Dynamic Landslide Evaluation Using PSI for Environmental Impact Assessment

Luis Carlos Mabaquiao
University of the Philippines

Landslide

A landslide is defined as the movement of a mass of rock, debris, or earth down a slope under the influence of gravity

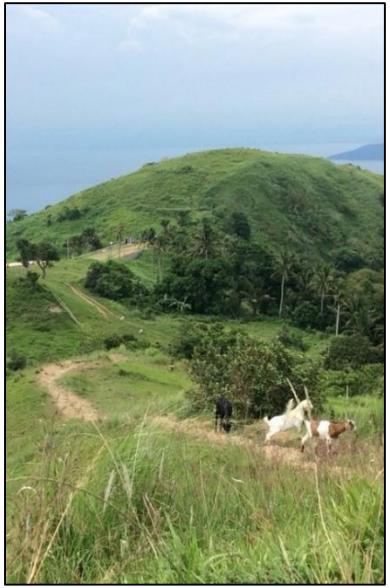
(Cruden et.al., 1996)

Landslide

Reactive processes that move or relocate materials that have become unstable due to **external forces** to maintain stability

(Crozier and Glade, 2005)

Impacts of Landslide



ENVIRONMENT

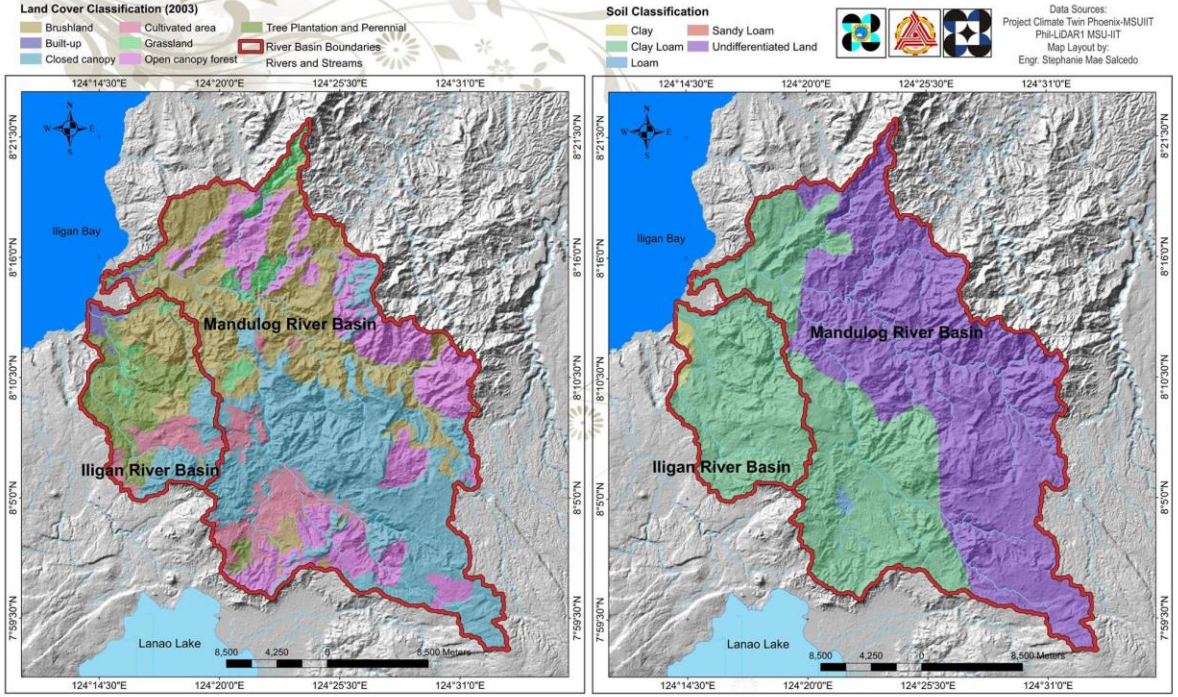
ECONOMY

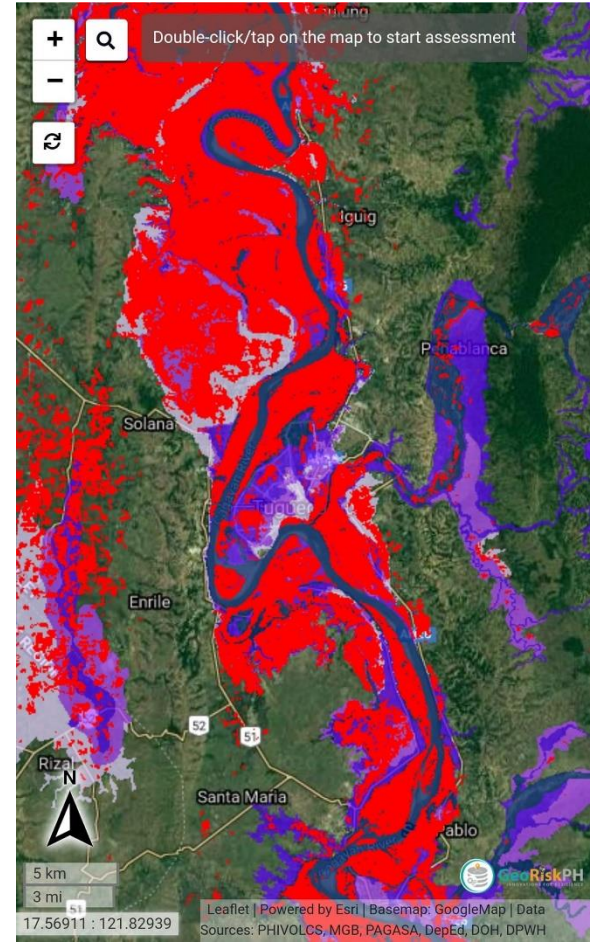
CASUALTY

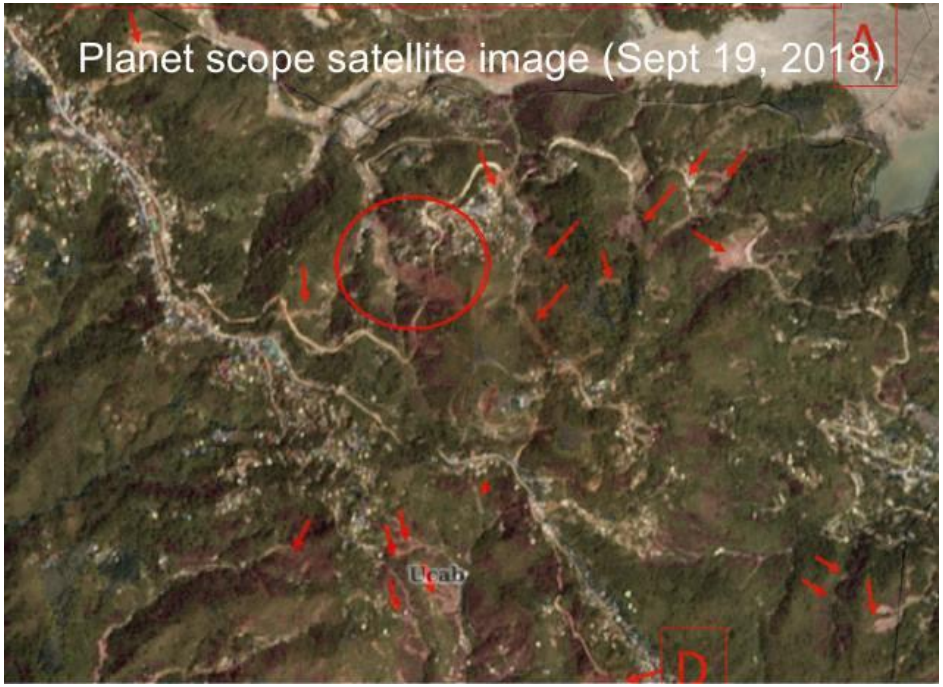
Philippines

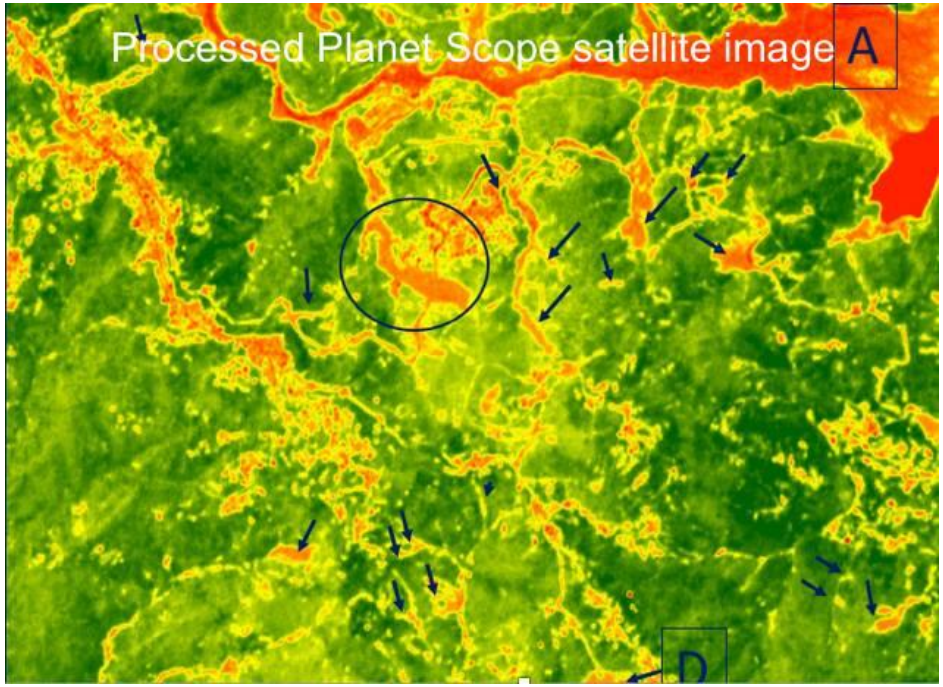
- Center of the Pacific Ring of Fire
- 20 Tropical Cyclones (annually)
- Typhoon Odette (Rai) - 11.1B USD
  - Agricultural Crops
  - Farmlands
- Flooding and Landslides

Iligan & Mandulog River Basins' Land Cover and Soil Map






Planet scope satellite image (Sept 19, 2018)
A
Ucab
D


Processed Planet Scope satellite image
A
D

Landslide-Affected Areas

Brgy. Bunga, Baybay, Leyte

15 April 2022

Datum: WGS 84

0 50 100 150 200 m

Legend

- Buildings/Houses
- Landslide Extent

Map Information

This map shows landslide extents and affected buildings as of April 15, 2022. The map is still subject to validation and the interpretation of remote sensing experts.

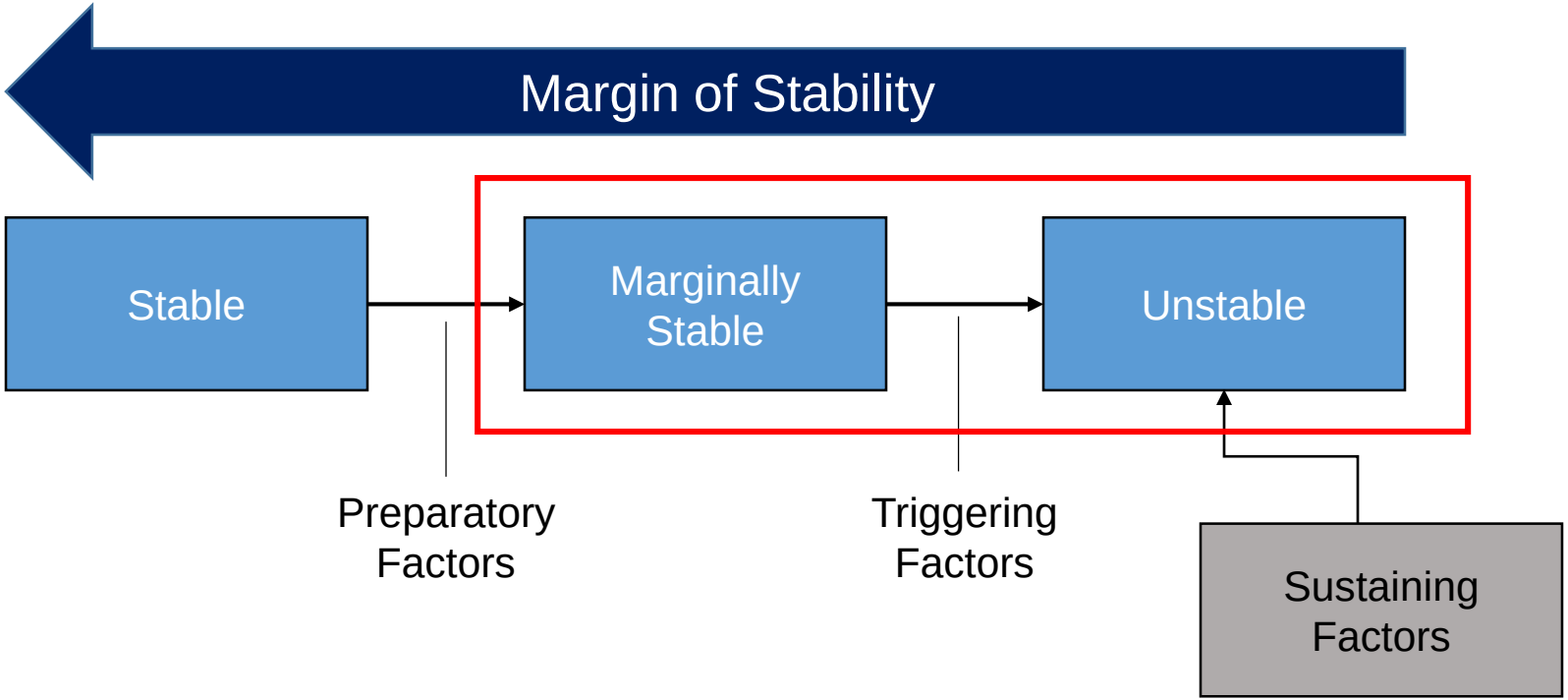
Data Sources

Very High Resolution satellite image from Kompsat-3 provided by DOST-ASTI's PEDRO Center.
Basemap by OSM.

DOST DOST-ASTI PHILSA

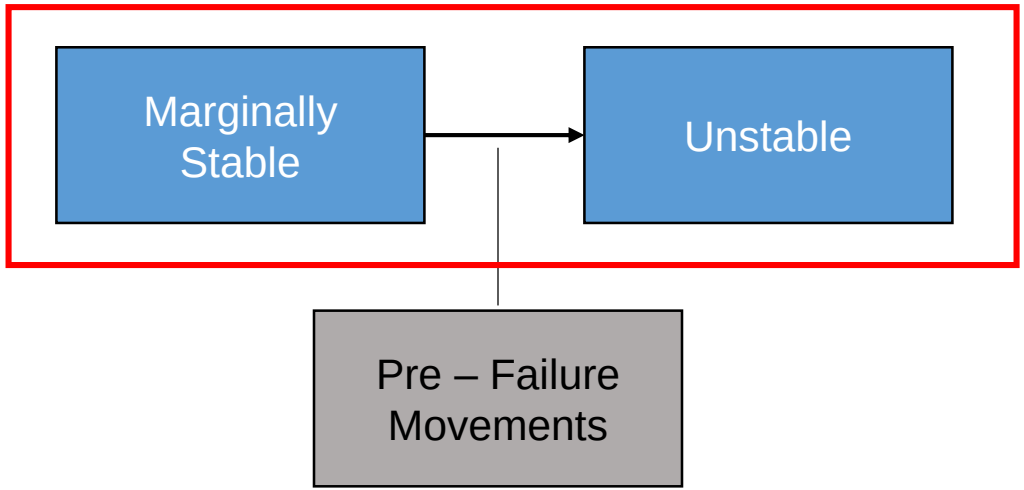
PRODUCED 19 APRIL 2022

Slope States (Crozier, 1989)



Slope Failure

Failure - single most significant movement in the anticipated history of a landslide (Hungr et.al, 2014)



Landslide Hazard Evaluation
in the Philippines

STATIC

DYNAMIC

Microwave REMOTE SENSING

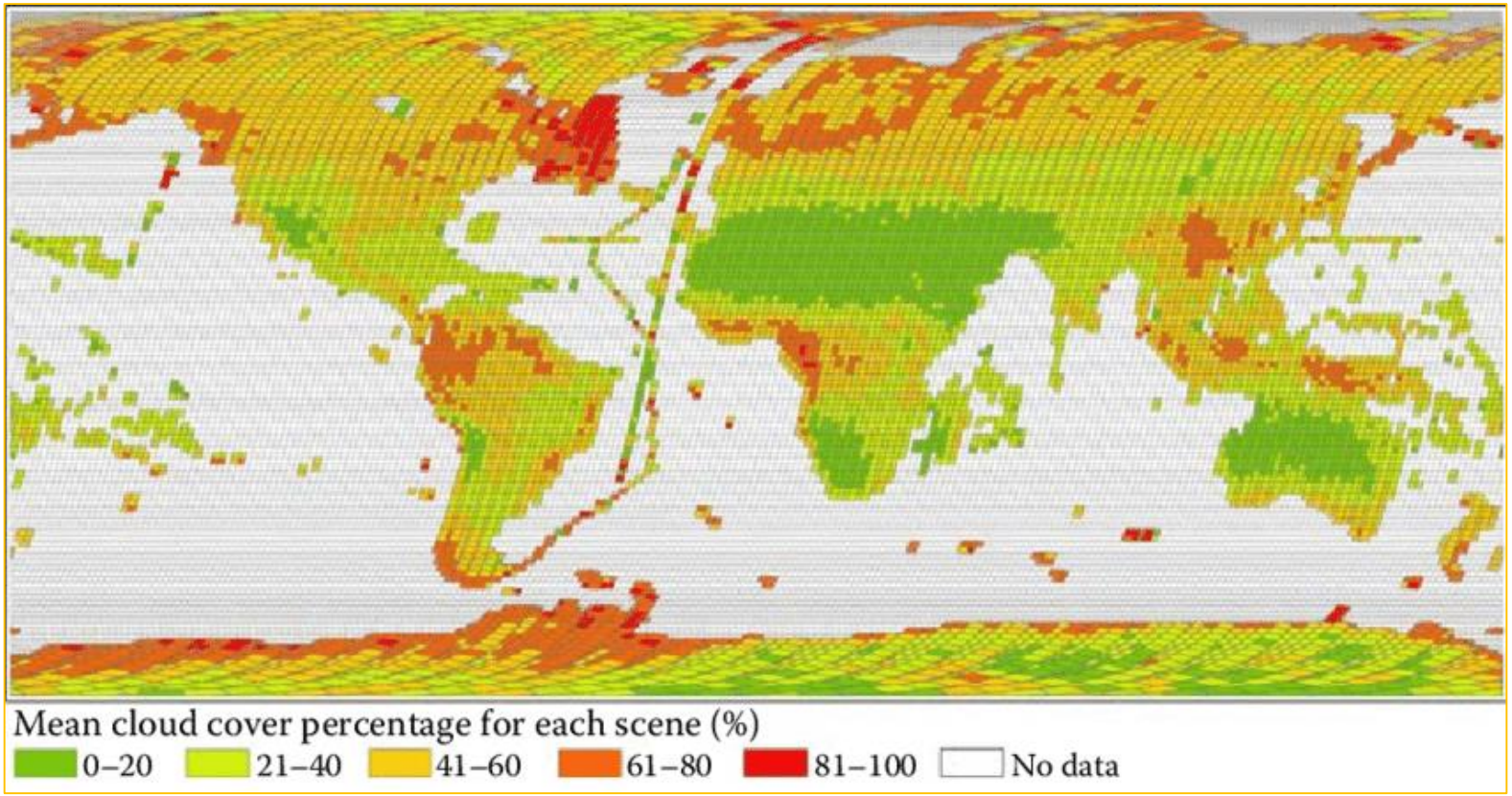
All Weather System

Detect mm level ground movement

SAR Interferometry

Persistent Scatter Interferometry

Time Series Analysis



Zhu, et. al. (2018)

SAR Interferometry

BACKSCATTER = Amplitude + **Phase**

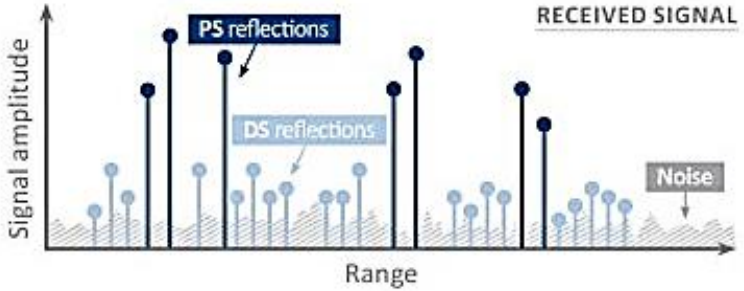
- Phase changes bet. 2 image acquisition
- Phase Difference ~ Deformation
- Done on a per pixel basis

INTERFEROGRAM

Persistent Scatter Interferometry

Persistent Scatterer

- Objects that exhibit consistent phase behavior
- resolution cells that exhibit a uniform and stable phase measurement over time

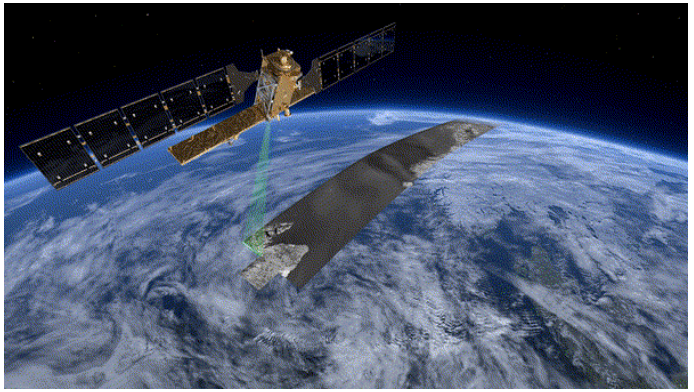


SAR Images

SENTINEL 1

European Space Agency

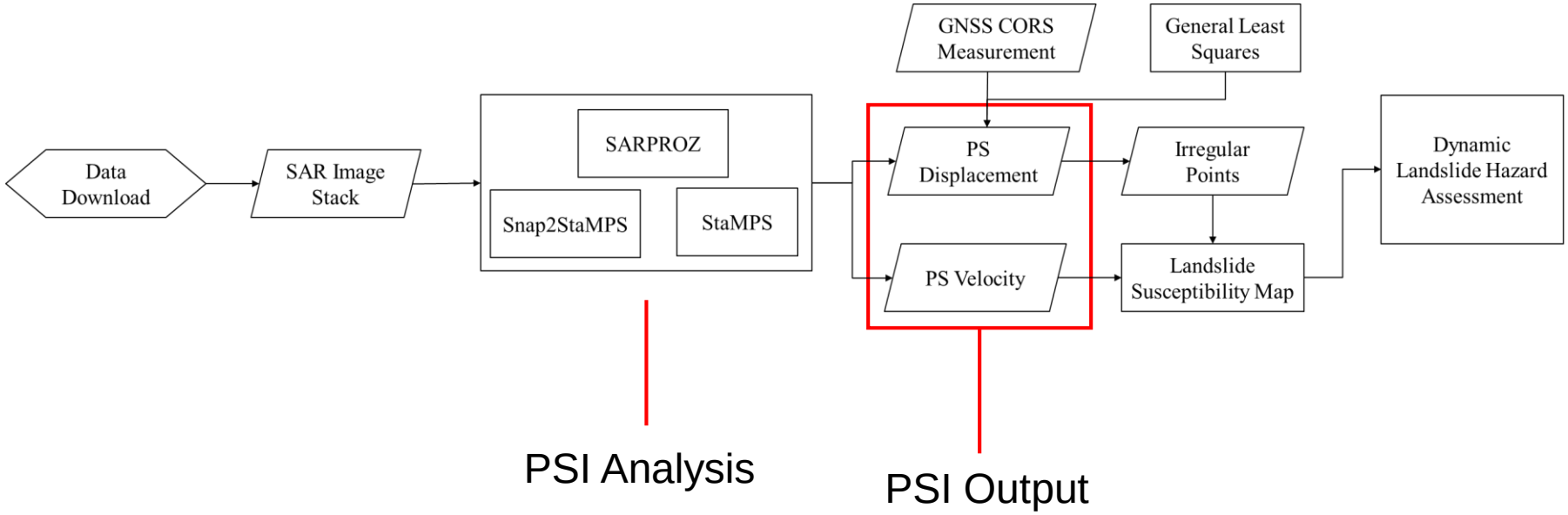
- Pair of RADAR Satellites (1A/1B)
- C Band (5.4cm λ)
- Stringent Orbit Pattern
- 12 Days Revisit Time
- Polar – Synchronous Orbit



SAR Images

Dates		
09 Jan. 2020	01 Jun. 2020	29 Sep. 2020
21 Jan. 2020	13 Jun. 2020	11 Oct. 2020
26 Feb. 2020	25 Jun. 2020	23 Oct. 2020
09 Mar. 2020	07 Jul. 2020	04 Nov. 2020
21 Mar. 2020	19 Jul. 2020	16 Nov. 2020
02 Apr. 2020	31 Jul. 2020	28 Nov. 2020
14 Apr. 2020	12 Aug. 2020	10 Dec. 2020
26 Apr. 2020	24 Aug. 2020	22 Dec. 2020
08 May 2020	05 Sep. 2020	03 Jan. 2021
20 May 2020	17 Sept. 2020	27 Jan. 2021

General Workflow



Irregular Points Determination

Irregular Points

- Do not follow a determined model from previous timeframes
- Show points moving faster than expected

- Plot deformation w.r.t. to time (15 dates)
- Determine Linear Model via **Least Squares**
- Get **residual** of the next point w.r.t. to model

Irregular Points Determination

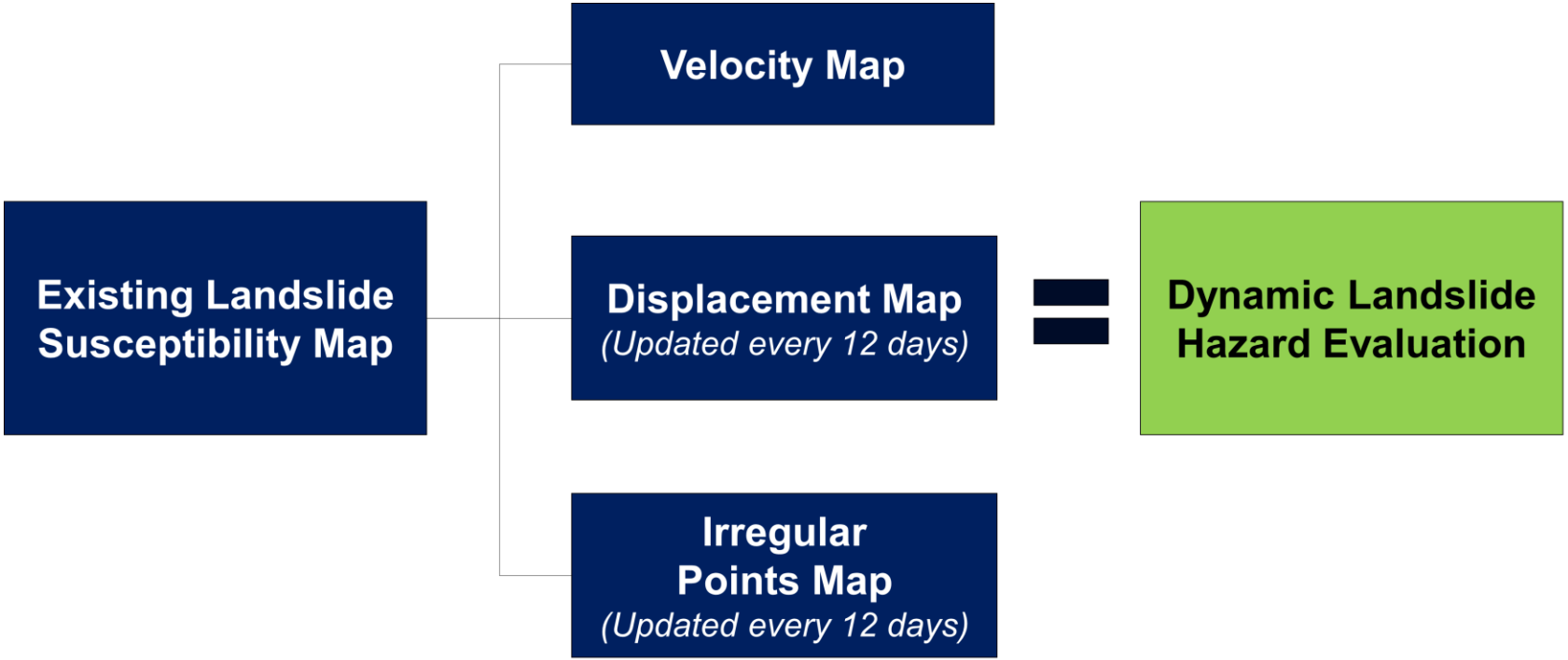
Residual = Theoretical – Observed

**Theoretical is based on Linear Model*

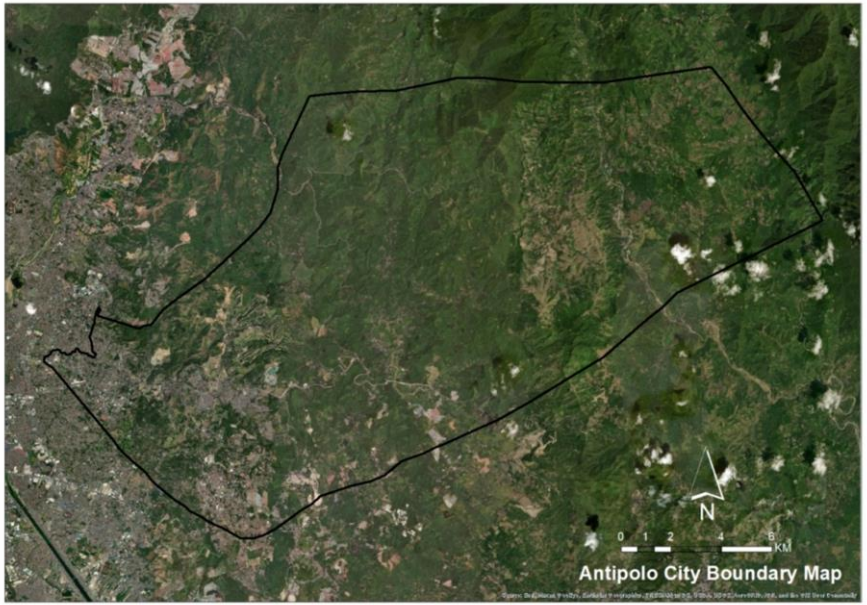
If Residual > 99% Confidence Interval: IP

If Residual < 99% Confidence Interval: Non-IP

Dynamic Hazard Evaluation

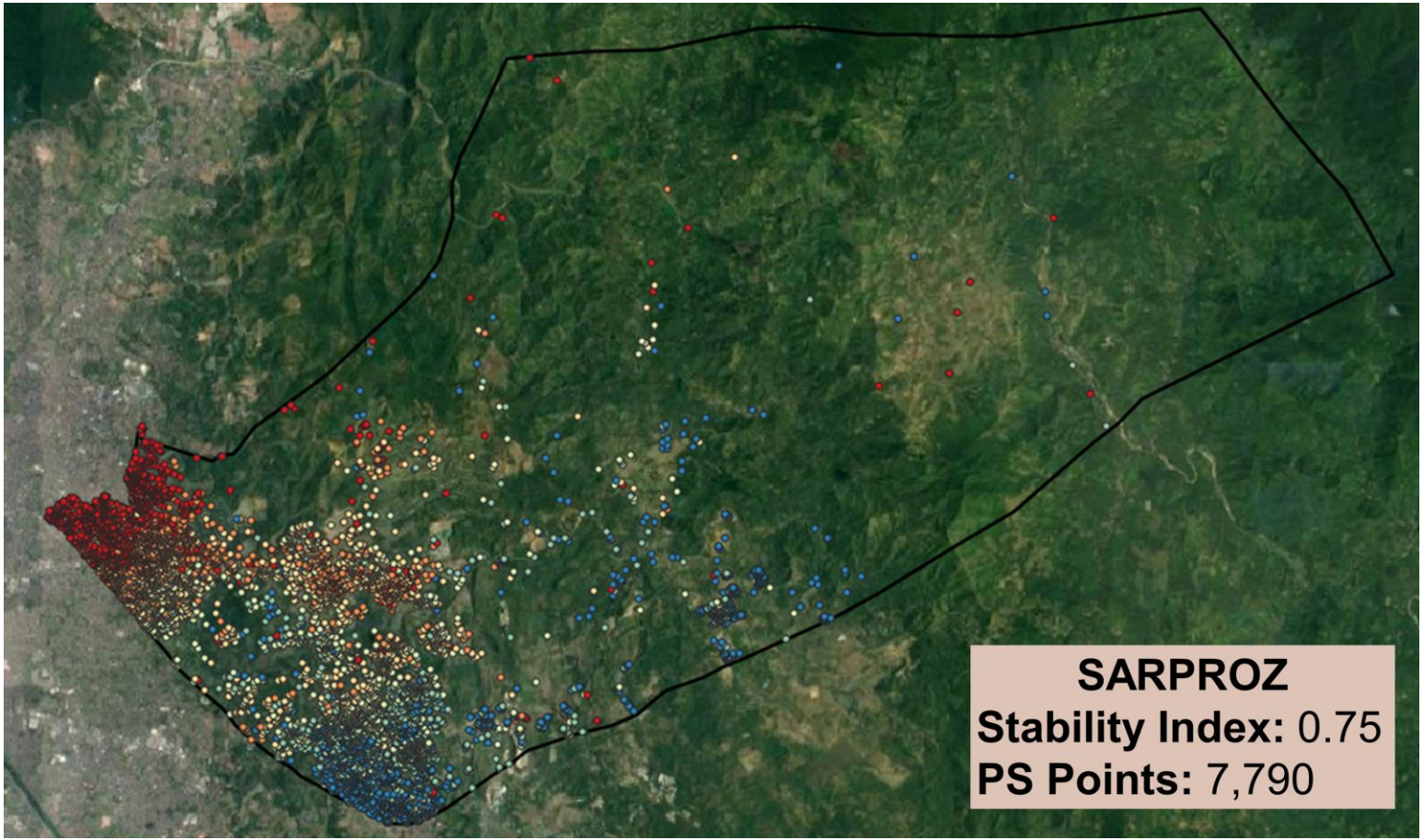


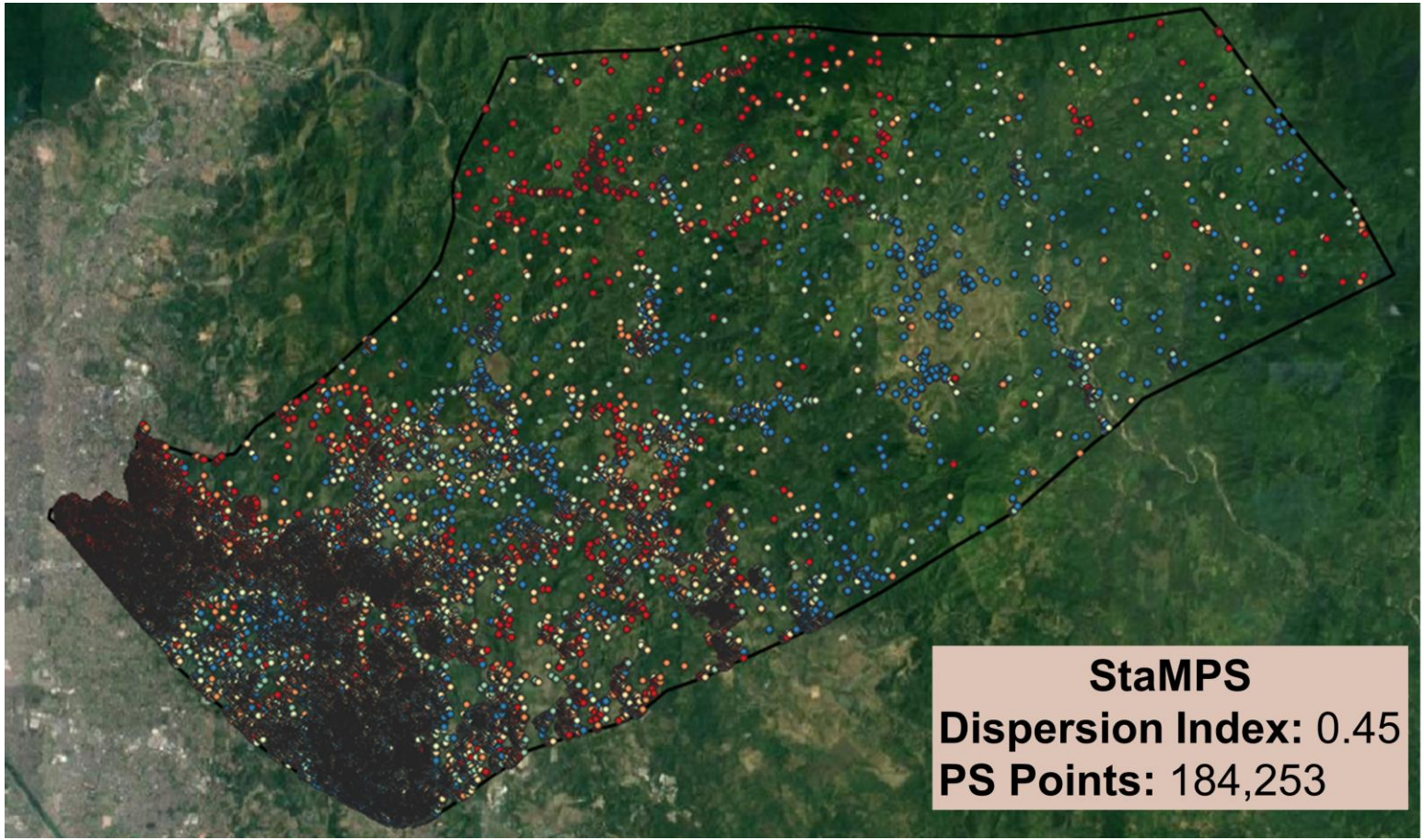
Study Area

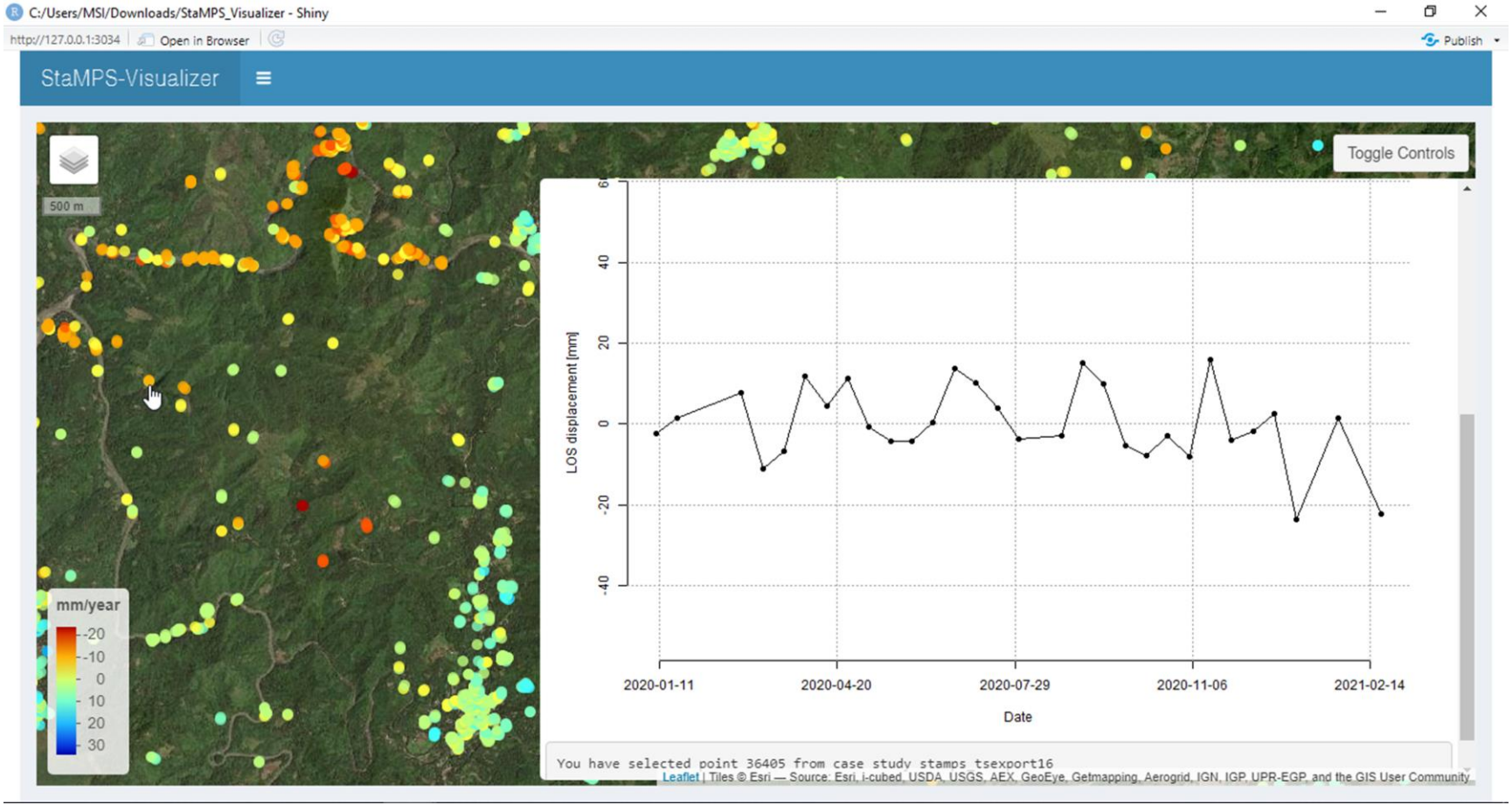


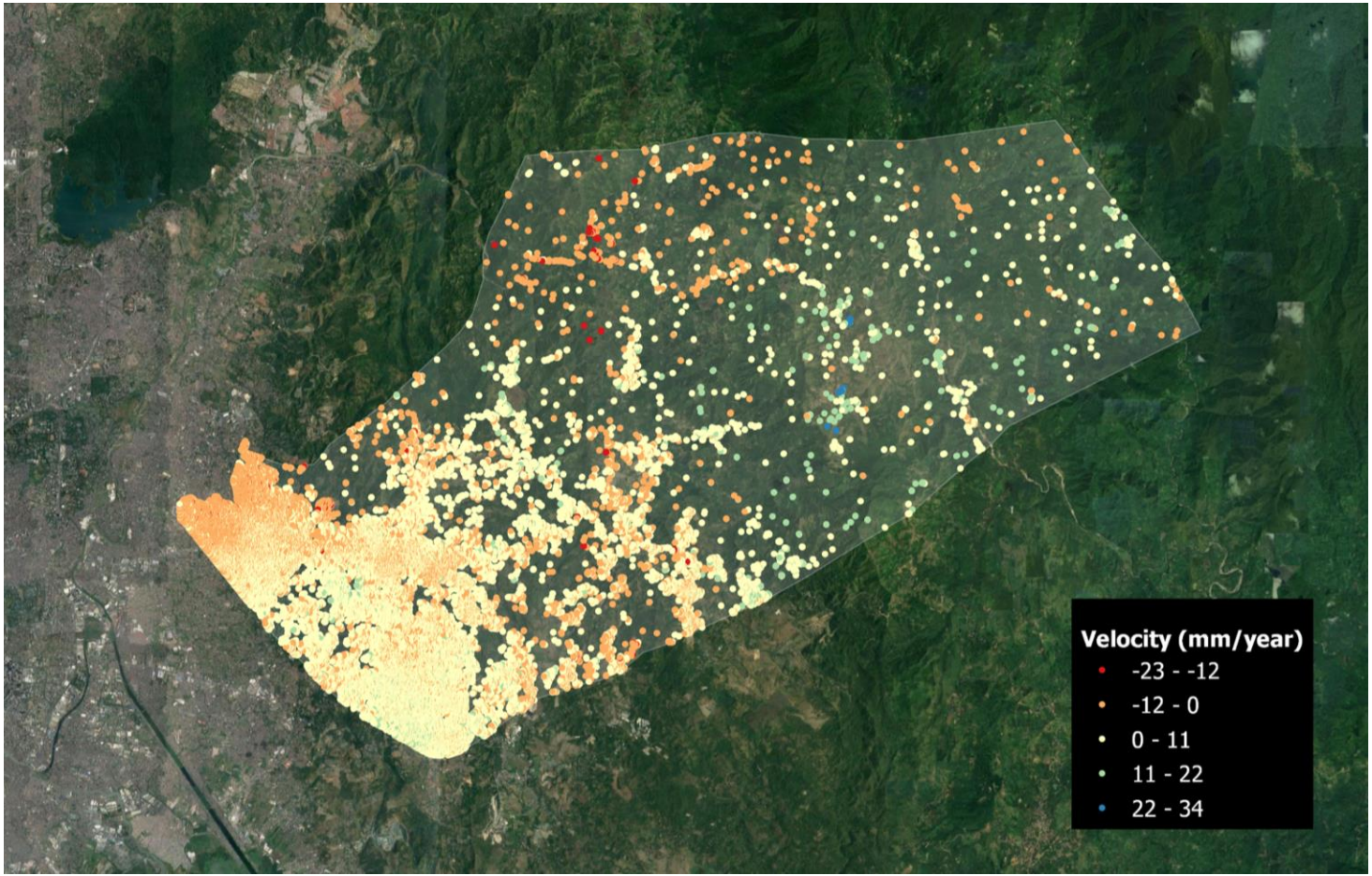
Antipolo City

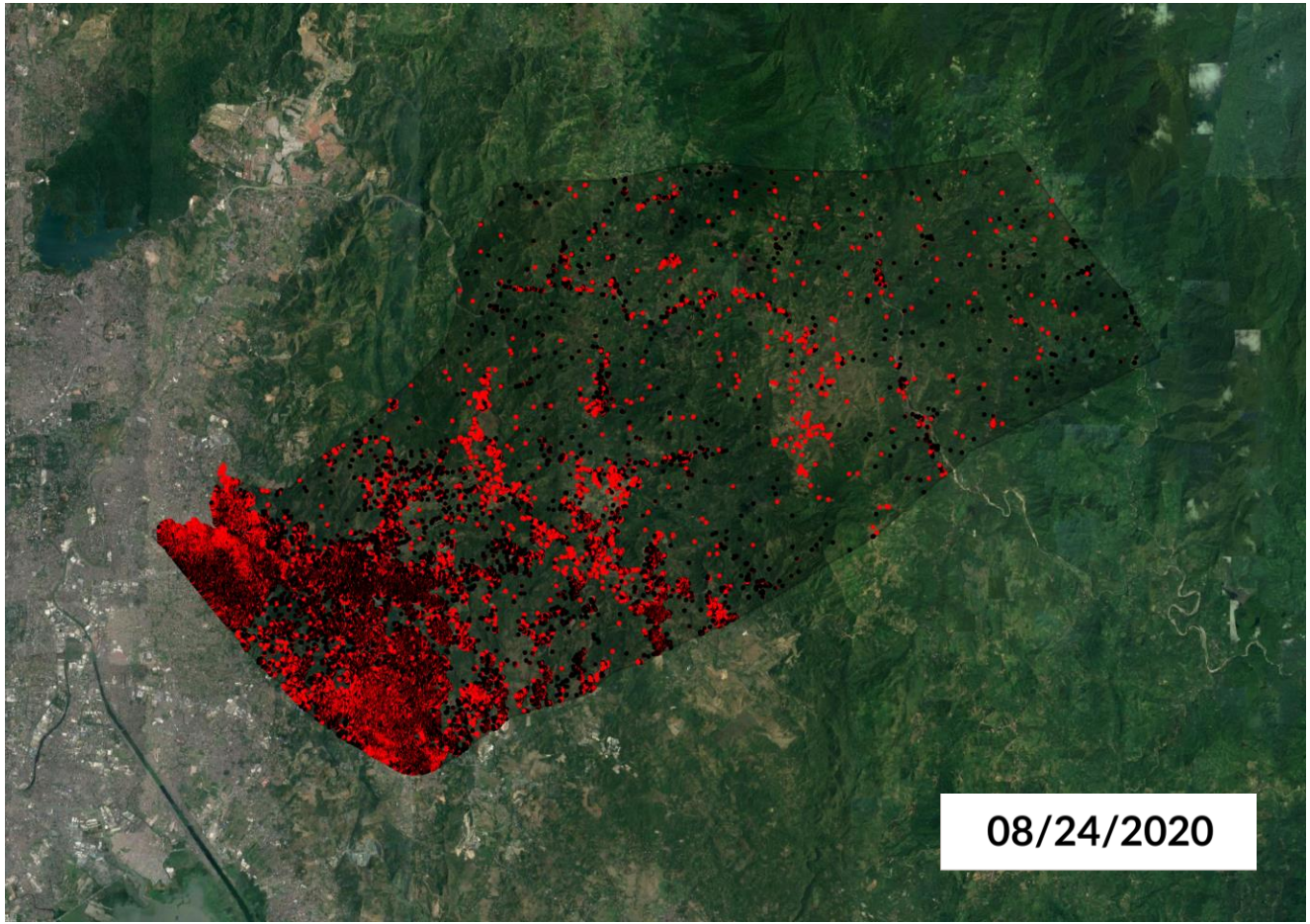
- ~880,000 Residents (2020)
- Mountainous Region
- High susceptibility to Landslides (NOAH)
- Existing Susceptibility Map
- Visible within swath of UP Base Station

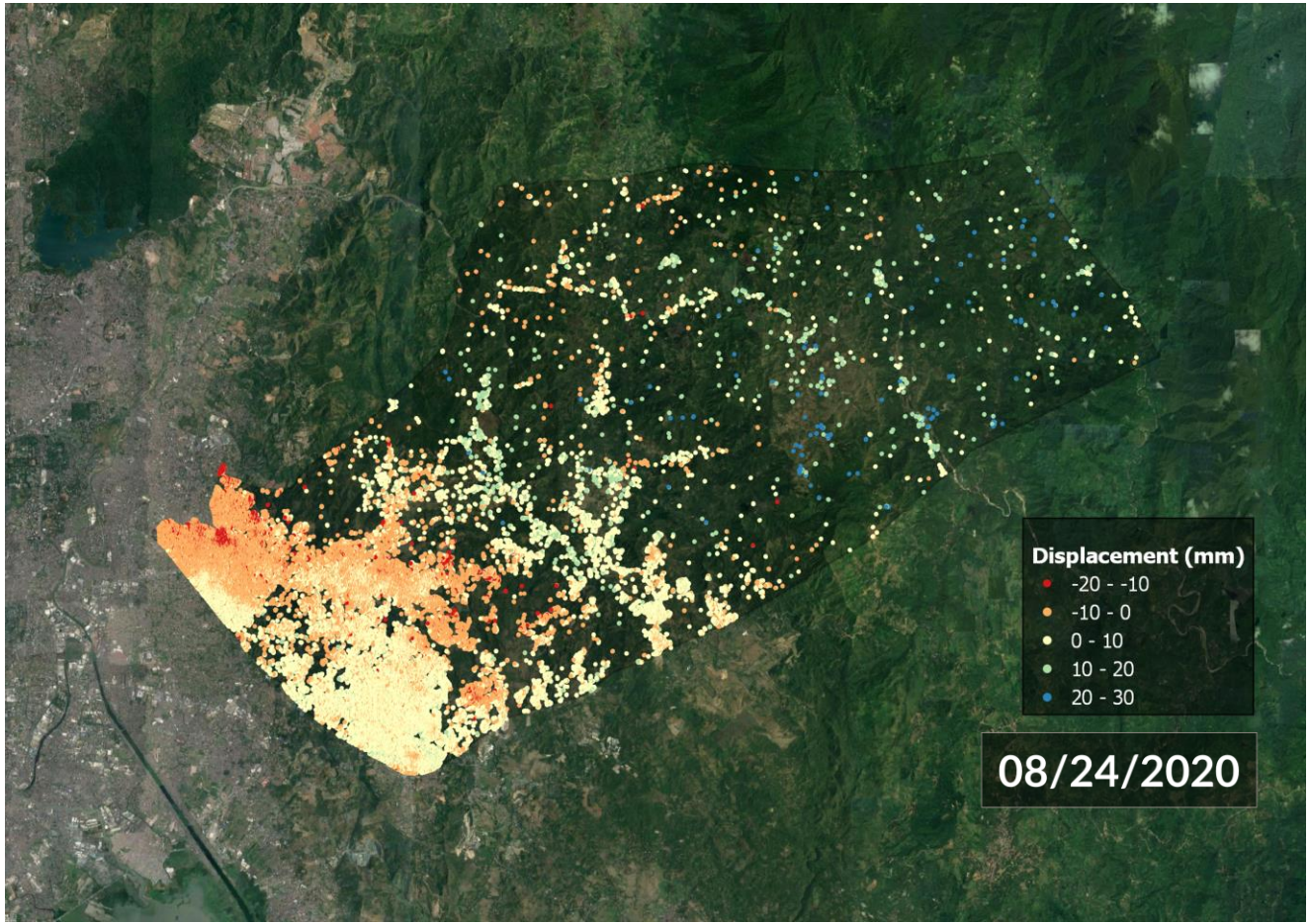

SARPROZ
Stability Index: 0.75
PS Points: 7,790

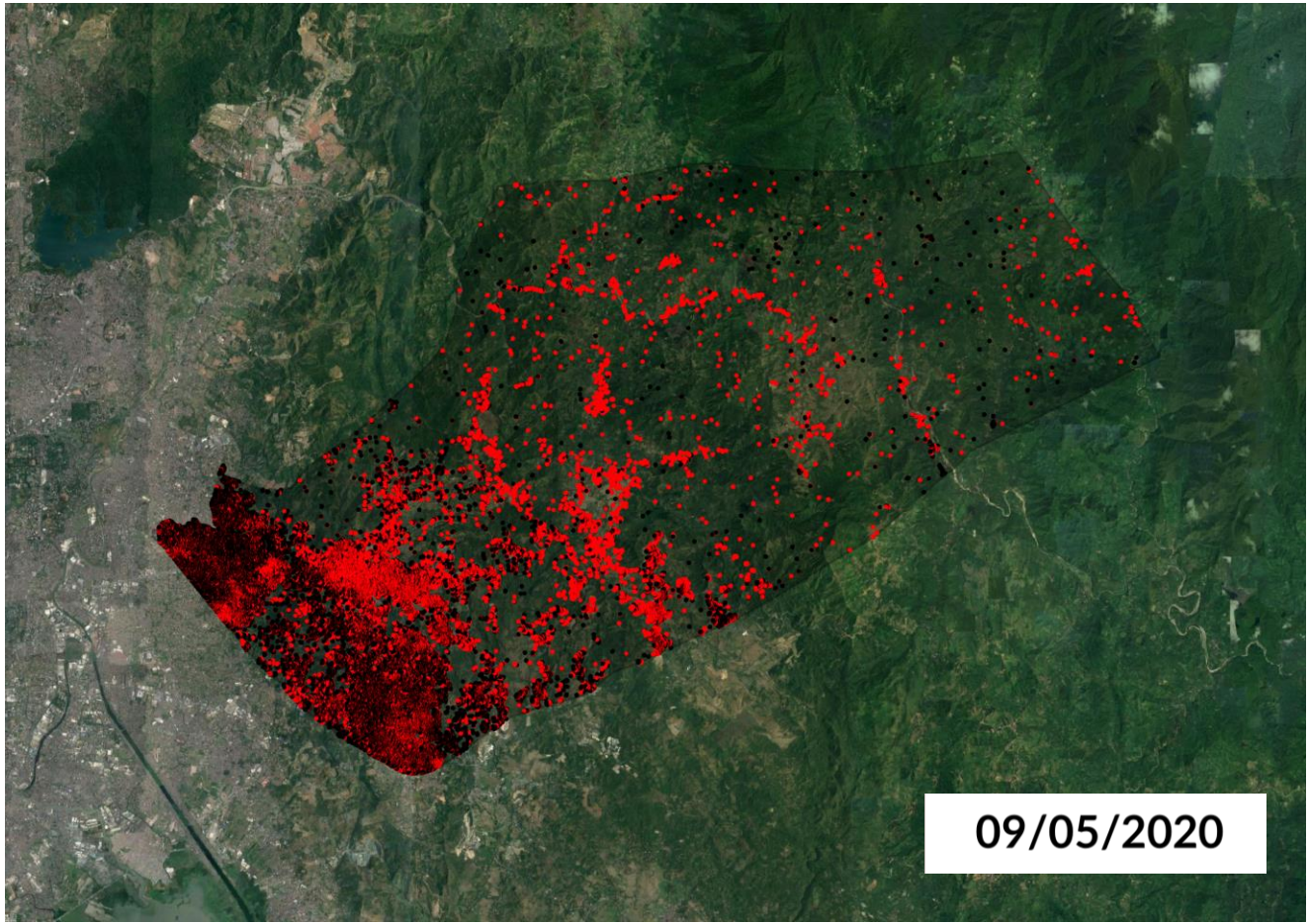

StaMPS
Dispersion Index: 0.45
PS Points: 184,253

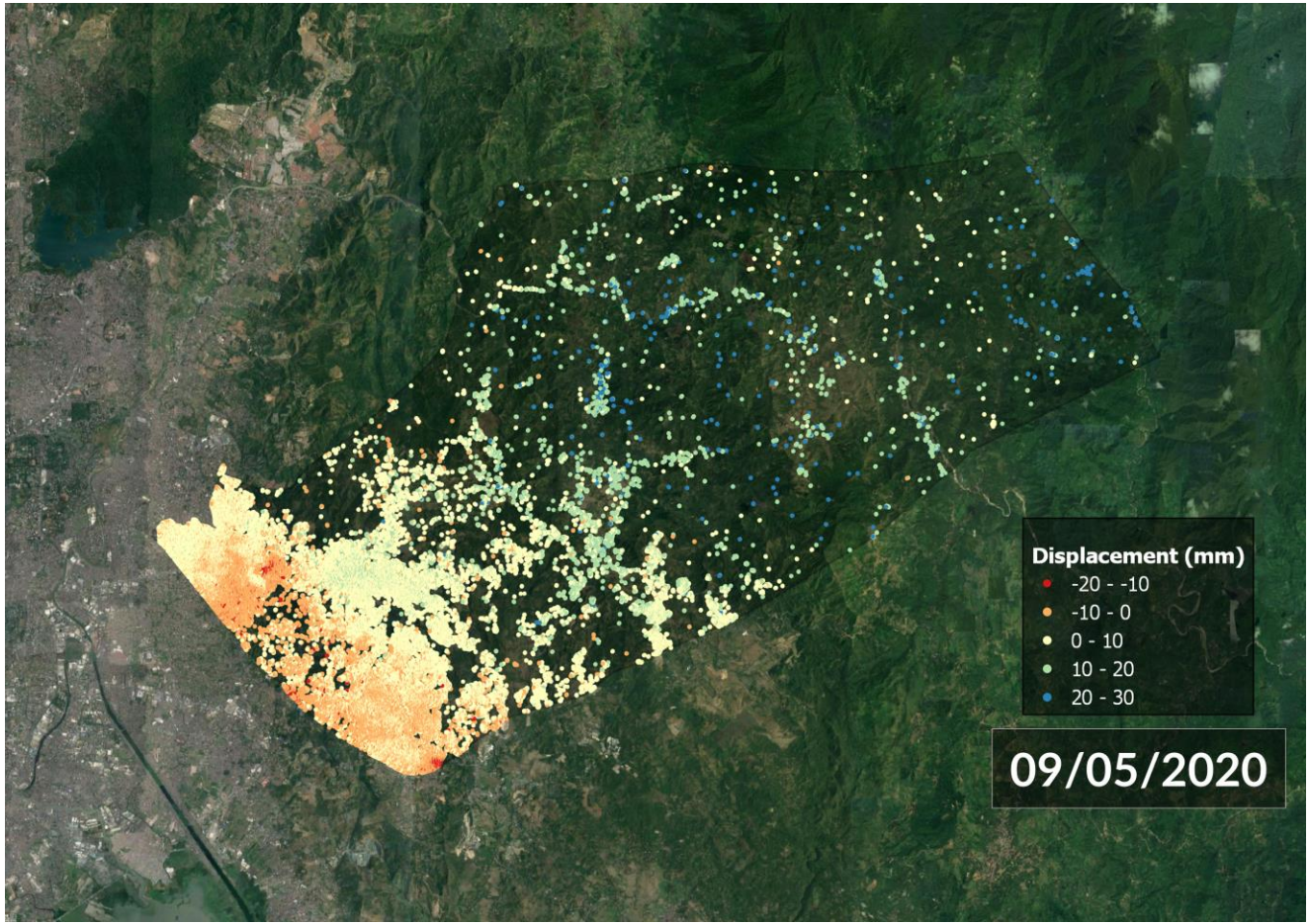

C:/Users/MSI/Downloads/StaMPS_Visualizer - Shiny
http://127.0.0.1:3034
Open in Browser
Publish
StaMPS-Visualizer
Toggle Controls
500 m
mm/year
-20
-10
0
10
20
30
LOS displacement [mm]
40
20
0
-20
-40
2020-01-11
2020-04-20
2020-07-29
2020-11-06
2021-02-14
Date
You have selected point 36405 from case study stamps tsexport16
Leaflet | Tiles © Esri — Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community


Velocity (mm/year)
-23 - -12
-12 - 0
0 - 11
11 - 22
22 - 34

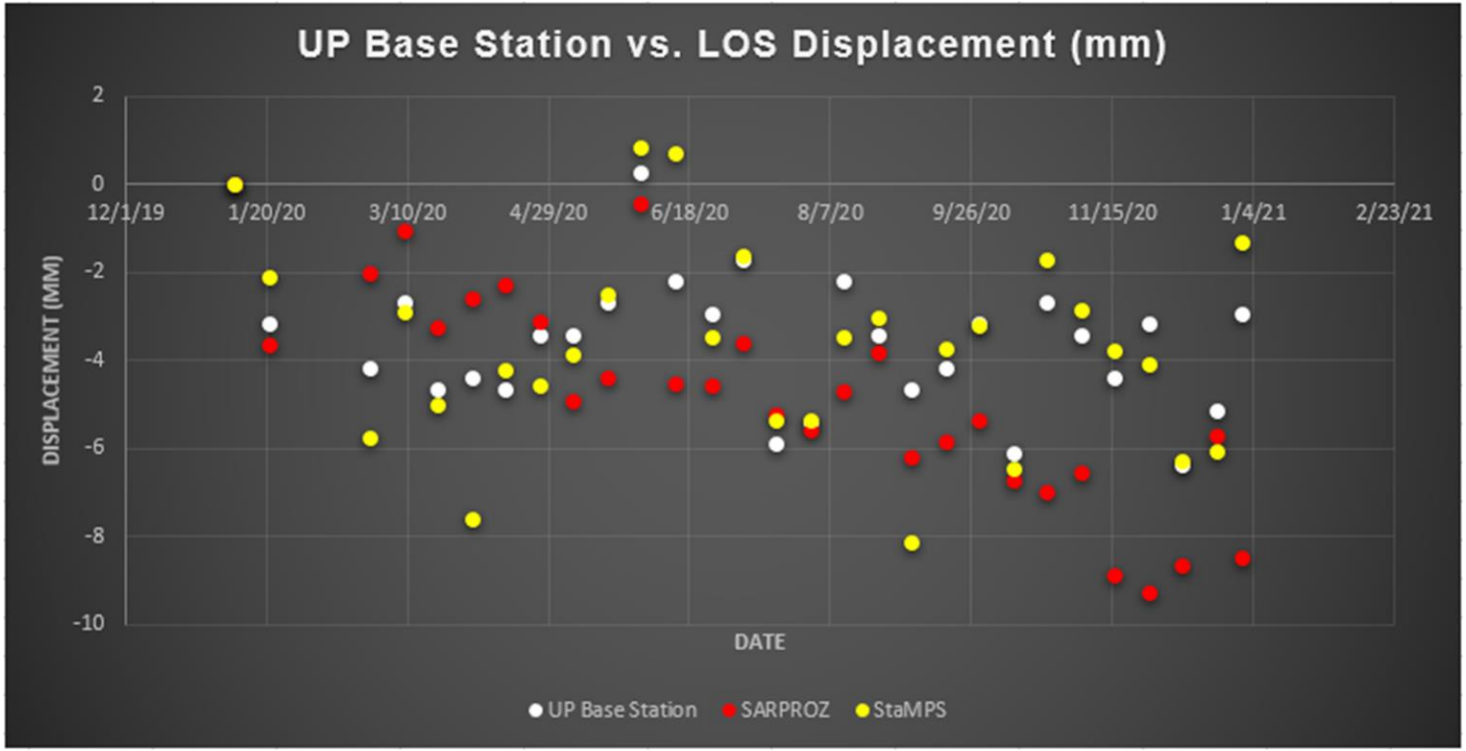

08/24/2020


Displacement (mm)
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
08/24/2020

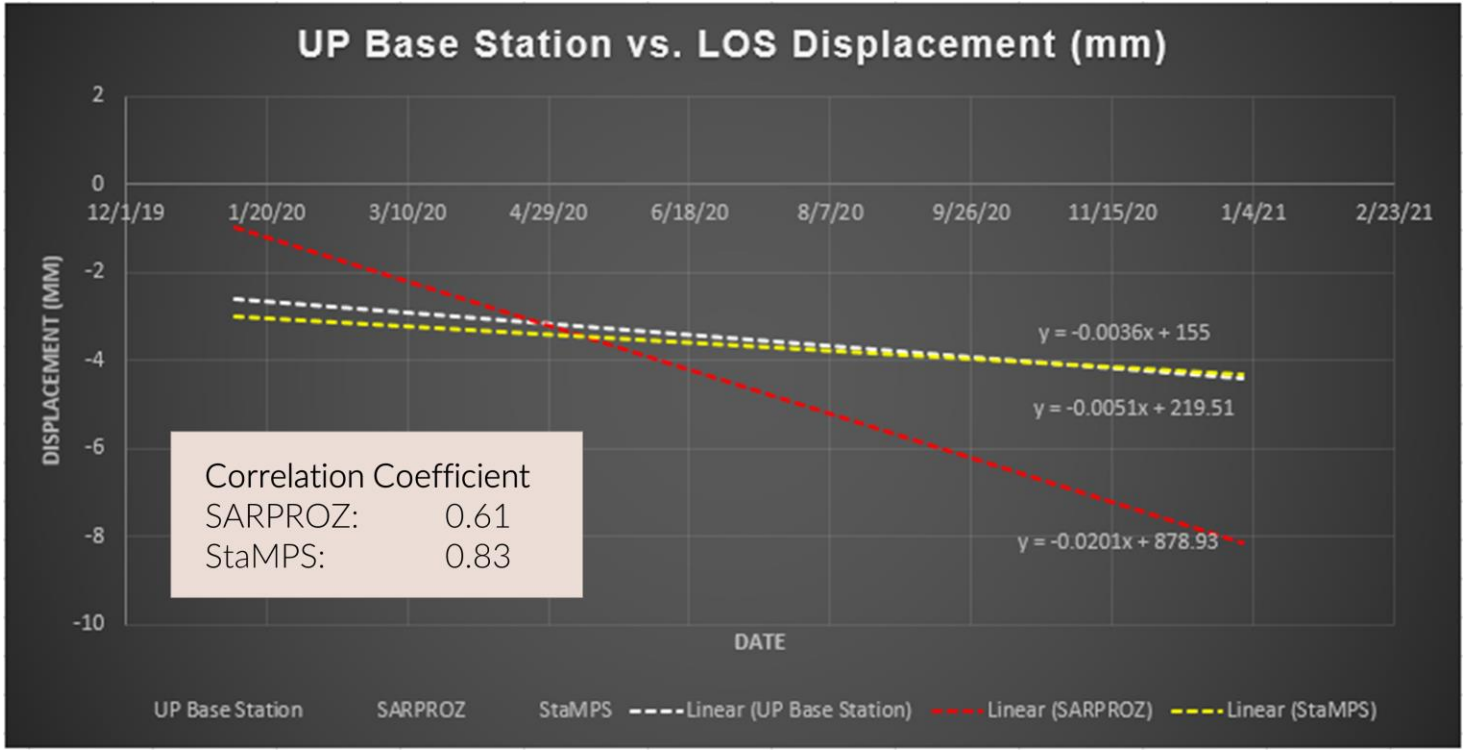

09/05/2020


Displacement (mm)
-20 - -10
-10 - 0
0 - 10
10 - 20
20 - 30
09/05/2020

GNSS Comparison



GNSS Comparison



Conclusions

- Applicability of **time-series analysis** of detected PS Points in landslide prone areas
- **184,253 PS points** were detected by StaMPS for a timeframe of one year
- **Mean LOS Velocity** of the PS points were derived
- **Irregular points** and their corresponding **displacement values** were detected for each PS point at each image acquisition

Conclusions

- Combination of the **3 additional layers** adds more insight to planning needs
- Displacement measurement derived by StaMPS achieved a **correlation of 0.83** with stationary GNSS observations
- Dynamic landslide hazard gets updated every 12 days

Moving Forward

- Calculate / delineate runoff area
- Combine with Sentinel 1B
  - Decompose displacement vectors
  - Updated every 6 days
- Use longer wavelength (L band) SAR sensors
- Utilize high-resolution X band sensors
- PSDS Analysis

Project AiRMoVE

- Ambient Air Remote Sensing, Modeling and Visualization Environment (**AiRMoVE**)
- DOST PCIEERD and UP TCAGP
- To identify **attainment and non-attainment areas** in National Capital Region for air quality monitoring using combinations RS, GIS and numerical modeling techniques
- outputs include geographical databases, software toolkits and scripts for image/data processing, air dispersion models and a webGIS-based platform for **visualizing and analyzing air quality data.**

Engr. Roseanne V. Ramos
Project Leader

Dr. Mylene G. Cayetano
Project Staff

Teodora Yumul-Calzado
Project Development Officer

Dr. Ayin Tamondong
Project Staff

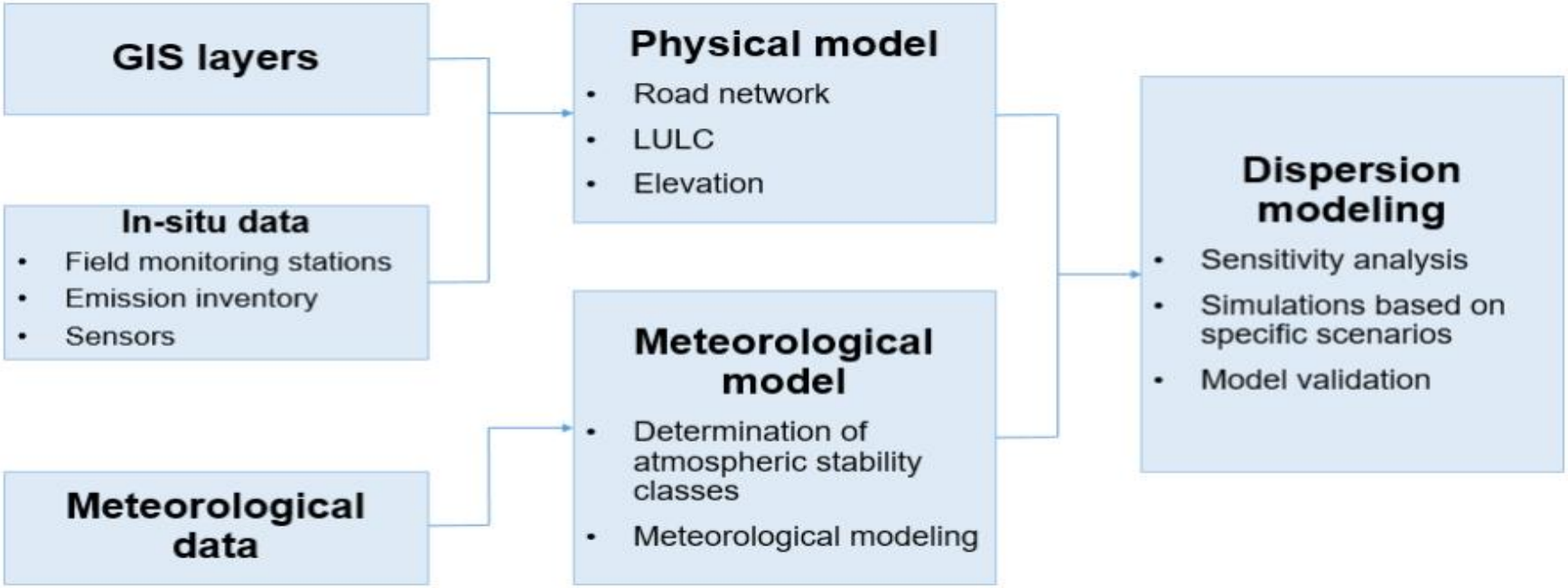
Benjie Jiao
Senior Science Research Specialist

Engr. Rodyvito Torres
Science Research Specialist II

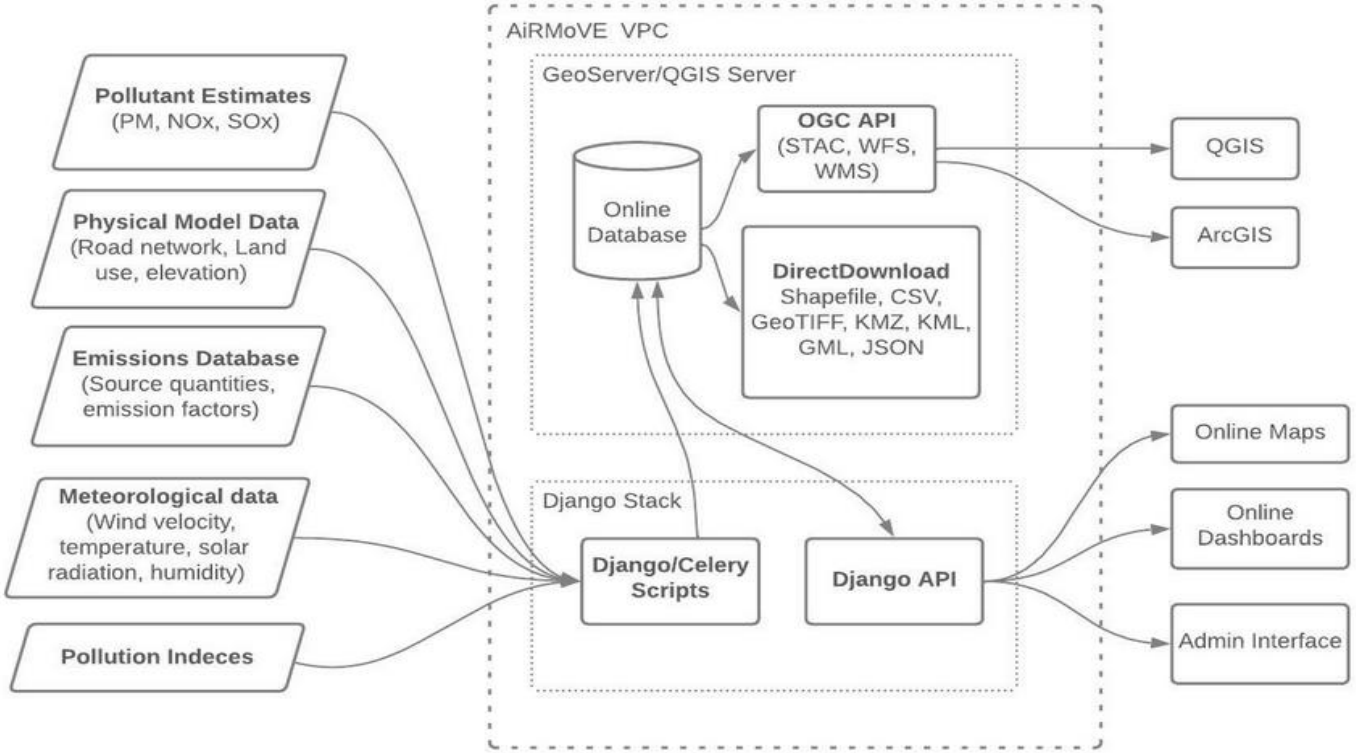
Engr. Bernadette Recto
Remote Sensing Analyst

EMB

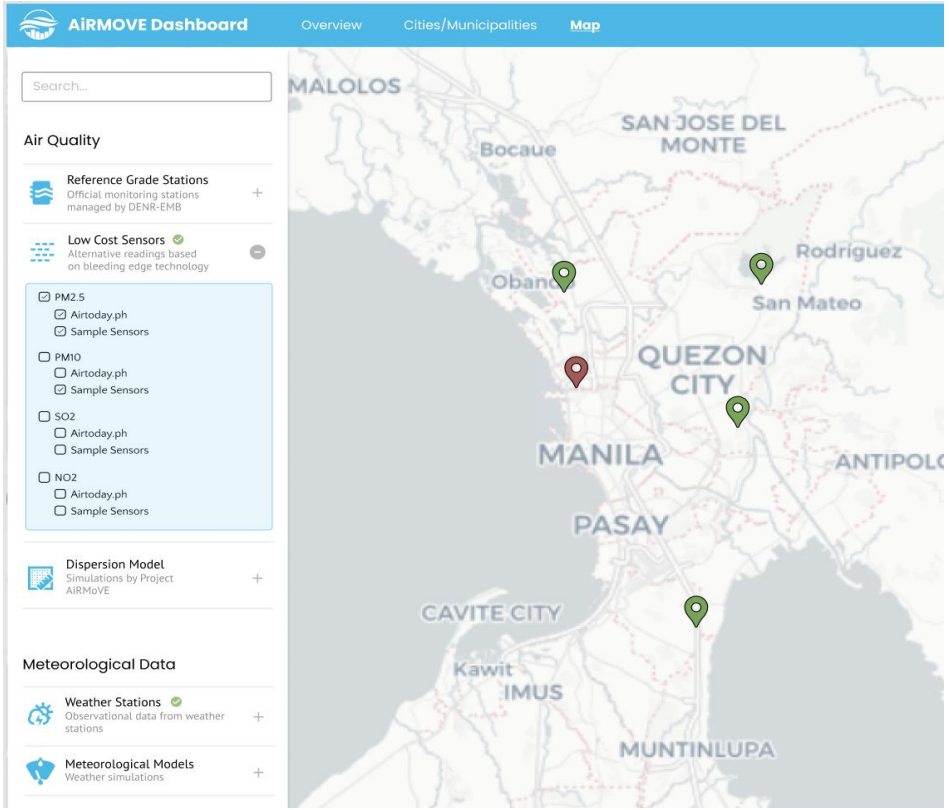
Partnership for Clean Air

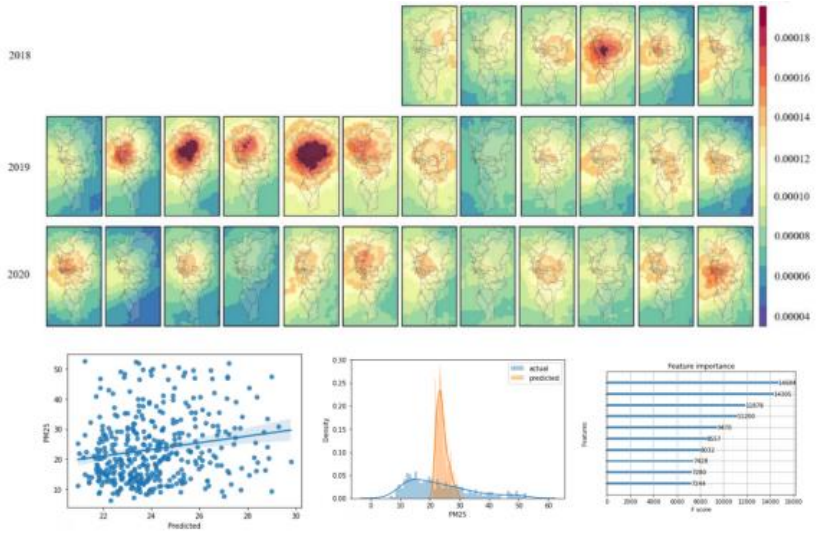


Modelling Framework



AiRMoVE Virtual Private Cloud


AiRMOVE Dashboard
Overview
Cities/Municipalities
Map
Search...
Air Quality
Reference Grade Stations
Official monitoring stations managed by DENR-EMB
Low Cost Sensors
Alternative readings based on bleeding edge technology
PM2.5
Airtoday.ph
Sample Sensors
PM10
Airtoday.ph
Sample Sensors
SO2
Airtoday.ph
Sample Sensors
NO2
Airtoday.ph
Sample Sensors
Dispersion Model
Simulations by Project AiRMoVE
Meteorological Data
Weather Stations
Observational data from weather stations
Meteorological Models
Weather simulations
MALOLOS
Bocaue
SAN JOSE DEL MONTE
Rodriguez
San Mateo
QUEZON CITY
MANILA
PASAY
CAVITE CITY
Kawit
IMUS
MUNTINLUPA


2018
2019
2020
0.00018
0.00016
0.00014
0.00012
0.00010
0.00008
0.00006
0.00004
Predicted
PM25
actual
predicted
Density
PM25
Feature importance
Importance
F score

Thank you for your time

lsmabaquiao@up.edu.ph