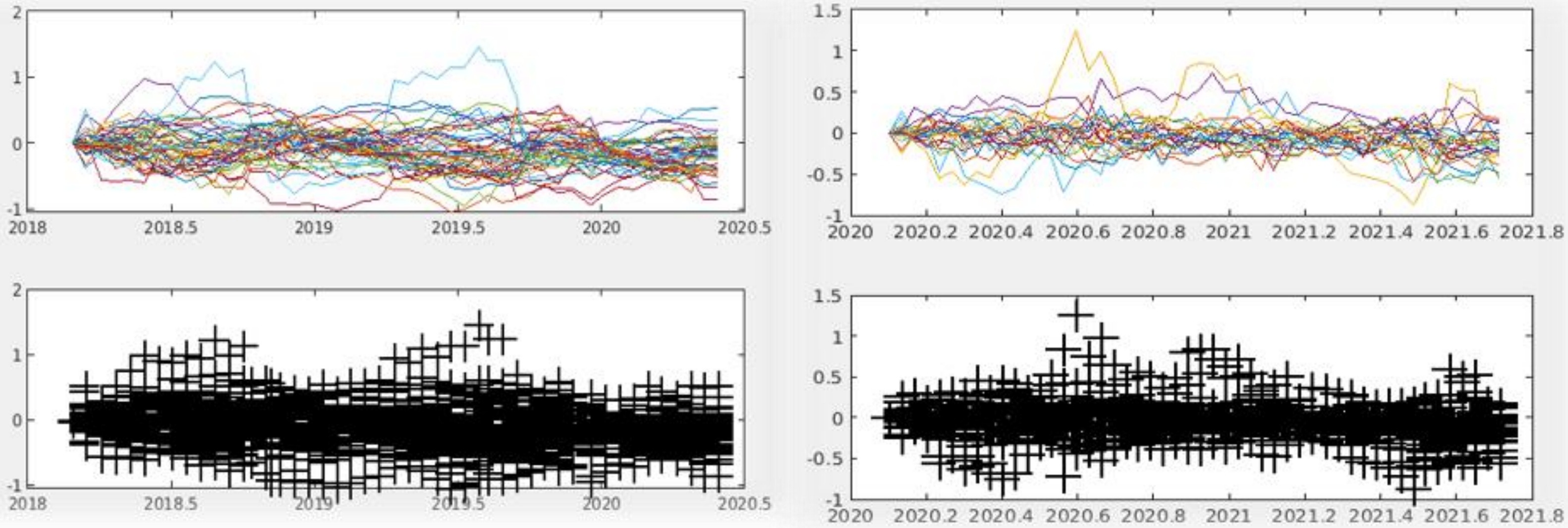
# 1.Results of Time-Series Analysis

UBAYE



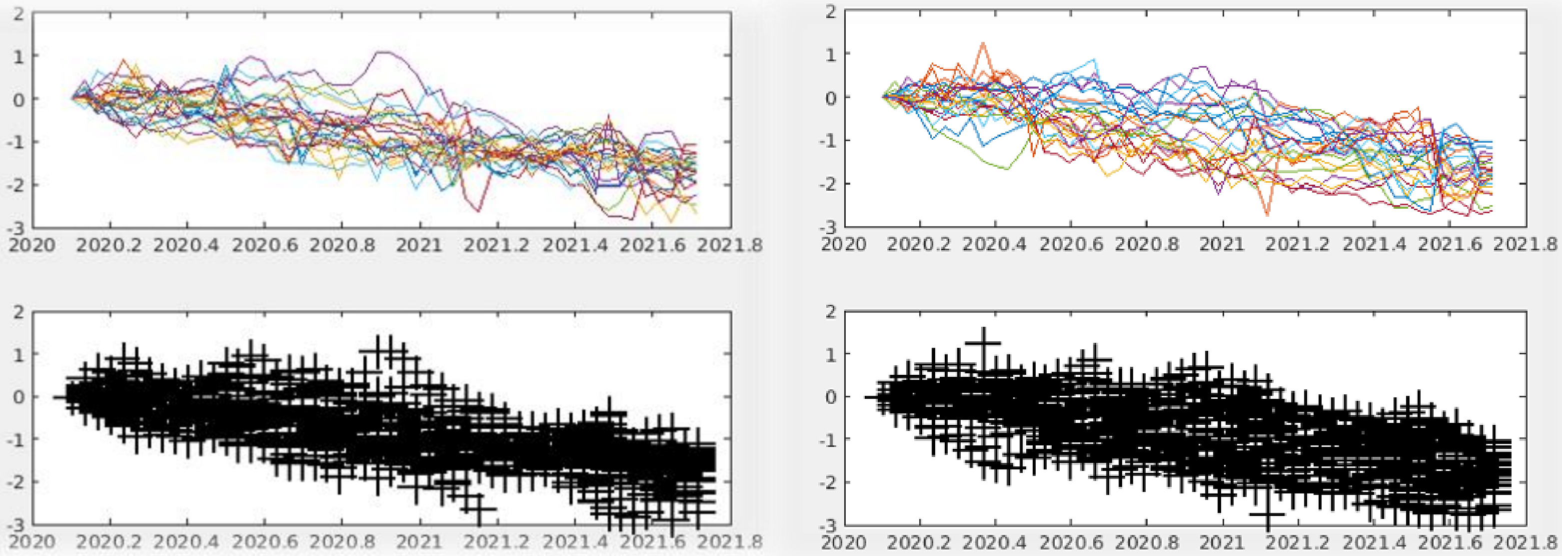
# 2. The Labelling Procedure was the most important and critical idea

# 2.The Methodology (Labelling)




**Stability Class Depending on The Displacement Time-Series (from 0 to - 0.3 cm/year)**

# 2.The Methodology (Labelling)




**Movement Class Depending on The Displacement Time-Series (less than - 0.3 cm/year)**

# 2.Results of Time-Series Analysis

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date_of_production: 2021-08-20T01:40:24Z | | | | | | | | | | | | | | | | | | | |
| Service_used_for_generation: EPOSAR | | | | | | | | | | | | | | | | | | | |
| Geographic_CS_type_code: EPSG_4326 | | | | | | | | | | | | | | | | | | | |
| Used_DEM: SRTM_1arcsec | | | | | | | | | | | | | | | | | | | |
| Super_master_SAR_image_ID: S1A_IW_SLC__1SDV_20201009T052719_20201009T052746_034715_040B45_7656.SAFE | | | | | | | | | | | | | | | | | | | |
| Spatial_resolution: 90 | 90 | | | | | | | | | | | | | | | | | | |
| Sensor: S1 | | | | | | | | | | | | | | | | | | | |
| Mode: IW | | | | | | | | | | | | | | | | | | | |
| Antenna_side: Right | | | | | | | | | | | | | | | | | | | |
| Relative_orbit_number: 168 | | | | | | | | | | | | | | | | | | | |
| Orbit_direction: DESCENDING | | | | | | | | | | | | | | | | | | | |
| Wavelenght: 0.055465760 | | | | | | | | | | | | | | | | | | | |
| Value_unit: N/A | deg | deg | m | cm/yr | N/A | N/A | N/A | N/A | cm | | | | | | | | | | |
| Number_of_looks_azimuth: 5 | | | | | | | | | | | | | | | | | | | |
| Number_of_looks_range: 20 | | | | | | | | | | | | | | | | | | | |
| Applied_filter: Goldstein_0.50 | | | | | | | | | | | | | | | | | | | |
| Number_of_dates: 50 | | | | | | | | | | | | | | | | | | | |
| Reference_date: 2020-01-07T05:27:10Z | | | | | | | | | | | | | | | | | | | |
| Reference_point: 8.5550873 45.526160 | | | | | | | | | | | | | | | | | | | |
| Applied_corrections: No_Corrections | | | | | | | | | | | | | | | | | | | |
| Time_Years: 2020.0198 | 2020.0527 | 2020.0856 | 2020.1168 | 2020.1497 | 2020.1865 | 2020.2193 | 2020.2522 | 2020.2835 | 2020.3164 | 2020.3504 | 2020.3833 | 2020.4161 | 2020.4474 | 2020.4803 | 2020.5143 | 2020.5472 | 2020.5801 | 2020.6114 | 2020.644 |
| List_of_dates: 2020-01-07T05:27 | 2020-01-19T | 2020-01-31T | 2020-02-12T | 2020-02-24T | 2020-03-07 | 2020-03-19T | 2020-03-31 | 2020-04-12T | 2020-04-24T | 2020-05-06 | 2020-05-18T | 2020-05-30T | 2020-06-11 | 2020-06-23T | 2020-07-05T | 2020-07-17 | 2020-07-29T | 2020-08-10 | 2020-08-2 |
| Palette: 3 | | | | | | | | | | | | | | | | | | | |
| #### | | | | | | | | | | | | | | | | | | | |
| ID | Lat | Lon | Topo | Vel | Coer | cosN | cosE | cosU | TS | | | | | | | | | | |
| 0 | 46.15375 | 12.16042 | 581.59 | 0.1866 | 0.8810547 | -0.0964655 | 0.5010124 | 0.8600471 | 0 | -0.1461 | 0.0885 | 0.0731 | -0.0214 | 0.0709 | 0.152 | 0.0721 | 0.0213 | 0.0219 | 0.109 |
| 1 | 46.15375 | 12.16042 | 579.39 | -0.1293 | 0.90523 | -0.0964646 | 0.5010077 | 0.8600499 | 0 | -0.2319 | 0.027 | 0.1618 | 0.0753 | 0.3563 | 0.1268 | 0.226 | 0.074 | 0.2441 | 0.328 |
| 2 | 46.15292 | 12.16042 | 576.72 | -0.3944 | 0.8591992 | -0.0964635 | 0.5010019 | 0.8600534 | 0 | -0.2095 | 0.0211 | 0.0834 | 0.0421 | 0.0297 | -0.0312 | -0.1419 | -0.0876 | -0.2021 | 0.067 |
| 3 | 46.15208 | 12.15958 | 575.1 | 0.2771 | 0.8610231 | -0.0964628 | 0.5009984 | 0.8600555 | 0 | -0.0547 | 0.0156 | 0.1143 | -0.0828 | 0.0473 | 0.1846 | 0.2394 | 0.2619 | 0.1096 | 0.239 |
| 4 | 46.15125 | 12.15958 | 575.74 | -0.2266 | 0.9325786 | -0.0964628 | 0.5010003 | 0.8600544 | 0 | -0.1252 | 0.0099 | 0.0879 | -0.0658 | 0.0161 | 0.0036 | 0.0176 | 0.1336 | 0.1056 | 0.249 |
| 5 | 46.12458 | 12.15292 | 524.63 | -0.3035 | 0.9417927 | -0.0964378 | 0.5008977 | 0.860117 | 0 | -0.0249 | 0.0169 | -0.0031 | 0.202 | 0.141 | 0.1697 | 0.172 | 0.1402 | 0.0175 | 0.323 |
| 6 | 46.12375 | 12.15292 | 526.3 | -0.0181 | 0.8916284 | -0.0964381 | 0.5009019 | 0.8601145 | 0 | 0.0385 | -0.034 | 0.0821 | 0.2626 | 0.1612 | 0.1675 | 0.1278 | 0.1669 | 0.0431 | 0.128 |
| 7 | 46.12292 | 12.15292 | 525.65 | -0.0676 | 0.8902928 | -0.0964377 | 0.5009007 | 0.8601152 | 0 | 0.0356 | -0.0468 | 0.0941 | 0.3324 | 0.1857 | 0.1346 | 0.0539 | 0.1586 | 0.0006 | 0.136 |
| 8 | 46.11375 | 12.15208 | 433.52 | -0.0578 | 0.8708078 | -0.0964058 | 0.5006932 | 0.8602397 | 0 | 0.011 | 0.1622 | 0.2161 | 0.1408 | 0.1773 | 0.2412 | 0.2294 | 0.0108 | 0.1168 | 0.357 |
| 9 | 46.11292 | 12.15208 | 431.32 | -0.1138 | 0.8870394 | -0.0964049 | 0.5006884 | 0.8602425 | 0 | 0.0019 | 0.1739 | 0.1587 | -0.0423 | -0.0427 | 0.0995 | 0.1526 | -0.1155 | -0.0769 | 0.18 |
| 10 | 46.11208 | 12.15208 | 433.76 | 0.0208 | 0.8924841 | -0.0964054 | 0.5006945 | 0.860239 | 0 | -0.0617 | 0.1672 | 0.1145 | -0.045 | -0.0606 | 0.0672 | -0.0333 | -0.0676 | -0.0678 | 0.188 |
| 11 | [illegible] | [illegible] | 431.78 | [illegible] | [illegible] | -0.0964046 | 0.5006902 | 0.8602415 | 0 | -0.1287 | 0.2314 | -0.0101 | -0.0023 | 0.0036 | 0.1171 | 0.0639 | -0.2372 | -0.2374 | -0.053 |

# 2.Results of Labelling Methodology



| | A | B | C | D | E |
|---|---|---|---|---|---|
| 3 | Movement | 0.970812 | 44.96375 | 11.73958 | -0.6357 |
| 4 | Movement | 0.9958739 | 44.96458 | 11.68292 | -0.6883 |
| 5 | Movement | 0.8564658 | 44.96625 | 11.73458 | -0.3221 |
| 6 | Stability | 0.9749139 | 44.96708 | 11.71625 | -0.2681 |
| 7 | Movement | 0.8740339 | 44.96792 | 11.72208 | -0.5 |
| 8 | Stability | 0.990781 | 44.96875 | 11.64958 | -0.2316 |
| 9 | Movement | 0.8945372 | 44.96958 | 11.74375 | -0.4497 |
| 0 | Movement | 0.8731802 | 44.97042 | 11.71208 | -0.4696 |
| 1 | Stability | 0.9751111 | 44.97125 | 11.72042 | -0.2661 |
| 2 | Stability | 0.9689941 | 44.97208 | 11.70958 | -0.1668 |
| 3 | Stability | 0.9689941 | 44.97208 | 11.70958 | -0.2207 |
| 4 | Movement | 0.9163603 | 44.97292 | 11.61542 | -0.9545 |
| 5 | Movement | 0.929069 | 44.97375 | 11.63292 | -0.6563 |
| 6 | Movement | 0.9931934 | 44.97458 | 11.63458 | -0.3216 |
| 7 | Movement | 0.9319142 | 44.97542 | 11.62625 | -0.6074 |
| 8 | Movement | 0.9072196 | 44.97625 | 11.62792 | -0.5049 |
| 9 | Movement | 0.9492776 | 44.97708 | 11.59042 | -0.3199 |
| 0 | Movement | 0.8707342 | 44.97792 | 11.58958 | -0.4959 |
| 1 | Movement | 0.9062911 | 44.97875 | 11.57208 | -0.3038 |
| 2 | Movement | 0.9043427 | 44.97958 | 11.62958 | -0.7534 |
| 3 | Movement | 0.9565856 | 44.98042 | 11.62208 | -0.3044 |
| 4 | Movement | 0.8933095 | 44.98125 | 11.68042 | -0.8979 |
| 5 | Stability | 0.8751608 | 44.98208 | 11.61458 | -0.2904 |
| 6 | Movement | 0.9493834 | 44.98292 | 11.64542 | -0.417 |
| 7 | Movement | 0.9405783 | 44.98375 | 11.59875 | -0.3643 |
| 8 | Stability | 0.9994925 | 44.98458 | 11.60958 | -0.1821 |
| 9 | Stability | 0.9994925 | 44.98458 | 11.60958 | -0.1823 |
| 0 | Movement | 0.8841575 | 44.98542 | 11.62708 | -0.4861 |
| 1 | Stability | 0.9958365 | 44.98708 | 11.50958 | -0.1631 |
| 2 | Stability | 0.936958 | 44.98792 | 11.50458 | -0.0023 |
| 3 | Stability | 0.9957873 | 44.99042 | 11.50958 | -0.2359 |

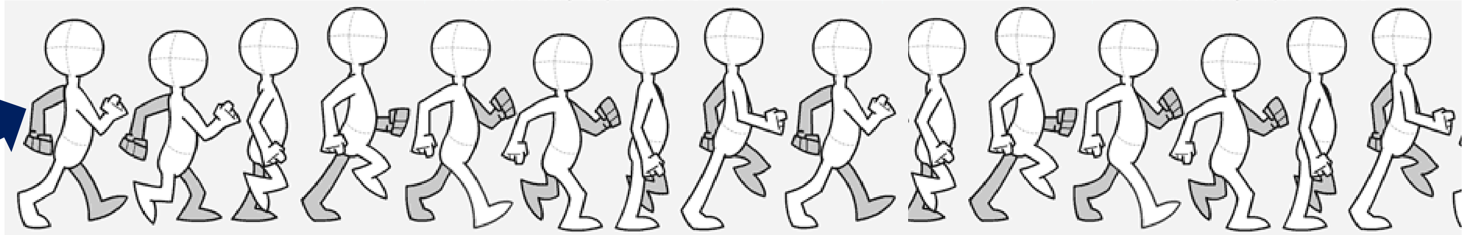
**A Labels**
**B Coherence**
**C Latitude**
**D Longitude**
**E Velocity**

# Explanation

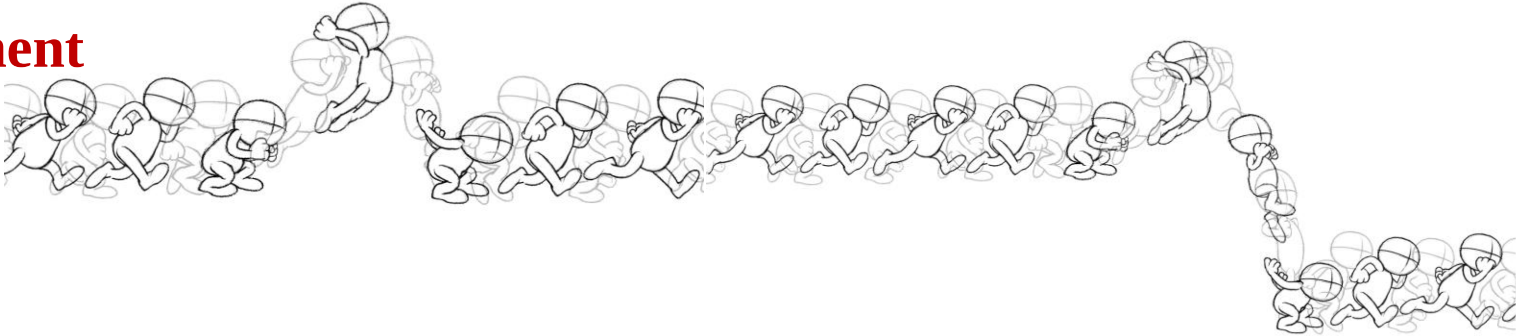
## Simplified Explanation:

**Stability**

**Pixel**



**Movement**

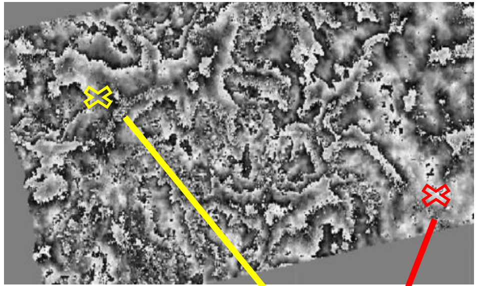


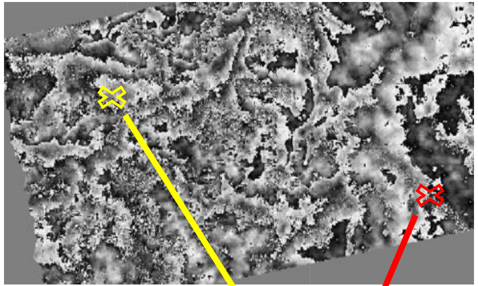
**Interferograms**

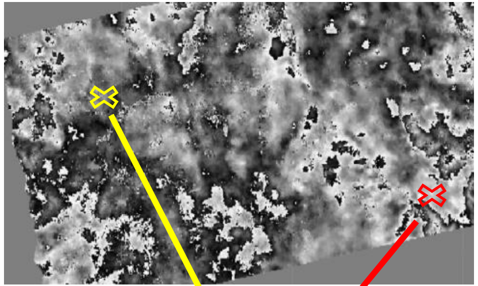
# Explanation



## Provided that the selected pixels meet the coherence threshold 0.6







| | | | | |
|---|---|---|---|---|
| Sample 1 | 0.1 | 0 | ..................... | 0.05 |
| Sample 2 | 0.3 | 0.01 | ..................... | 1 |
| . | . | . | | . |
| . | . | . | | . |
| . | . | . | | . |
| . | . | . | | . |
| Sample m | 1 | 0.2 | ..................... | 0.8 |

# 2.Results of Labelling Methodology

OUTPUTS

INPUTS

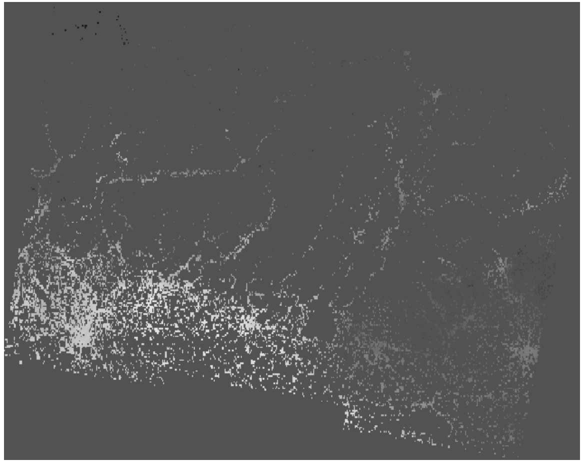
| Lat | Lon | Name | Vel | | | | 7378152722 | 737827LHAH | 737827Q6GC | 7378394KGK | 737845A77I | 737845AIXV | 737845N4J5 | 737851MQ15 | 737851U5JG | 737851UV00 | 737857Q7SA | 737875I135 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 45.0246 | 11.639 | Movemer | -0.8173 | | | | 0 | 0 | 1 | 0.43115 | 1 | 0.43395 | 0 | 0 | 1 | 0 | 0 | |
| 45.3421 | 10.874 | Stability | -0.0477 | | | | 0 | 0.42113 | 1 | 1 | 1 | 0.12104 | 0 | 0 | 0.43027 | 0 | 0 | |
| 45.3646 | 11.002 | Stability | -0.0126 | 0 | 0 | 1 | 0 | 0 | 1 | 0.68332 | 1 | 0 | 0 | 0 | 0.26682 | 0 | 0.13897 | |
| 46.0571 | 11.237 | Stability | -0.166 | 1 | 0.38005 | 1 | 0 | 0.98912 | 1 | 0 | 0.92665 | 0 | 0 | 0 | 0 | 0 | 0.14262 | |
| 45.6996 | 11.435 | Stability | -0.1523 | 0 | 0 | 0.71696 | 0 | 0 | 1 | 0.0015496 | 1 | 0 | 0 | 0 | 0.16037 | 0 | 0.7705 | |
| 46.0012 | 11.341 | Stability | -0.2209 | 0.15903 | 0.33128 | 1 | 0 | 0.52753 | 0.94481 | 0.049974 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 45.0729 | 11.753 | Movemer | -0.5278 | 0 | 0 | 0.74383 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | |
| 45.5321 | 11.582 | Movemer | -0.9585 | 0 | 0 | 0.32964 | 0.18592 | 0 | 0.96405 | 0.84097 | 1 | 0.84464 | 0 | 0 | 0.39873 | 0 | 0.74888 | |
| 46.1737 | 11.220 | Movemer | -0.5086 | 1 | 0.78335 | 1 | 0 | 1 | 0.70659 | 0 | 0.83682 | 0 | 0 | 0 | 1 | 0.074384 | 0.46576 | |
| 45.5063 | 10.942 | Stability | -0.0387 | 0 | 0 | 1 | 0 | 0.50673 | 1 | 0.12842 | 1 | 0 | 0 | 0 | 0 | 0 | 0.9328 | |
| 46.4079 | 11.137 | Movemer | -0.6435 | 0.26455 | 0.17046 | 1 | 0 | 0.6692 | 0.81384 | 0 | 0.80164 | 0 | 0 | 0 | 1 | 1 | 1 | |
| 45.4504 | 10.932 | Stability | -0.214 | 0 | 0 | 0.94224 | 0 | 0.72864 | 1 | 0.88553 | 1 | 0 | 0 | 0 | 0 | 0 | 0.71877 | |
| 45.7563 | 11.003 | Stability | -0.2478 | 0.26838 | 0 | 1 | 0 | 0.057572 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0.2256 | |
| 46.4937 | 11.358 | Stability | -0.1431 | 0.69729 | 0.24607 | 1 | 0 | 1 | 0.78695 | 0 | 1 | 0.43667 | 0 | 0 | 1 | 1 | 1 | |
| 46.0112 | 11.310 | Stability | -0.0208 | 0.27541 | 0.15375 | 1 | 0 | 0.63427 | 1 | 0.11547 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 46.3862 | 11.252 | Stability | -0.0213 | 1 | 0.55442 | 1 | 0 | 0.85284 | 0.56808 | 0 | 0.30961 | 0 | 0 | 0 | 1 | 1 | 1 | |
| 45.7046 | 11.677 | Movemer | -0.455 | 0 | 0 | 1 | 0.26181 | 0 | 1 | 0 | 1 | 0.54494 | 0 | 0 | 0.32444 | 0 | 1 | |
| 46.0154 | 11.264 | Movemer | -0.3075 | 1 | 0.27979 | 1 | 0 | 0.66768 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 45.3421 | 10.939 | | -0.0543 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0.37345 | 0 | 0 | |
| 45.0812 | 11.489 | | -0.4452 | 0 | 0 | 1 | 0 | 0 | 1 | 0.34386 | 1 | 0.47467 | 0 | 0 | 1 | 0 | 0.019397 | |
| 46.3446 | 11.337 | | -0.0532 | 0.69216 | 1 | 0.72429 | 0 | 0.85804 | 0 | 0 | 0.1743 | 0 | 0.087646 | 0 | 1 | 1 | 1 | |
| 45.8829 | 11.032 | | -0.3818 | 0.97183 | 0.42659 | 1 | 0 | 0.064319 | 1 | 0 | 0.2546 | 0 | 0 | 0 | 0.1593 | 0 | 0.0033954 | |
| 45.5321 | 11.062 | | -0.0758 | 0 | 0 | 0.95749 | 0.098701 | 0 | 1 | 0.63881 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 45.7313 | 11.494 | | -0.1217 | 0 | 0 | 0.29799 | 0 | 0.17136 | 1 | 0.39595 | 1 | 0 | 0 | 0 | 0.21864 | 0 | 0.87264 | |
| 46.3362 | 11.238 | | -0.404 | 0.9158 | 0.49213 | 0.6854 | 0 | 0.64346 | 0.19445 | 0 | 0.045097 | 0 | 0 | 0 | 1 | 1 | 1 | |
| 46.0429 | 11.231 | | -0.629 | 1 | 0.30181 | 1 | 0 | 0.41053 | 1 | 0 | 0.64735 | 0 | 0 | 0 | 0 | 0 | 0.069003 | |
| 46.0746 | 11.227 | | -0.3995 | 1 | 1 | 1 | 0 | 0.85366 | 0.99174 | 0 | 0.2935 | 0 | 0 | 0 | 0 | 0.0037171 | 0.54331 | |
| 46.0679 | 11.218 | | -0.1984 | 1 | 1 | 1 | 0 | 0.6976 | 0.77991 | 0 | 0.082691 | 0 | 0 | 0 | 0 | 0 | 0.55958 | |
| 46.0404 | 11.110 | | -0.1274 | 1 | 0.32236 | 1 | 0 | 0.74731 | 1 | 0 | 0.5269 | 0 | 0 | 0 | 1 | 0.34603 | 0.46573 | |
| 45.1446 | 11.007 | | -0.3023 | 0 | 0 | 1 | 0 | 0.0002903 | 1 | 0.75625 | 1 | 0.28671 | 0 | 0 | 1 | 0 | 0 | |
| 45.9029 | 12.009 | | -0.3694 | 0 | 0 | 0.88481 | 0.53677 | 0 | 1 | 0 | 1 | 0.83682 | 0 | 0 | 0.33892 | 0 | 1 | |

## The Labelled Dataset

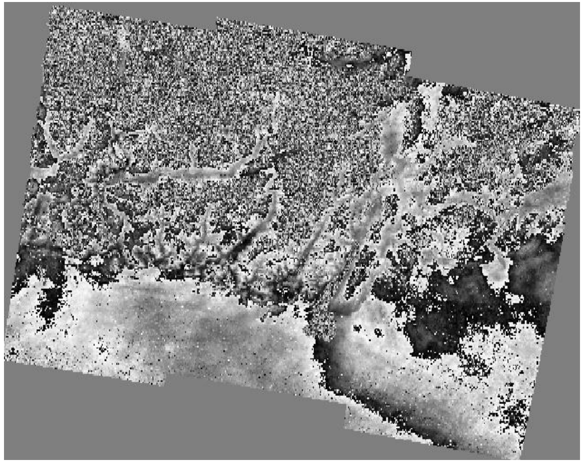
# 2.Results of Labelling Methodology

The main step influencing the precision of the displacement time series is

**phase unwrapping and phase contribution estimation**



Unwrapped Interferogram



Wrapped Interferogram

# 2.Results of Labelling Methodology

## MILAN DATASETS

**First Dataset**

156442 training example extracted from the Unwrapped Interferograms

**Second Dataset**

226967 training example extracted from the Wrapped Interferograms

## UBAYE DATASETS

**First Dataset**

24243 training example extracted from the Unwrapped Interferograms

**Second Dataset**

46440 training example extracted from the Wrapped Interferograms

# 2.The Methodology (Labelling)

## First Phase (One Interferogram)

A. Cut the interferogram into pixels and keep only the pixels that meet a predefined coherence threshold of 0.6

B. Check every pixel in the interferogram if it has more than one measurement point (MP) and select only the MP of the highest coherence

C. Assign a label for each pixel depending on the related velocity value of the MP:

**Velocity < -0.3 cm/year → Stability**

**Velocity >= -0.3 cm/year → Movement**

D. Produce an excel table contains the **latitude, longitude, velocity and label of each selected MP of each pixel**

# 2.The Methodology (Labelling)

**Second Phase (The whole series of the sequenced interferograms)**

A. Cut every pixel contains a MP from the whole sequenced series of the produced interferograms (depending on the latitude and longitude of the MP)

B. Normalize the pixel values ($-\pi$ to $+\pi$ ) to get a new range from 0 to 1

C. Remove zeros and duplicated tapes

D. Label the produced tape of pixels

E. Balance the labels between the two classes (Stability and Movement)

F. Produce the final dataset csv that contains **latitudes, longitudes, velocities , labels and normalized pixel values for each MP**

# 3. Implementing ANN models to train the datasets

# 3.The Methodology (Training)

## Artificial Neural Network Model (ANN)

| HYPERPARAMETERS | | | |
|---|---|---|---|
| **Learning rate** | 0.001 | **L2 Regularization** | 0.003 -0.005 |
| **Number of Dense Layers** | 3 | **Epochs** | 125 - 200 |
| **Batch size** | 1024 | **Loss Function** | Binary Cross Entropy |
| **Metrics** | Accuracy | **Optimizer** | Adam |

# Visualizing And Validating The Results

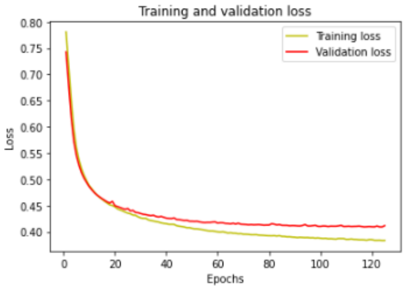


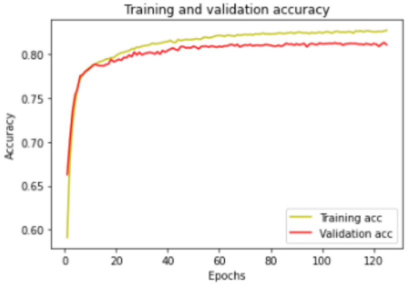
| A | B | C | D | E | F |
|---|---|---|---|---|---|
| | Lat | Lon | Vel | te_yNew | te_y |
| 0 | 44.9637 | 11.7613 | -0.4711 | 0.257573 | 0 |
| 1 | 46.1079 | 11.1037 | -0.2121 | 0.663635 | 1 |
| 2 | 46.5262 | 11.2504 | -0.1643 | 0.15222 | 1 |
| 3 | 45.7788 | 11.0154 | -0.3061 | 0.316986 | 0 |
| 4 | 45.9988 | 11.2629 | -1.0391 | 0.541626 | 0 |
| 5 | 46.0746 | 11.1412 | -0.3159 | 0.774867 | 0 |
| 6 | 45.4521 | 10.9637 | -0.0035 | 0.935744 | 1 |
| 7 | 45.0388 | 11.2221 | -0.2463 | 0.645194 | 1 |
| 8 | 45.0454 | 11.1421 | -0.3467 | 0.34322 | 0 |
| 9 | 45.4046 | 10.9571 | -0.0189 | 0.881704 | 1 |
| 10 | 45.5154 | 10.9121 | -0.1416 | 0.916502 | 1 |
| 11 | 45.6829 | 11.9162 | -1.1502 | 6.80E-08 | 0 |
| 12 | 45.7196 | 11.3129 | -0.1579 | 0.980569 | 1 |
| 13 | 46.1587 | 11.1396 | -0.4257 | 0.029266 | 0 |
| 14 | 45.4396 | 11.0288 | -0.0335 | 0.923004 | 1 |
| 15 | 45.4546 | 10.9004 | -0.158 | 0.90368 | 1 |
| 16 | 45.2537 | 11.1762 | -0.4002 | 0.860114 | 0 |
| 17 | 45.5829 | 11.0454 | -0.232 | 0.021053 | 1 |
| 18 | 45.1229 | 10.9046 | -0.1371 | 0.869931 | 1 |
| 19 | 45.1013 | 11.6613 | -0.3472 | 0.044764 | 0 |
| 20 | 46.0671 | 11.2104 | -0.2022 | 0.673283 | 1 |
| 21 | 46.0412 | 11.1154 | -0.0706 | 0.745586 | 1 |
| 22 | 46.2163 | 11.0979 | -0.2636 | 0.88941 | 1 |
| 23 | 46.0504 | 11.4654 | -0.9878 | 0.003665 | 0 |
| 24 | [illegible] | [illegible] | [illegible] | [illegible] | 1 |

# 3.Results of Milan Dataset

## Model for the Unwrapped Interferograms

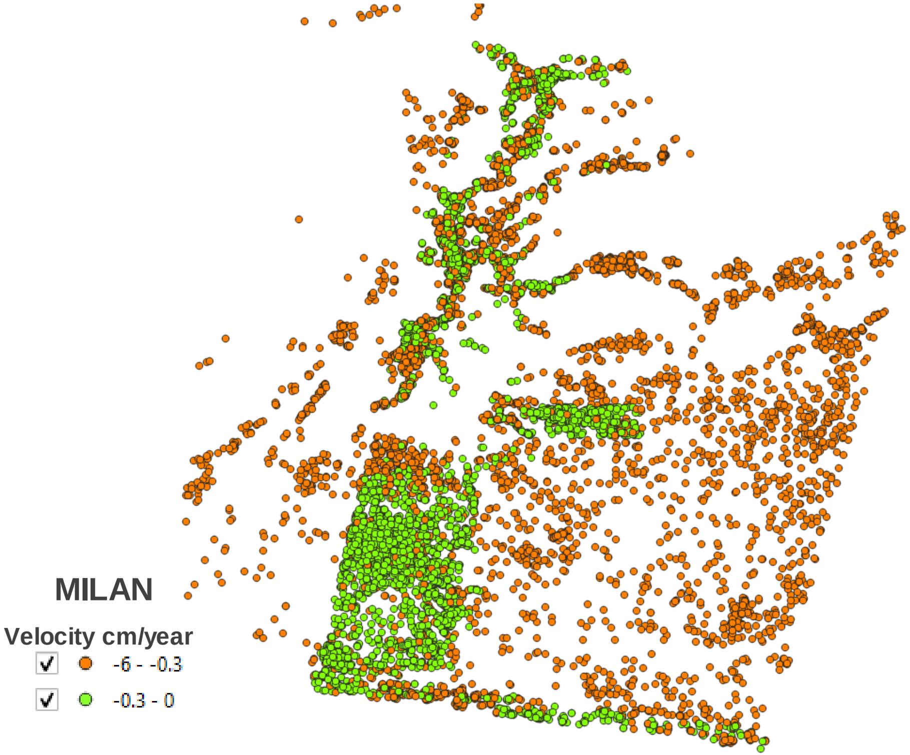
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_184 (Dense)            (None, 16)                1280

dense_185 (Dense)            (None, 32)                544

dense_186 (Dense)            (None, 1)                 33

=================================================================
Total params: 1,857
Trainable params: 1,857
Non-trainable params: 0
_________________________________________________________________
```




## Cross validation (5 folds) for 30000 Training Examples

```
Accuracy: 0.802 (0.002)
```

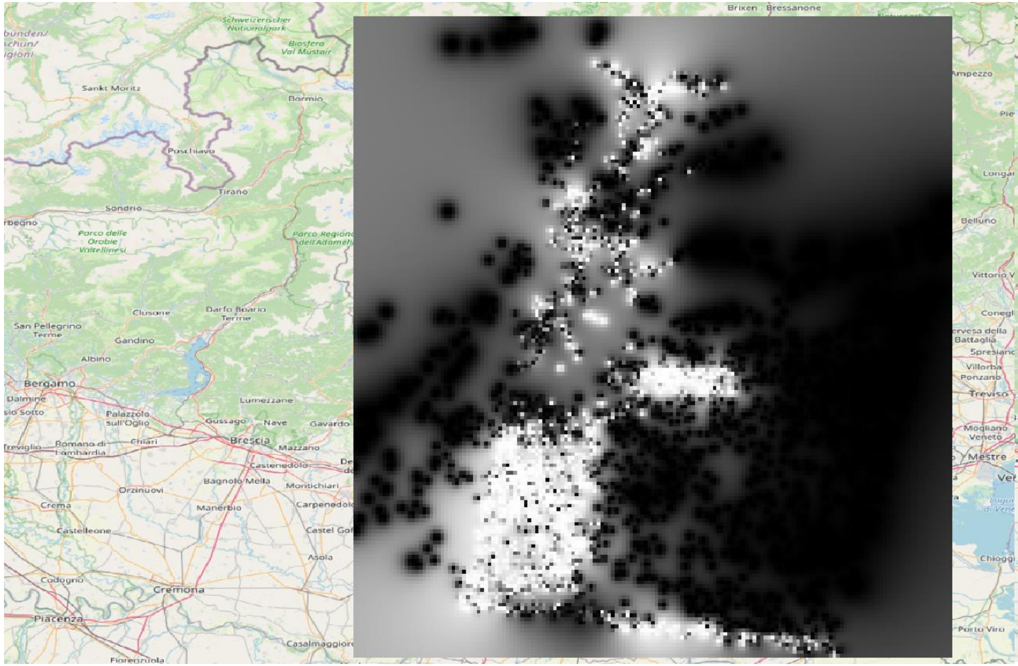


# 3.Results of Milan Dataset

## Results of the Unwrapped Interferograms

```
--------------------------------------------------------------------------------
Accuracy: 0.802 (0.002)
```

### Ground Truth



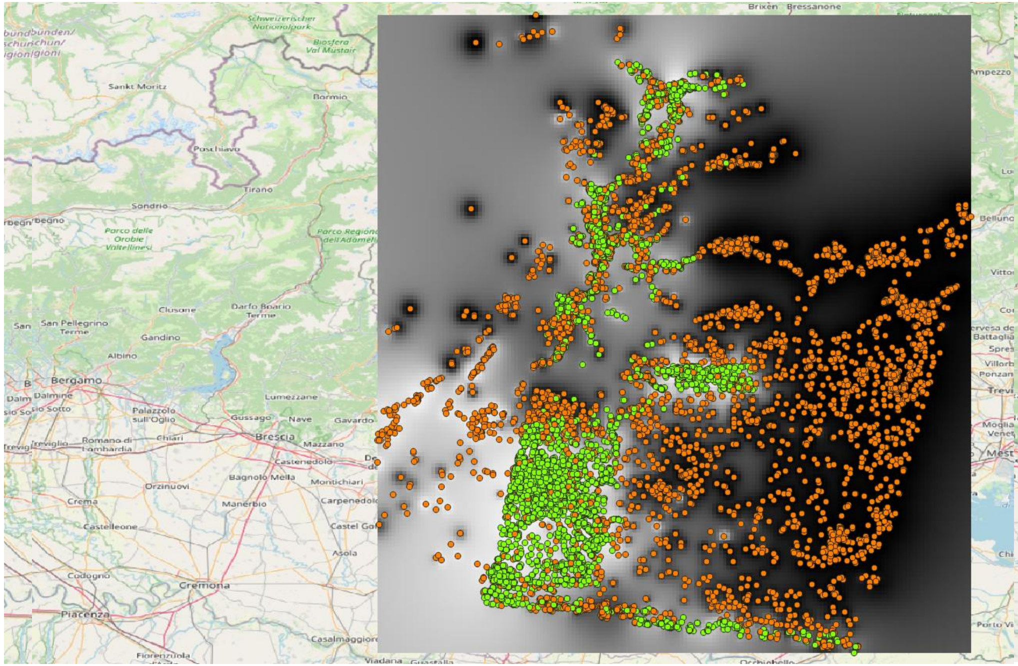
### Prediction

# 3.Results of Milan Dataset

## Results of the Unwrapped Interferograms

```
Accuracy: 0.802 (0.002)
```

### Ground Truth

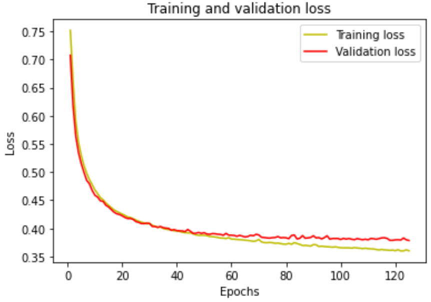


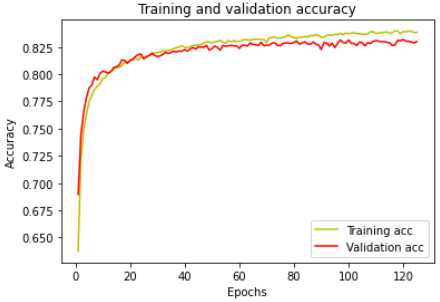
### Prediction

# 3.Results of Milan Dataset

## Model for the Wrapped Interferograms

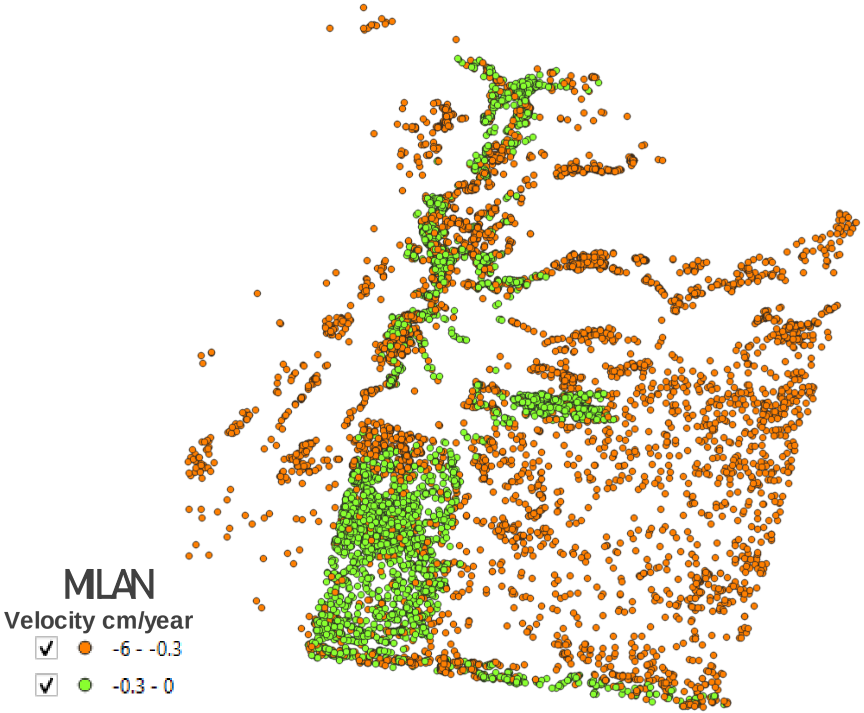
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_169 (Dense)            (None, 16)                2192

dense_170 (Dense)            (None, 32)                544

dense_171 (Dense)            (None, 1)                 33

=================================================================
Total params: 2,769
Trainable params: 2,769
Non-trainable params: 0
_________________________________________________________________
```




## Cross validation (5 folds) for 30000 Training Examples

```
Accuracy: 0.809 (0.003)
```



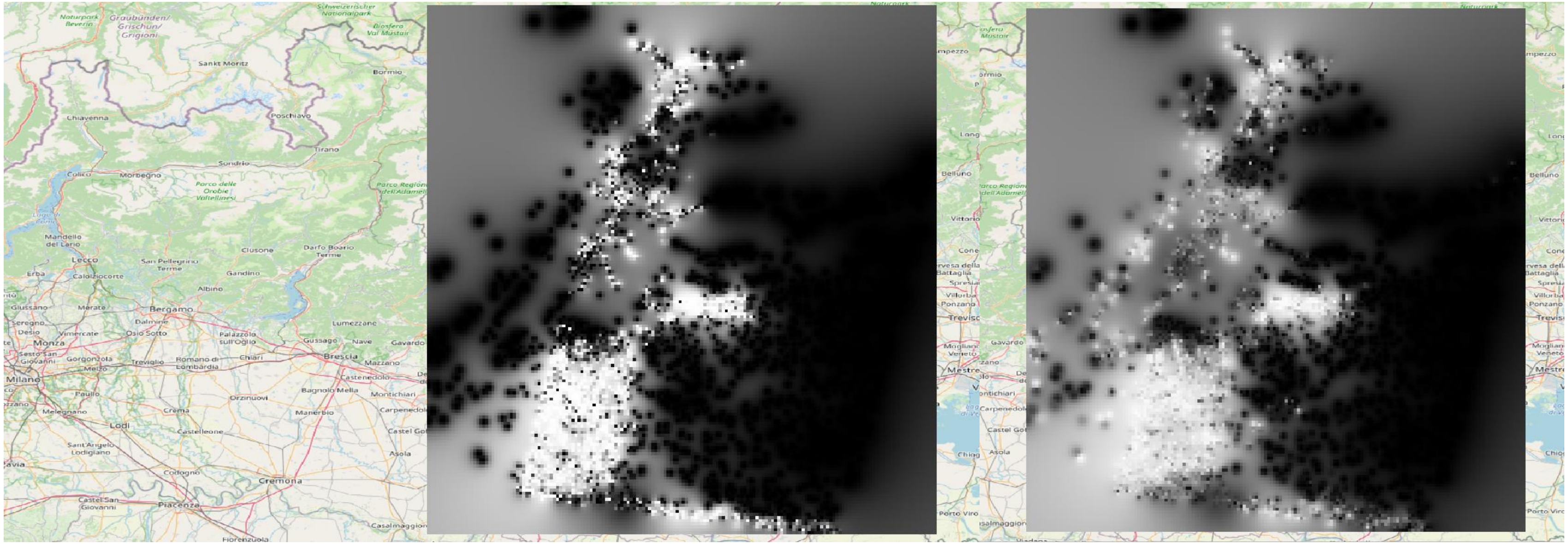
# 3.Results of Milan Dataset



## Results of the Wrapped Interferograms

Accuracy: 0.809 (0.003)

**Ground Truth** **Prediction**

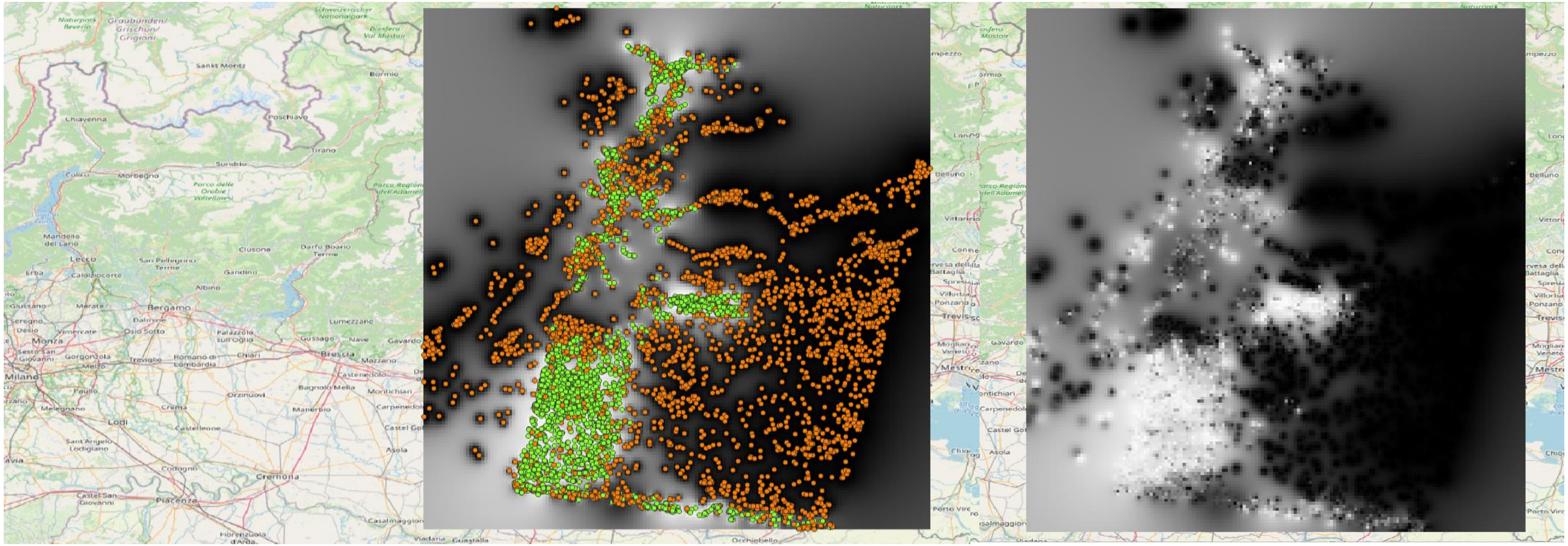


# 3.Results of Milan Dataset

## Results of the Wrapped Interferograms

Accuracy: 0.809 (0.003)

**Ground Truth** **Prediction**

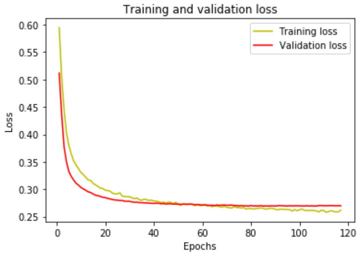


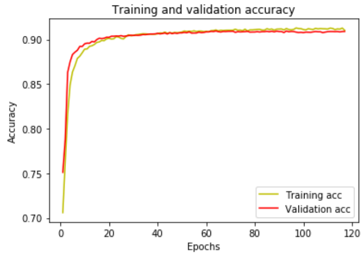
# 3.Results of Milan Dataset

# 3.Results of Milan Dataset

Model for the Wrapped Interferograms

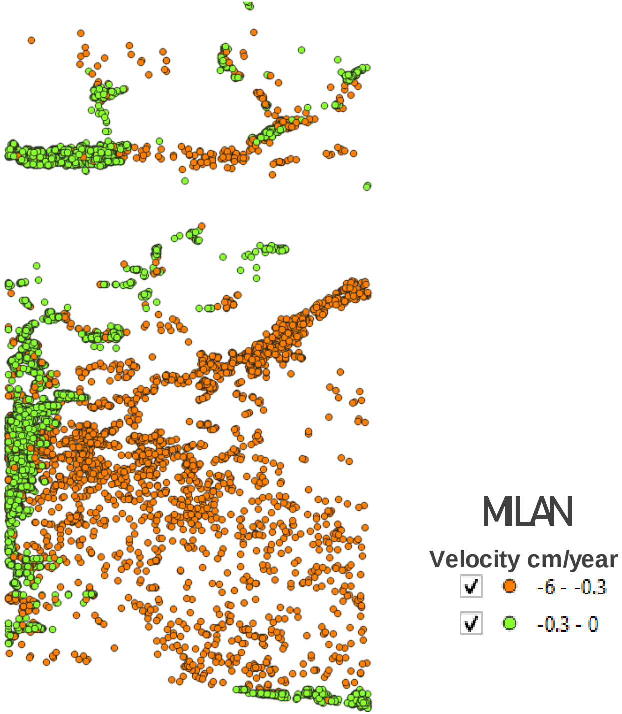
```
Model: "sequential_25"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_75 (Dense)             (None, 25)                2000

dropout_40 (Dropout)         (None, 25)                0

dense_76 (Dense)             (None, 50)                1300

dropout_41 (Dropout)         (None, 50)                0

dense_77 (Dense)             (None, 1)                 51

=================================================================
Total params: 3,351
Trainable params: 3,351
Non-trainable params: 0
_________________________________________________________________
```



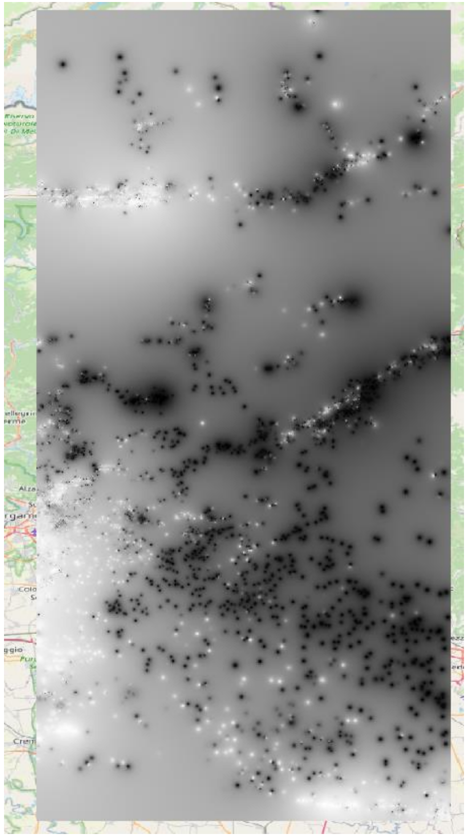

## Cross validation (5 folds) for 40000 Training Examples (Different Area)

```
Accuracy: 0.783 (0.003)
```

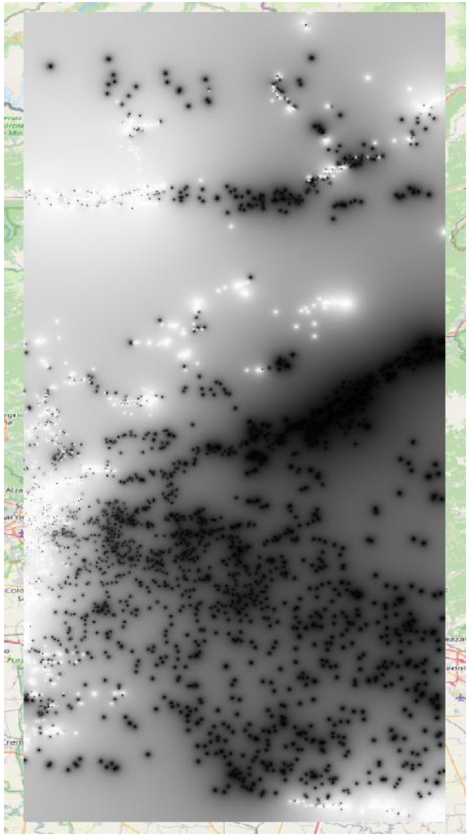


# 3.Results of Milan Dataset

Prediction



Ground Truth



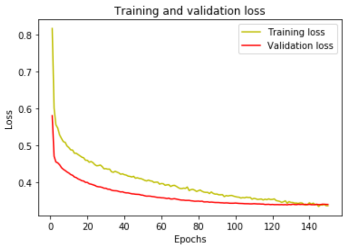
## Results of the Wrapped Interferograms

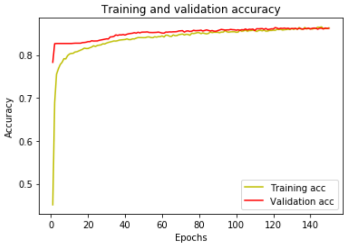
```
Accuracy: 0.783 (0.003)
```

# 3.Results of Ubaye Dataset

## Model for the Wrapped Interferograms

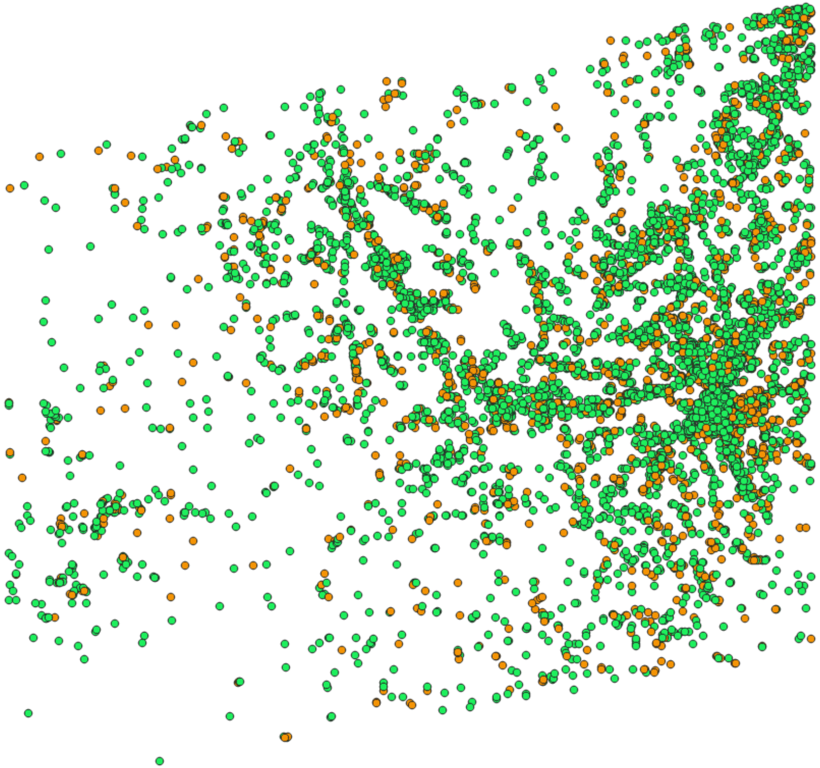
```
Model: "sequential_71"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_213 (Dense)            (None, 25)                2150

dropout_121 (Dropout)        (None, 25)                0

dense_214 (Dense)            (None, 10)                260

dropout_122 (Dropout)        (None, 10)                0

dense_215 (Dense)            (None, 1)                 11

=================================================================
Total params: 2,421
Trainable params: 2,421
Non-trainable params: 0
_________________________________________________________________
```




## Cross validation (5 folds) for 22000 Training Examples **(Different Area)**

Accuracy: 0.743 (0.001)



UBAYE

Velocity cm/year

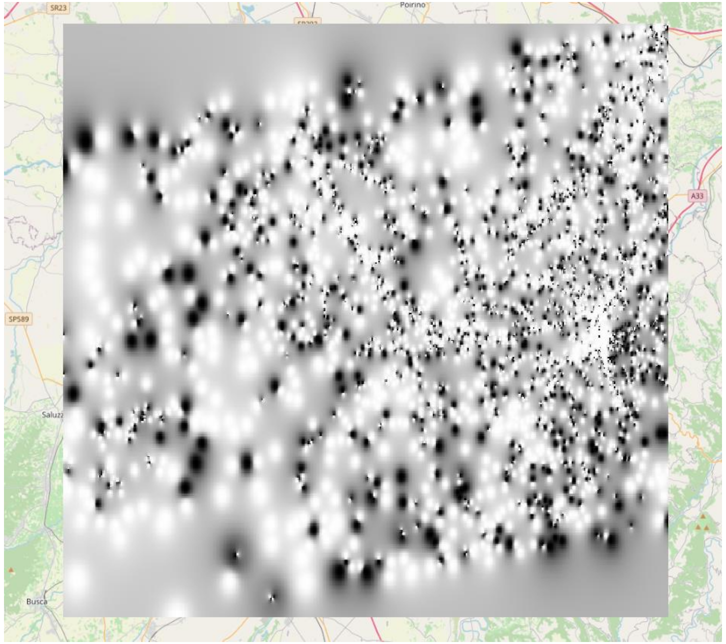
- ✓ -6 - -0.3
- ✓ -0.3 - 0

# 3.Results of Ubaye Dataset

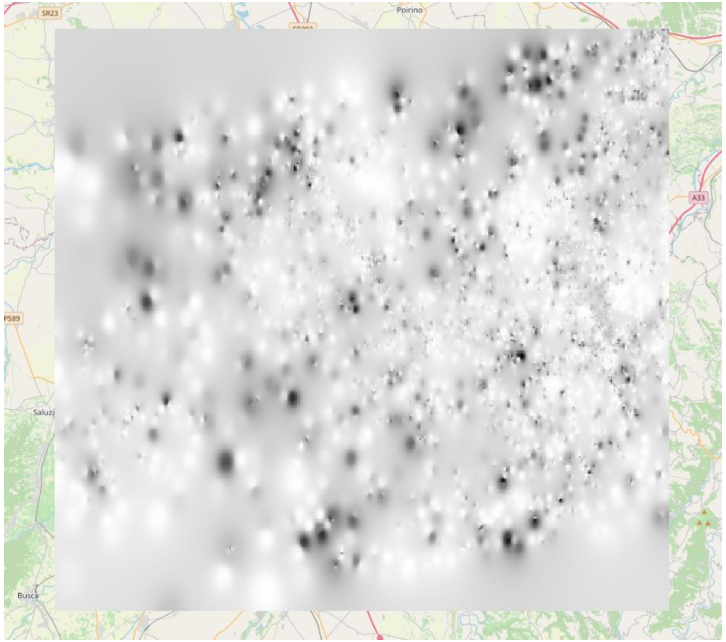
**Results of the Wrapped Interferograms**

```
Accuracy: 0.743 (0.001)
```

## Ground Truth




## Prediction



# FUTURE WORK PLAN

**Using Intelligent algorithms in developing a methodology that can automatically analyze large InSar data packets and identify areas where infrastructure are at risk of displacement due to ground movement**

# FUTURE WORK PLAN

- **Implementing LSTM Algorithm to develop a predictive model for the timeseries of displacements (the number of predicted time steps should be defined)**
- **Developing the ArcGIS Toolbox**

# Thanks for the attention

1222 · 2022
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