ICESat-2 based Ground photons retrieval in urban areas by using Deep Learning Approach

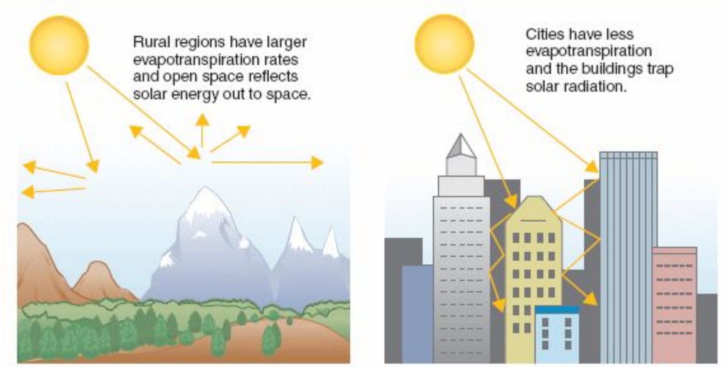
User Interaction Meet 12-13 March, 2024

DR. PRIYANKA HARJULE

Outline

INTRODUCTION AND MOTIVATION

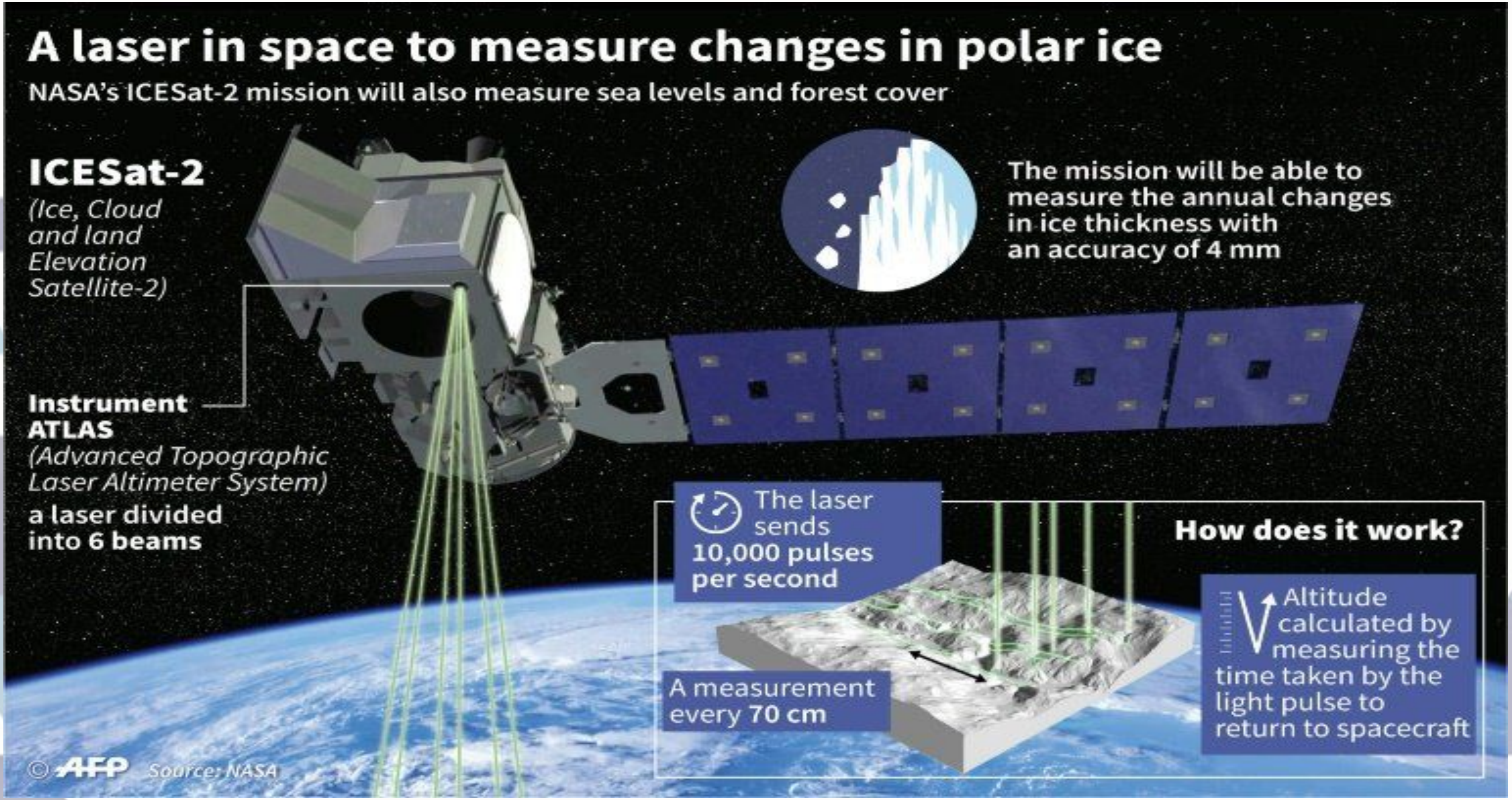
- According to United Nations report, structure and form of the buildings in cities are the major factors in carbon emissions in the urban cities.
- Building height is helpful for accurate estimation of the concentration and distribution of the population, urban heat island effects, building energy consumption and greenhouse gas emissions.
- Essential in understanding the impacts of the vertical characteristics of urban areas on the environment and human wellbeing.
- Need precise digital terrain models for urban areas which does not include the building heights in order to design a system for analyzing urban floods.



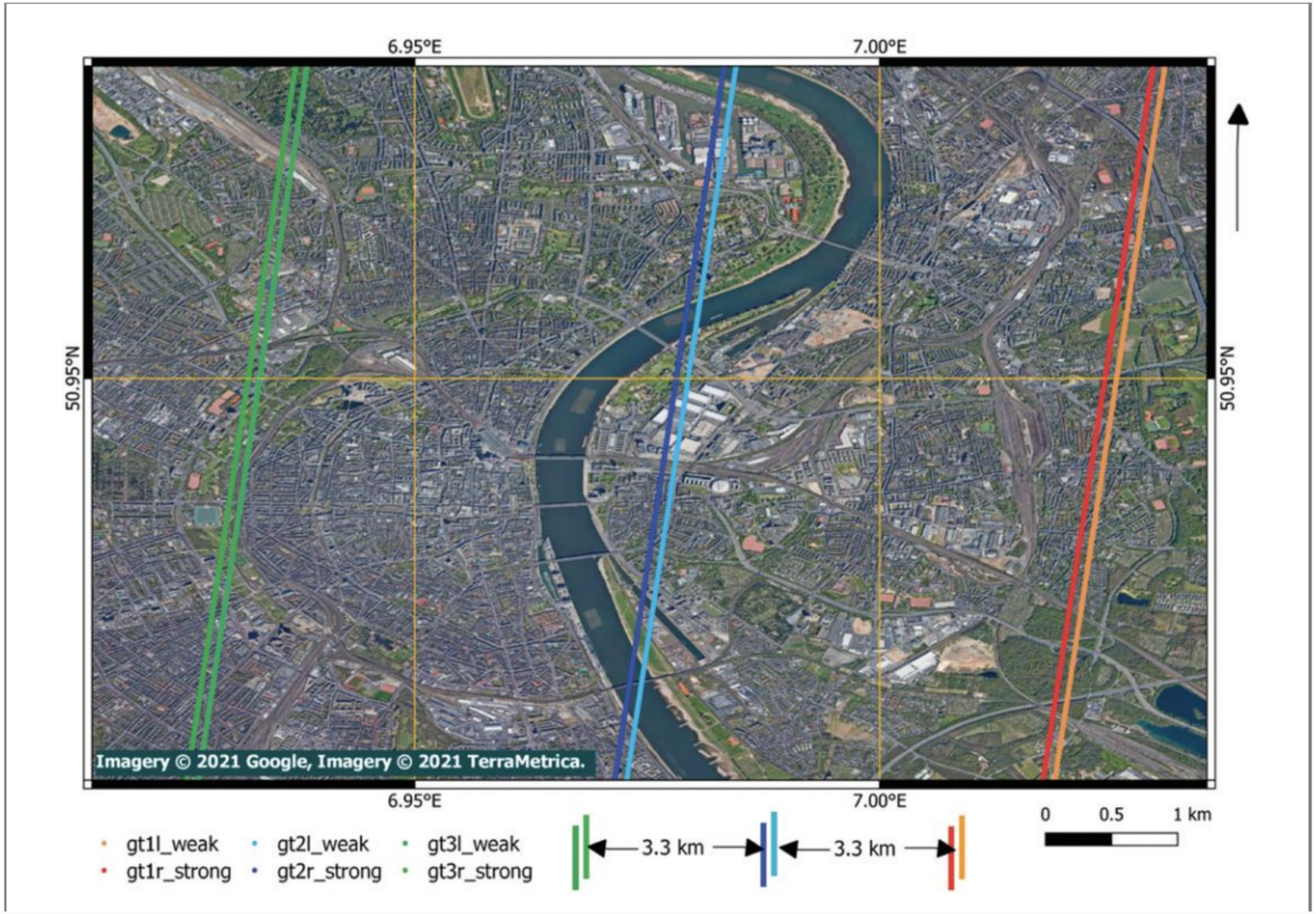
MOTIVATION: THE NEED FOR ACCURATE ELEVATION DATA

- Utilizing ICESat-2 Data
- Digital Surface Models (DSMs)
- Environmental Challenges
- Informed Decision Making
- Sustainable Development

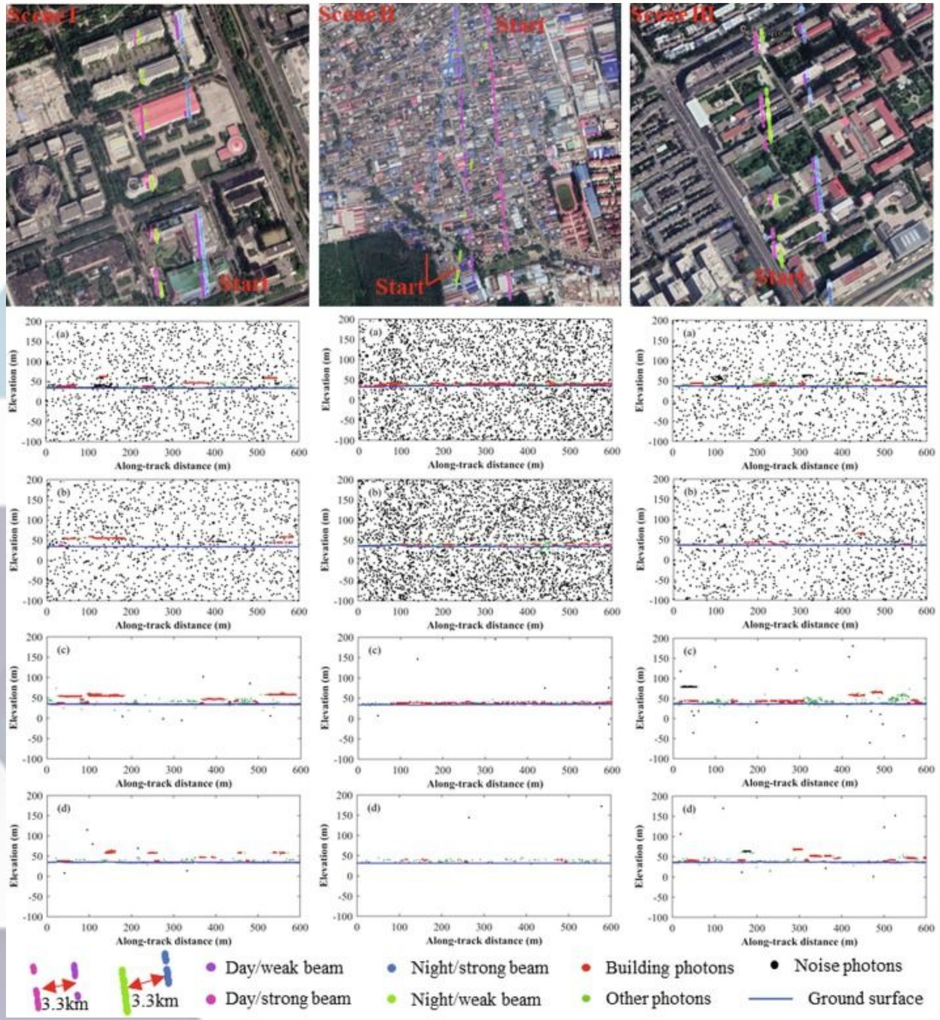
ICESAT-2


A laser in space to measure changes in polar ice
NASA's ICESat-2 mission will also measure sea levels and forest cover
ICESat-2
(Ice, Cloud and land Elevation Satellite-2)
The mission will be able to measure the annual changes in ice thickness with an accuracy of 4 mm
Instrument ATLAS
(Advanced Topographic Laser Altimeter System)
a laser divided into 6 beams
The laser sends 10,000 pulses per second
How does it work?
Altitude calculated by measuring the time taken by the light pulse to return to spacecraft
A measurement every 70 cm
© AFP Source: NASA

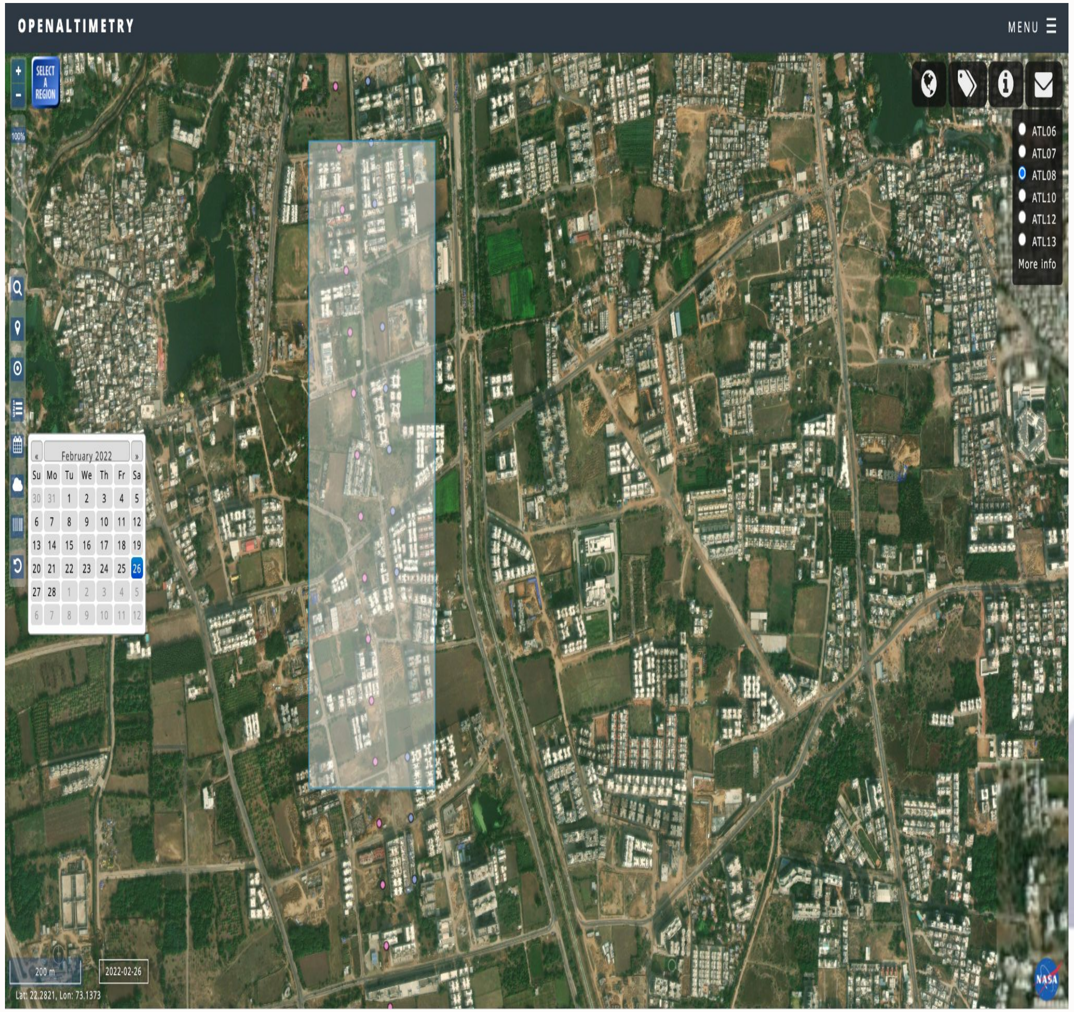
ICESAT-2


6.95°E
7.00°E
50.95°N
Imagery © 2021 Google, Imagery © 2021 TerraMetrica.
0
0.5
1 km
gt1l_weak
gt1r_strong
gt2l_weak
gt2r_strong
gt3l_weak
gt3r_strong
3.3 km
3.3 km

ICESAT-2



Scene I
Scene II
Scene III
Start
Start
Start
Elevation (m)
Along-track distance (m)
(a)
(b)
(c)
(d)
3.3km
3.3km
Day/weak beam
Day/strong beam
Night/strong beam
Night/weak beam
Building photons
Other photons
Noise photons
Ground surface



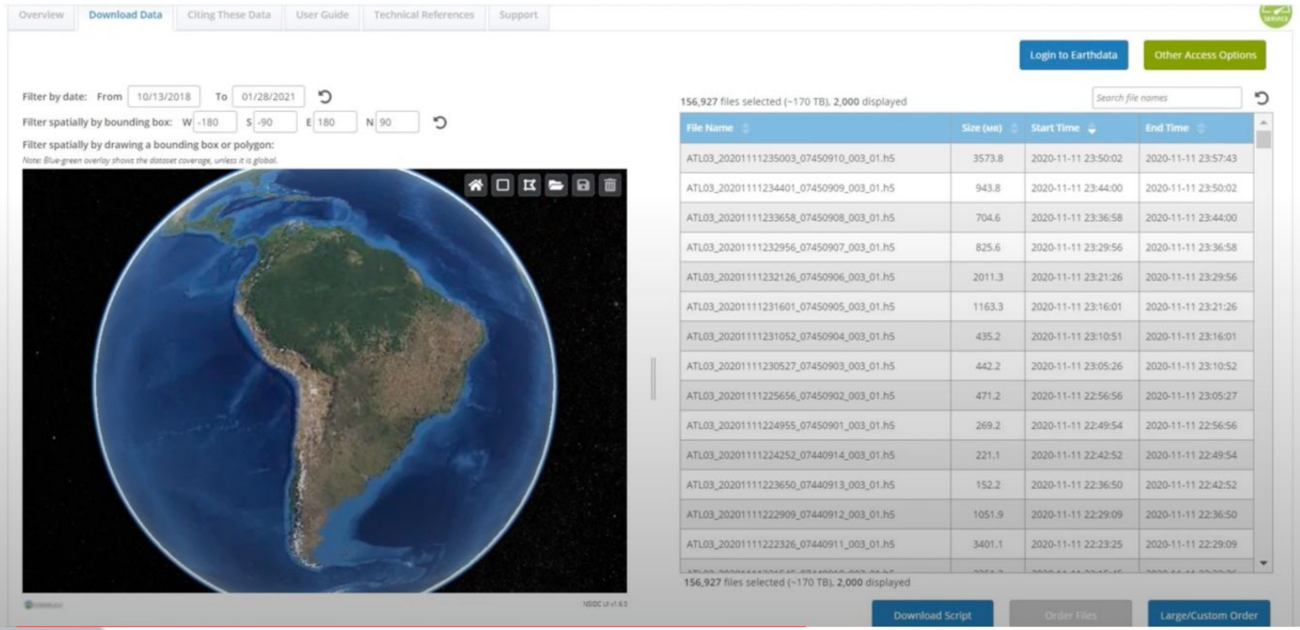
OPENALTIMETRY
MENU
SELECT A REGION
ATL06
ATL07
ATL08
ATL10
ATL12
ATL13
More info
February 2022
Su Mo Tu We Th Fr Sa
200 m
2022-02-26
Lat: 22.2821, Lon: 73.1373
NASA

ICESAT-2

NASA Distributed Active Archive Center (DAAC) at NSIDC

The NASA National Snow and Ice Data Center Distributed Active Archive Center (NASA NSIDC DAAC) provides tools and services to reduce data size and perform on-demand analysis of ICESat-2 data.

- Open and free for access by anyone
- Provides a single point of entry for discovery, access and customization of ICESat-2 data.
- Each ICESat-2 product has its own landing page
- Distributes and archives ICESat-2 data

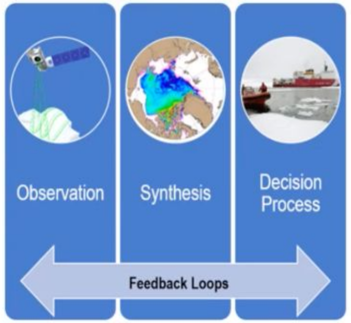


Level	File	Product Name	Frequency	Daily Frequency	est file size (GB)	GB/day
0	ATL00	Telemetry Data	every 2 hours; 12/day	12	6.04	72.48
1A	ATL01	Reformatted Telemetry	10/orbit; 16 orbits/day	160	0.52	83.84
1B	ATL02	Science Unit Converted Telemetry	10/orbit; 16 orbits/day	160	0.89	141.92
2A	ATL03	Global Geo-located Photon Data	10/orbit; 16 orbits/day	160	3.10	496.00
2A	ATL04	Uncalibrated Backscatter Profiles	2 orbits; ~8/day	8	1.00	8.00
	ATL05	undefined				
3A	ATL06	Antarctica Ice Sheet Height / Greenland Ice Sheet Height	8/day	8	0.48	3.84
3A	ATL07	Arctic Sea Ice Height/ Antarctic Sea Ice Height	2/day	2	5.16	10.32
3A	ATL08	Land Water Vegetation Heights	32/day	32	1.55	49.60
3A	ATL09	Calibrated backscatter and atmosphere characteristic	2 orbits; ~8/day	8	1.09	8.72
3A	ATL10	Arctic Sea Ice Freeboard / Antarctic Sea Ice Freeboard	2/day	2	3.74	7.48
3B	ATL11	Antarctica Ice Sheet H(t) Series/ Greenland Ice Sheet H(t) Series	1/year	0.00274	566.00000	1.55068
3A	ATL12	Ocean Height	4/day	4	1.48000	5.92000
3B	ATL13	Inland Water Height	8/day	8	0.10800	0.86400
3B	ATL14	Antarctica Ice Sheet Gridded/ Greenland Ice Sheet Gridded	1/year	0.00274	1.00000	0.00274
3B	ATL15	Antarctica Ice Sheet dh/dt Gridded/ Greenland Ice Sheet dh/dt Gridded	1/year	0.00274	1.00000	0.00274
3B	ATL16	ICESat-2 Atmosphere Weekly	1/week	0.14286	0.78000	0.11143
3B	ATL17	ICESat-2 Atmosphere Monthly	1/month	0.03333	3.10000	0.10333
3B	ATL18	Land Height/ Canopy Height Gridded	1.5/year	0.00183	3.30000	0.00603
3B	ATL19	Ocean MSS	1/month	0.03333	1.00000	0.03333
3B	ATL20	Arctic Gridded Sea Ice Freeboard/ Antarctic Gridded Sea Ice Freeboard	1/month	0.03333	2.00000	0.06667
3B	ATL21	Arctic Gridded Sea Surface Height within Sea Ice/ Antarctic Gridded Sea Surface Height within Sea Ice	1/month	0.03333	2.00000	0.06667
	ANC	Adjusted daily value of all ANC files				0.8929
		daily total (ATL + ANC)				891.82

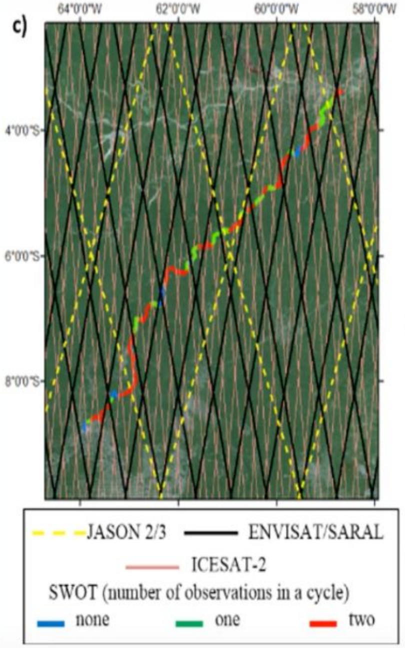
https://nsidc.org/data/icesat-2

ICESAT-2

ICESat-2 Applications



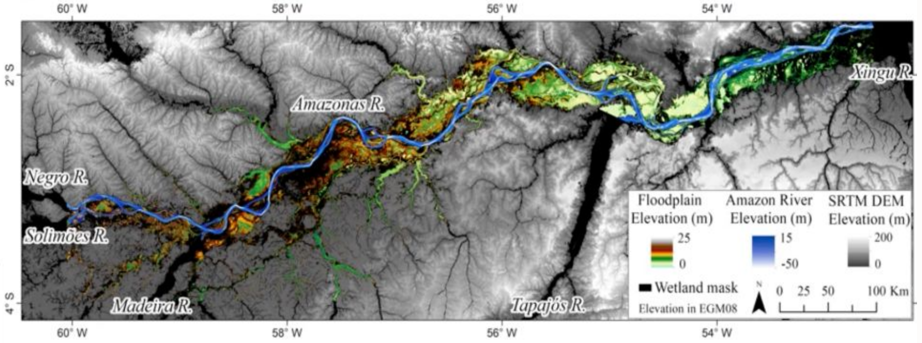
Applications research provides fundamental knowledge of how mission data products can be scaled and integrated to inform resource management, policy development, and decision making.



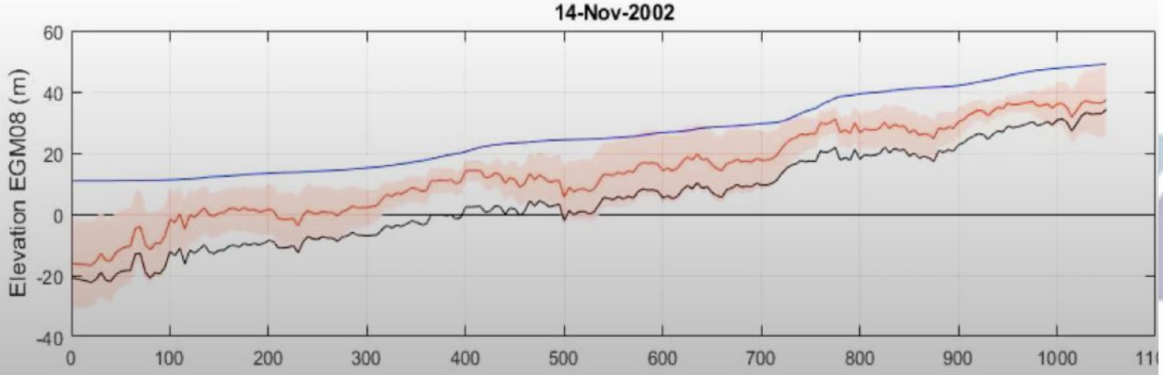
Early Adopter Spotlight: PI: Rodrigo Paiva, UFRGS

"High resolution mapping of floodplain bathymetry from space: a case study in the Amazon"

Fassoni-Andrade A., Paiva,RCD, Rudorff,C. et al
Remote Sensing of Environment,
https://doi.org/10.1016/j.rse.2020.112065



Madeira River Profile



AGU100 ADVANCING EARTH AND SPACE SCIENCE

Water Resources Research

RESEARCH ARTICLE
10.1029/2018WR024010

Key Points:
- Different past/present/future satellite altimetry missions are used for estimating effective river bathymetry through data assimilation
- It is introduced a Kalman filter method with hydraulically based variance and covariance for altimetry data assimilation
- Greater spatial coverage of satellite altimetry missions improves data assimilation performances to a limit

Supporting Information:
- Supporting Information S1
- Movie S1
- Movie S2

Assimilation of Satellite Altimetry Data for Effective River Bathymetry

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[1]Instituto de Pesquisas Hidráulicas, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil, [2]Companhia de Pesquisa de Recursos Minerais, Rio de Janeiro, Brazil

Abstract One of the main problems of hydrologic/hydrodynamic routing models is defining the right set of parameters, especially on inaccessible and/or large basins. Remote sensing techniques provide measurements of the basin topography, drainage system, and channel width; however current methods for estimating riverbed elevation are not as accurate. This paper presents methods of altimetry data assimilation (DA) for estimating effective bathymetry of a hydrodynamic model. We tested past altimetry observations from satellites ENVISAT, ICESAT, and JASON 2 and synthetic altimetry data from satellites ICESAT 2, JASON 3, SARAL, and Surface Water and Ocean Topography to assess future/present mission's potential. The DA methods used were direct insertion, linear interpolation, the Shuffled Complex Evolution-University of Arizona optimization algorithm, and an adapted Kalman filter developed with

https://icesat-2.gsfc.nasa.gov/applications

Objectives

Deep Learning algorithm for classification of Ground and building photon using ICESAT-2 data

Deep Learning algorithm for Extraction of building footprints from very high resolution satellite data.

Building height estimation from ICESat-2 data and building footprints.

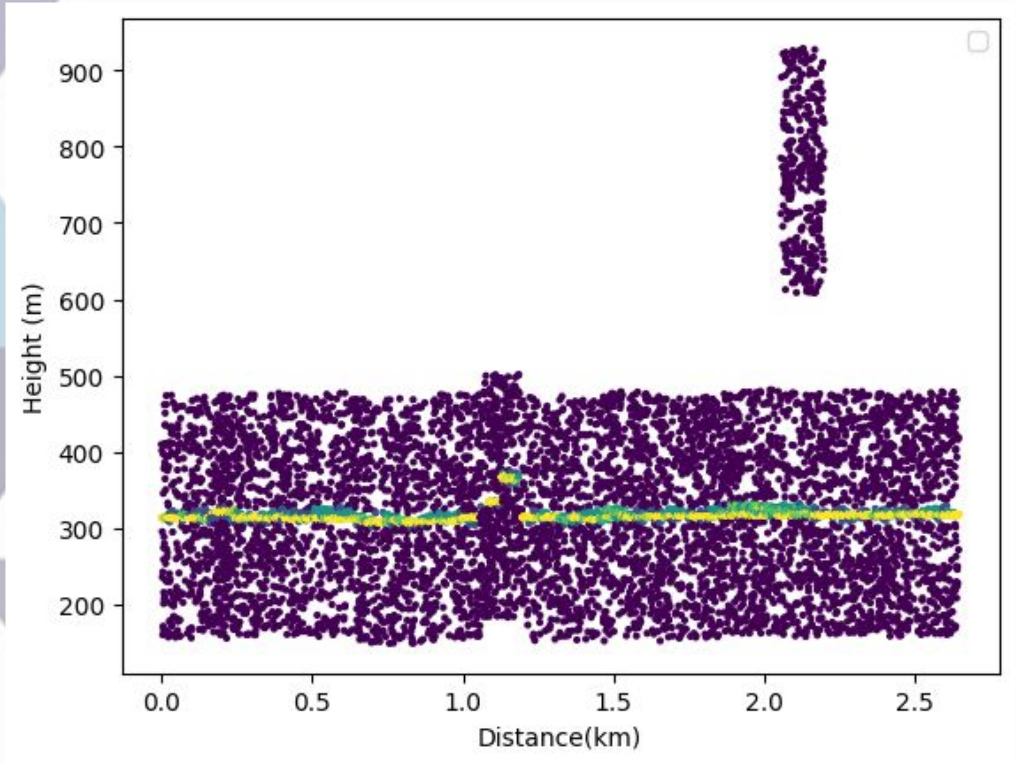
Study Area : Jaipur City

ICESat-2 Photon beam data

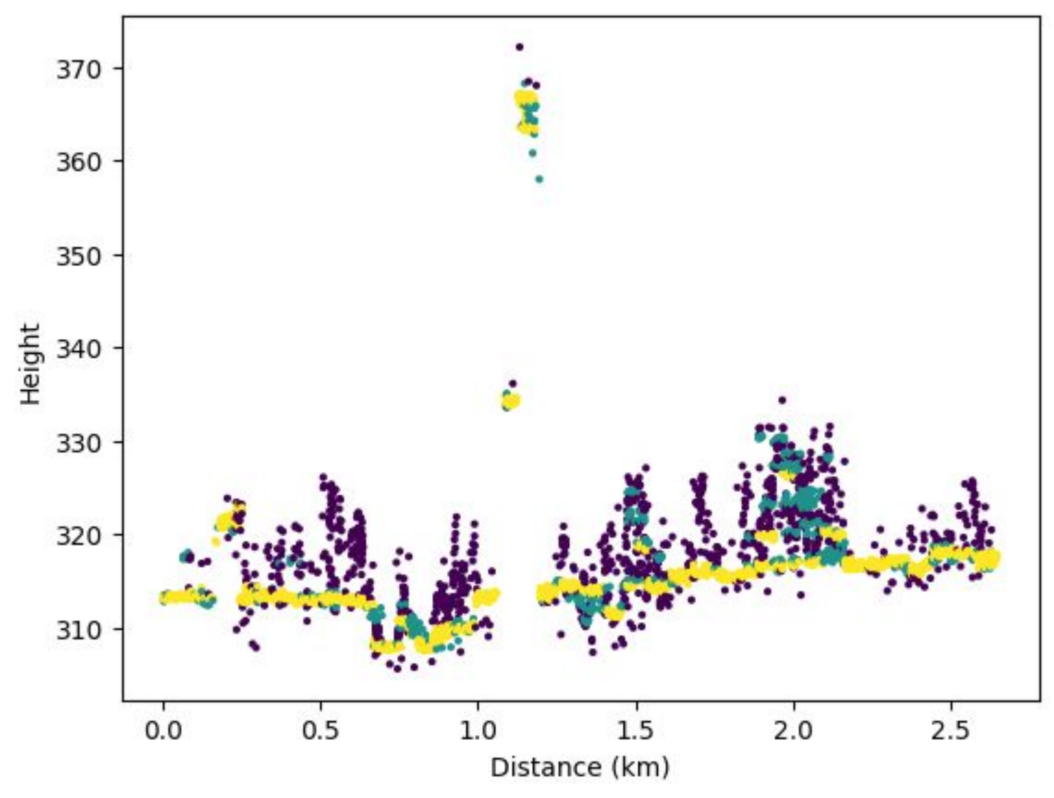
latitude	longitude	quality_ph	height	signal_conf_ph_0
26.7270577	75.82936721	0	296.1605	4
26.72706407	75.82936654	0	296.0493	4
26.72707683	75.82936514	0	296.05197	4
26.72708321	75.82936443	0	296.10025	4
26.72708321	75.82936442	0	296.12582	4
26.72708958	75.82936375	0	296.00412	4
26.72709596	75.82936303	0	296.1165	4
26.7271151	75.82936091	0	296.19537	4
26.72712786	75.82935955	0	296.0286	4
26.72715338	75.82935676	0	296.04095	4
26.72715338	75.82935676	0	296.0352	4
26.72715339	75.8293567	0	296.26938	4
26.72717252	75.82935462	0	296.218	4
26.7271789	75.82935395	0	296.10068	4

Sample Beam data

Comparison of Photon beam data

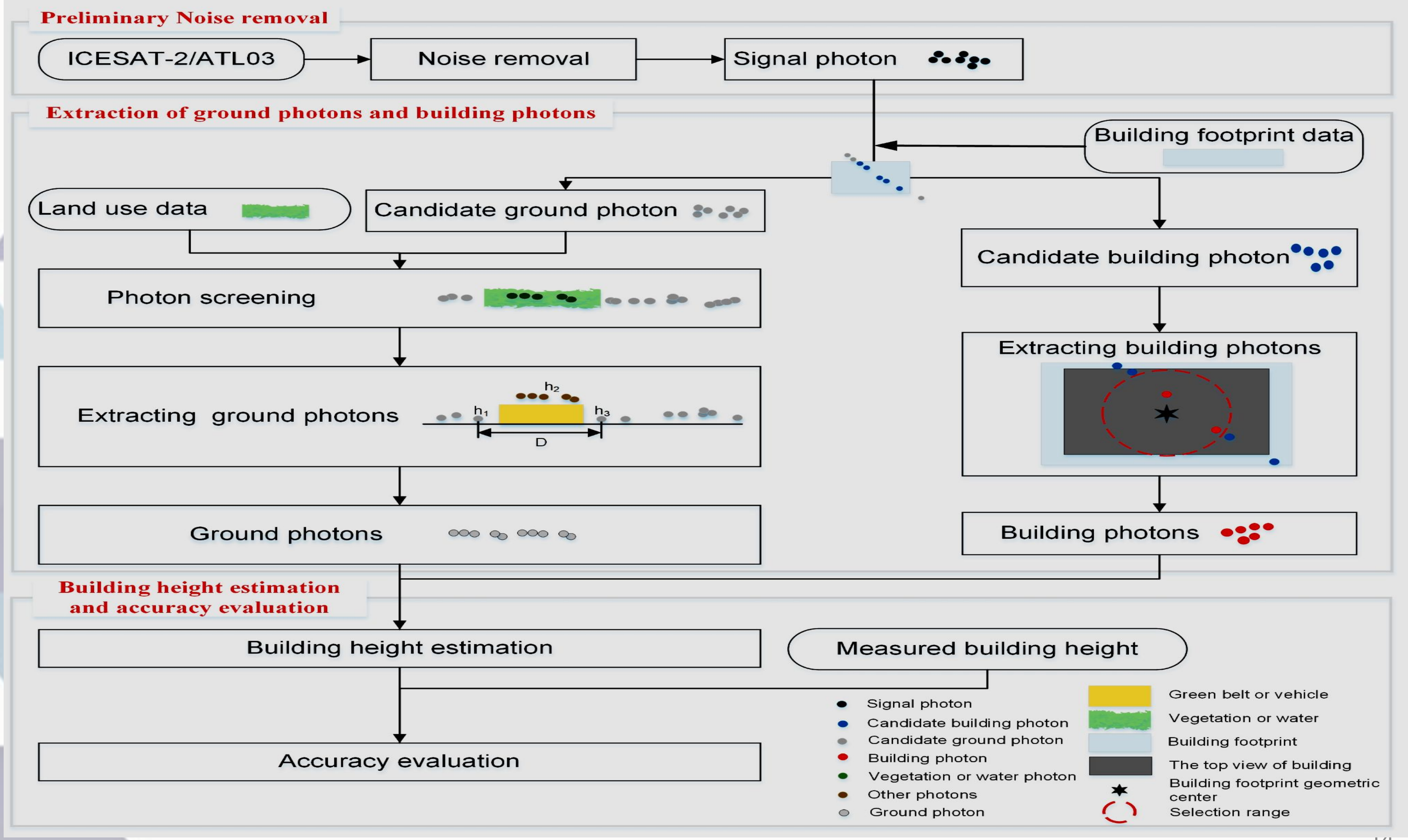


Photon data with confidence code (0,1,2,3,4)

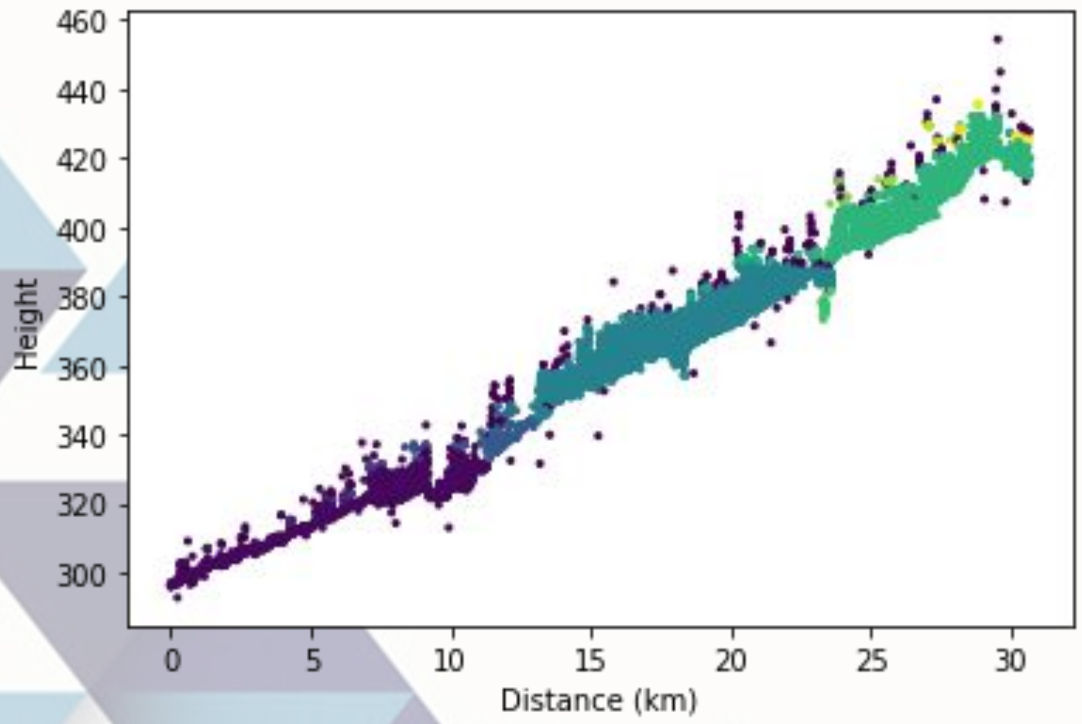


Photon data with confidence code (4)

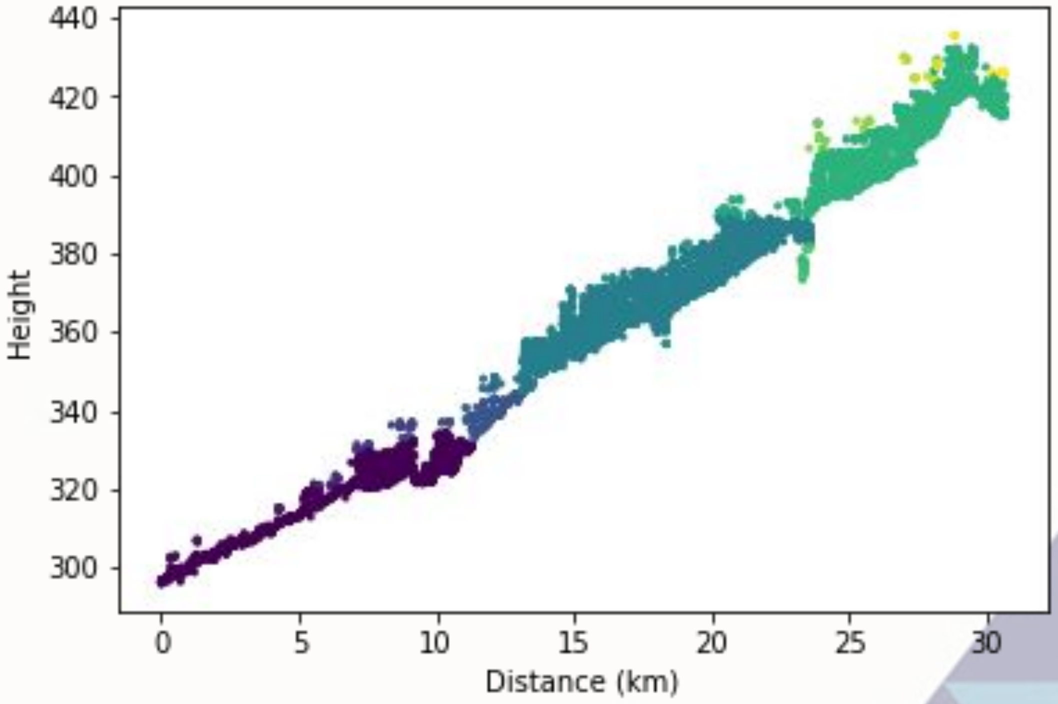
Workflow of the proposed Deep Learning approach



GW-DBSCAN: MECHANISM 1
Noise Removal

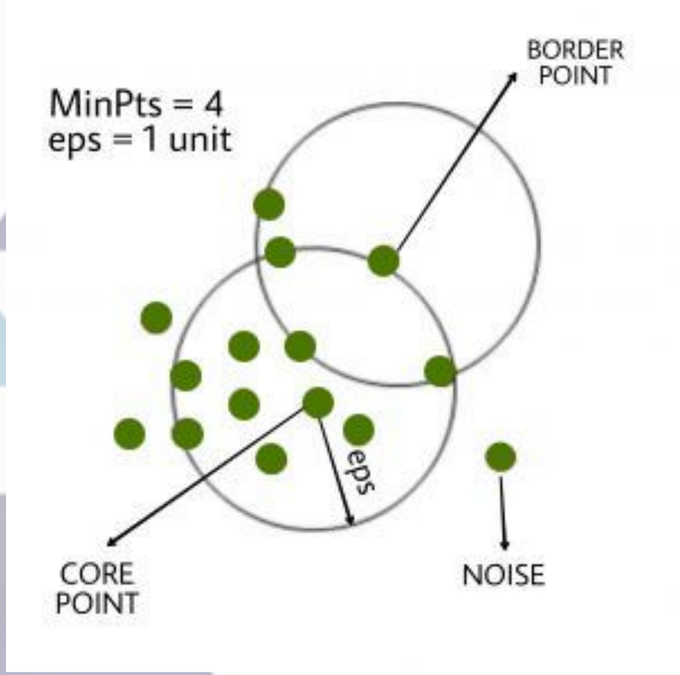


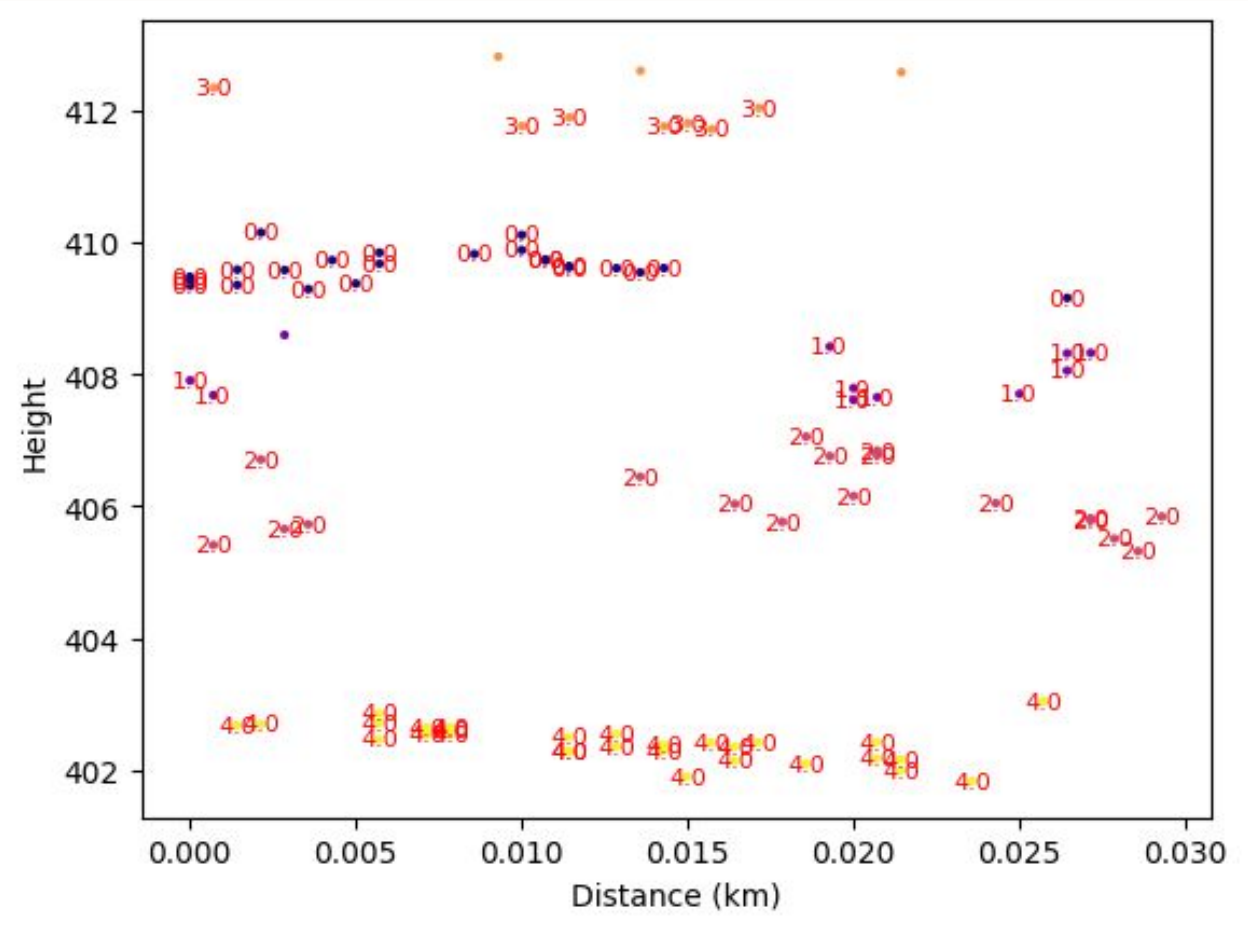
Before Noise removal



After Noise removal

GW-DBSCAN: MECHANISM 2
Classification





MECHANISM 3:
Height Computation

Latitude	Longitude	Quality_ph	Photon_height	Distance	label	Building_height
26.73066	75.80147	0	293.38187	0.4015064	1	0
26.73067	75.80147	0	293.51245	0.4022188	1	0
26.73067	75.80147	0	293.48517	0.402219	1	0
26.73067	75.80147	0	293.32016	0.40222	1	0
26.73067	75.80147	0	293.38263	0.4022196	1	0
26.73067	75.80146	0	293.16794	0.4029342	1	0
26.73067	75.80146	0	293.07205	0.4029348	1	0
26.73067	75.80146	0	297.74387	0.4029061	2	4.67182
26.73068	75.80146	0	293.22903	0.4036471	1	0
26.73069	75.80146	0	293.5364	0.4043585	1	0
26.73069	75.80146	0	293.489	0.4043587	1	0

Calculating distance along track direction

The first step involves calculating the differences in longitude and latitude by subtracting the respective coordinates of the two points. Next, the haversine formula uses these differences along with trigonometric functions to compute intermediate values. These values are then utilized in the calculation of the great-circle distance, considering the curvature of the Earth. The final distance is obtained by multiplying the radius of the Earth (R) with the computed value.

The haversine formula :

$$\Delta lon = longitude2 - longitude1,$$

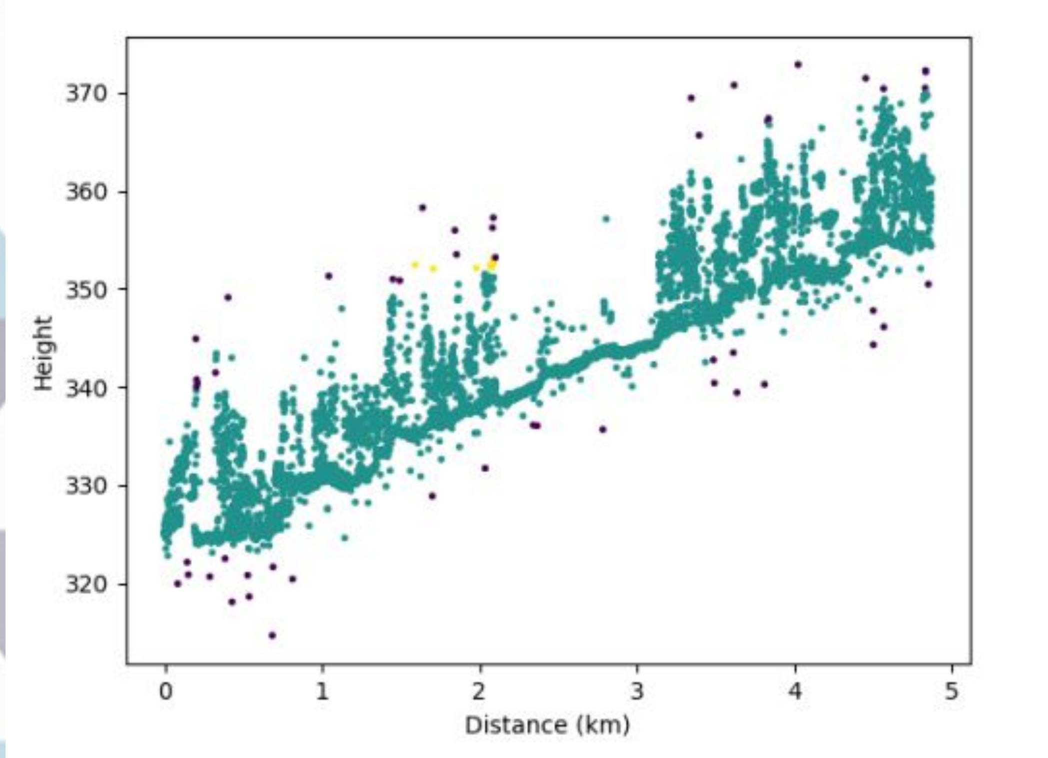
$$\Delta lat = latitude2 - latitude1,$$

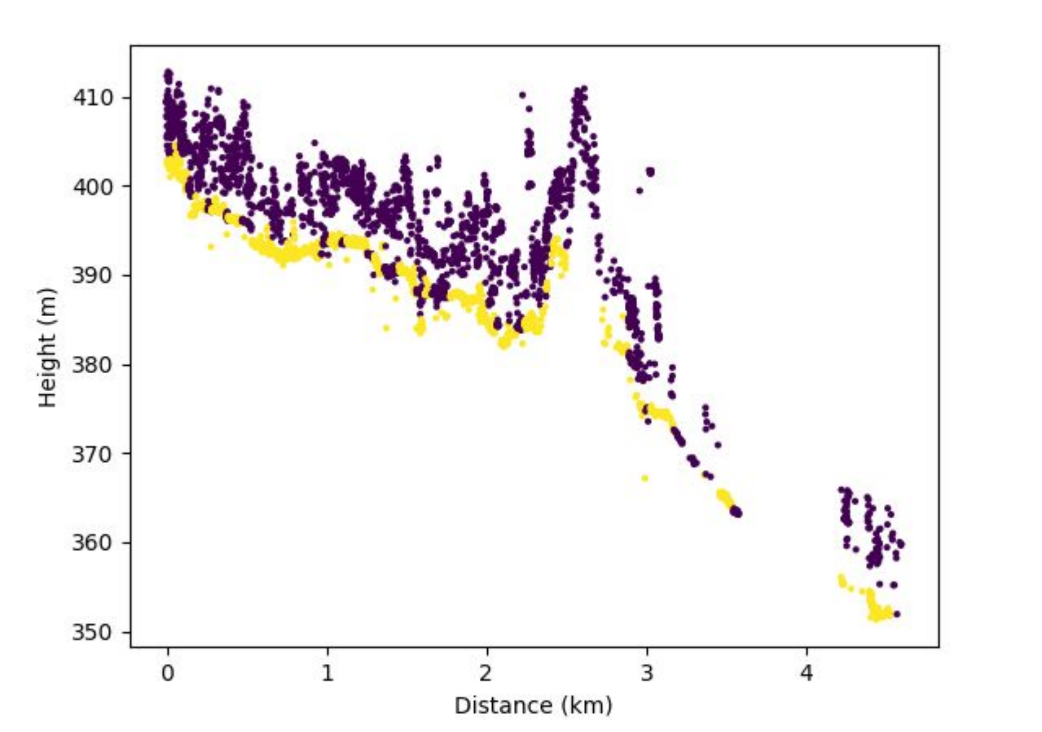
$$a = (sin(\frac{\Delta lat}{2}))^2 + cos(latitude1) \times cos(latitude2) \times (sin(\frac{\Delta lon}{2}))^2,$$

$$c = 2 \times atan2(\sqrt{(a)}, \sqrt{(1 - a)}),$$

$$d = R \times c,$$

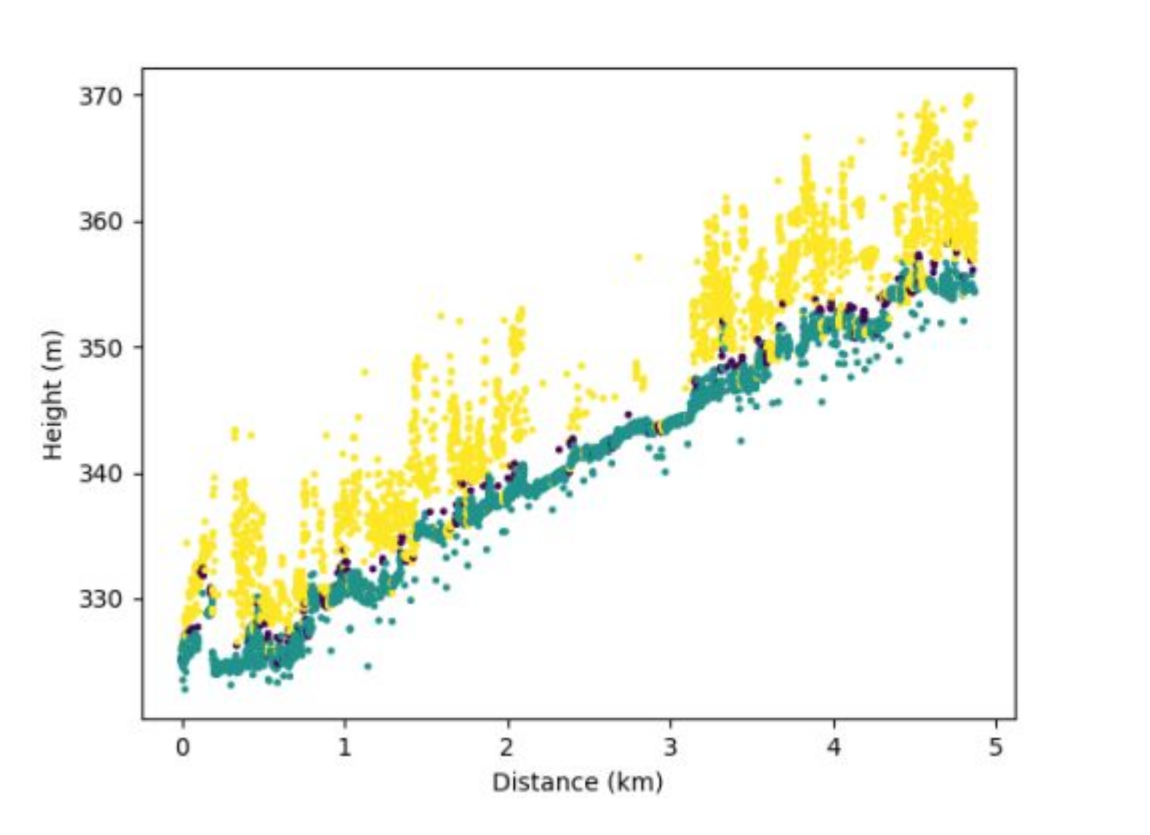
where d is the distance between two coordinates.





Noise removal from proposed GW-DBSCAN Algorithm

Identified ground photons(in yellow) from GW-DBSCAN



Elevated photons detected(in yellow) after applying a threshold of 2.5 meters

Predicted Building Heights

Sr. No.	Building	Latitude	Longitude	On-field Height (m)	Predicted Height (m)	Difference in Height (m)
1.	Build1	26.917376° N	75.846121° E	5.92	5.96	0.04
2.	Build2	26.871329° N	75.819814° E	24.90	24.96	0.06
3.	Build3	26.856722° N	75.816034° E	19.52	19.59	0.07
4.	Build4	26.843440° N	75.814589° E	19.00	19.017	0.017
5.	Build5	26.835718° N	75.788686° E	13.57	13.47	0.10
6.	Build6	26.970007° N	75.775155° E	8.19	8.188	0.02
7.	Build7	26.844921° N	75.756465° E	8.20	7.53	0.67
8.	Build8	26.871329° N	75.816460° E	19.67	19.61	0.06
9.	Build9	26.797105° N	75.826685° E	49.31	49.31	0
10.	F-63 Water Tank 2	26.865617	75.815840	7.61	7.7	0.09
11.	Indian Institute Of Crafts & Design (IICD)	26.87297888	75.81665679	11.89	12.01	0.12
12..	Vinodini	26.86406085	75.81568848	9.8	8.99	0.81
13.	F-63 Water Tank 1	26.865777	75.815880	3.5	3.86	0.36

Sadhwani T., Pareek H., Harjule P., Agarwal B. and Rao S.S (2024), ***Noise filtering algorithm based on Machine learning for identification of ground hitting photons in Jaipur city,*** **Advances in Data-Driven Computing and Intelligent Systems, Lecture Notes in Networks and Systems 893, Springer; https://doi.org/10.1007/978-981-99-9518-9_4**

Predicted Building Heights

Sr. No.	Building Address	Latitude	Logitude	On-field height (m)	Predicted height (m)	Difference in Height (m)
14.	VLTC, MNIT	26.8631023	75.8138354	ž7.81	27.99	0.17
15.	Brahmkuamri Ishaariya Vishv Vidalya Malviya Nagar Jaipur	26.85767328	75.81517559	10.80	11	0.2
16.	Nagar Residency, Jhalana Gram, Malviya Nagar	26.85886	75.815049	15.6	15.904	0.3
17.	A-432, Govind Marg, Block-B, Sector 4, Malviya Nagar, Jaipur,	26.85358273	75.81560646	6.82	7	0.18
18.	4/189, Vidyut Abhiyanta Colony, Sector 4, Malviya Nagar, Jaipur,	26.85260137	75.81571304	7.10	7.1161	0.01
19.	Vidyut Abhiyanta Colony, Sector 4, Malviya Nagar, Jaipur, Rajasthan 302017	26.85152028	75.81583	7.45	7.58	0.13
20.	4/159 Vidyut Abhiyanta Colony, Sector 4, Malviya Nagar, Jaipur, Rajasthan 302017	26.85149469	75.81583271	7.50	7.61103	0.11
21.	Vidyut Abhiyanta Colony, Sector 4, Malviya Nagar, Jaipur, Rajasthan 302017	26.8514755	75.81584773	7.71	7.8	0.09
22.	157, Vidyut Abhiyanta Colony, Sector 10, Malviya Nagar, Jaipur	26.85135394	75.81584773	7.78	7.87	0.09
23.	Sector 3, Malviya Nagar, Jaipur, Rajasthan 302017	26.84828878	75.81617815	3.70	3.754	0.054
24.	3/424, Sector 3, Malviya Nagar, Jaipur, Rajasthan 302017	26.84845444	75.81615982	3.27	3.3	0.03
25.	Sector 3, Malviya Nagar, Jaipur, Rajasthan 302017	26.84857553	75.81614648	3.24	3.4	0.16
26.	Sector 3, Malviya Nagar, Jaipur, Rajasthan 302017	26.84864564	75.81613878	3.00	3.021	0.021
27.	Singh Mobile Center, Sector 3, Malviya Nagar, Jaipur, Rajasthan 302017	26.84745458	75.81627133	2.88	2.99	0.11
28.	Sector 3, Malviya Nagar, Jaipur, Rajasthan 302017	26.84682256	75.81634126	2.60	2.72	0.12
29.	3 Sector Upas, Sector 3, Malviya Nagar, Jaipur, Rajasthan 302017	26.84630908	75.81639538	5.87	6	0.13
30.	Sector 3, Malviya Nagar, Jaipur, Rajasthan 302017	26.84609697	75.81641782	5.69	5.726	0.036
31.	Nandpuri Colony, Malviya Nagar, Jaipur, Rajasthan 302017	26.84201473	75.81687487	9.79	10	0.21
32.	Nandpuri Colony, Malviya Nagar, Jaipur, Rajasthan 302017	26.8414935	75.8169176	7.98	8.06	0.08
33.	Sector 3, Malviya Nagar, Jaipur, Rajasthan 302017	26.84888721	75.81546896	25.00	25.13	0.13
34.	Jhalana Gram, Malviya Nagar, Jaipur, Rajasthan 302017	26.86485995	75.81663941	23.34	23.5	0.16
35.	VRC8+QW9, Jhalana Institutional Area, Jhalana Doongri, Jaipur, Rajasthan 302004	26.87187532	75.81740658	11.80	11.96	0.16
36.	Jhalana Institutional Area, Jhalana Doongri, Jaipur, Rajasthan 302004	26.87159413	75.81737609	14.58	14.8	0.22
37.	State Resource Centre, Jhalana Institutional Area, Jhalana Doongri, Jaipur, Rajasthan 302004	26.87477614	75.81772154	10.68	10.8	0.12
38.	H-152, Jhalana Gram, Malviya Nagar, Jaipur, Rajasthan 302017	26.85941108	75.81860033	8.88	8.94	0.06

Predicted Building Heights

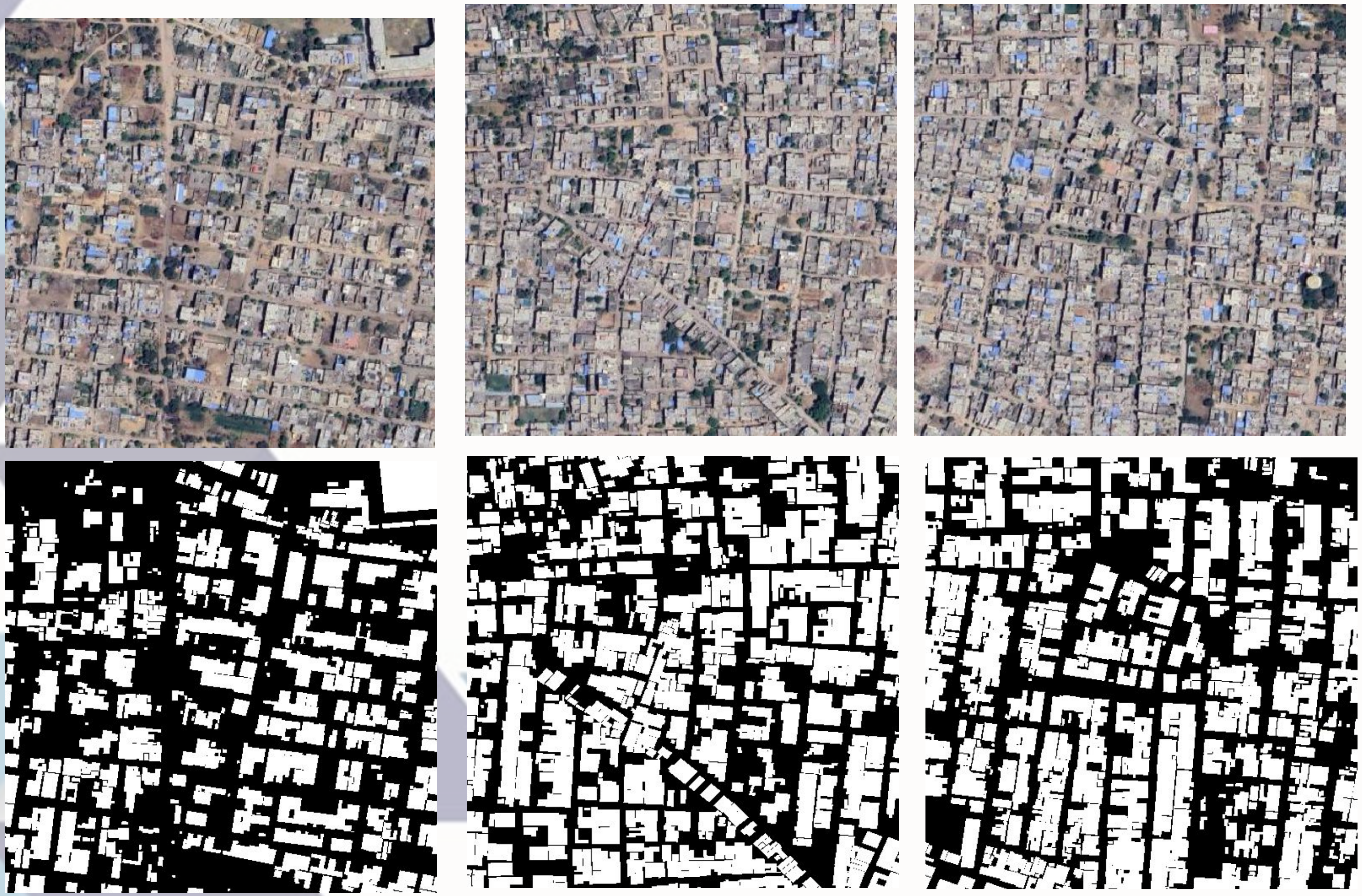
Sr. No.	Building Address	Latitude	Logitude	On-field height (m)	Predicted height (m)	Difference in height (cm)
39.	GSI Colony, Model Town, Jagatpura, Jaipur, Rajasthan 302017	26.84542986	75.82011922	11.35	11.5	0.15
40.	Govt Girls Sen Sec school, Sector 2, Malviya Nagar, Jaipur, Rajasthan 302017	26.8502555	75.8204764	7.05	7.12	0.07
41.	VR59+GRC, Gurjar colony, Jhalana Gram, Malviya Nagar, Jaipur, Rajasthan 302017	26.85876647	75.81955138	13.25	13.3	0.05
42.	Civil lines metro top	26.90978637	75.78170487	25.10	25.118	0.018
43.	Hasanpura, Jaipur, Rajasthan 302006	26.92247549	75.78033117	8.30	8.44	0.14
44.	Bright Step School	26.90951	75.78173545	28.32	28.4m	0.08
45.	Mantri House, 48, Jai Ambey Colony, Civil Lines, Jaipur, Rajasthan 302006	26.90521475	75.78220681	8.5	8.69m	0.19
46.	Adarsh Krishna Nagar, Kartarpur, Gopal Pura Mode, Jaipur	26.8834757	75.78554536	8.00	8.09m	0.09
47.	Building 47	26.916741606854227,	75.80879964167458	7.00	7.0353400	0.035
48.	Building 48	26.915423398	75.8089412	28.28	28.2978499	0.017
49.	Building 49	26.9152828	75.808956	28.52	28.632999	0.11
50.	Building 50	26.91286021	75.809220	11.00	11.08916	0.089
51.	Building 51	26.91175577	75.80933	8.22	8.32	0.10
52.	Building 52	26.911397	75.809376	13.86	13.943	0.083
53.	Building 53	13.9431100	75.80952	9.80	9.8627700	0.06

Sample Image for Prediction of Building Footprints

Description of Image

This raster image depicts the geographical area of Jaipur.

Image Patches and Predicted Mask



- Patch Generation
- Segmentation with SAM
- Prediction Fusion

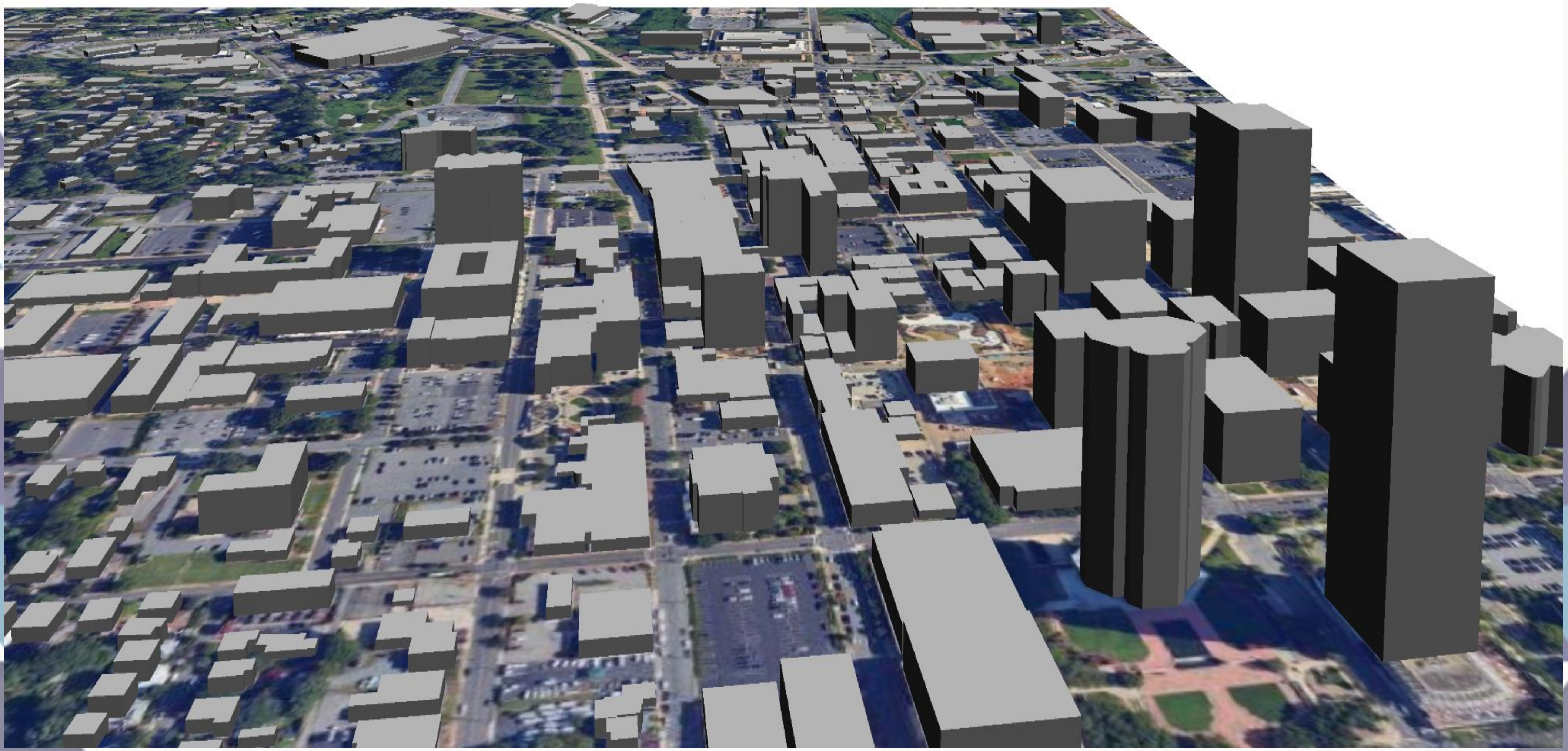
Fused Predicted Mask and Imposed on Image

DIGITAL TWIN MODEL

latitude_footprints	longitude_footprints	area_in_meters	confidence	geometry	height
26.87332	75.81667	34.6336	0.8345	POLYGON((75.8167242321344 26.8733207785854, 75.8167176061793 26.8733489746176, 75.8166109717956 26.8733288215324, 75.8166175977765 26.8733006255047, 75.8167242321344 26.8733207785854))	10.471519999999998
26.87332	75.81667	34.6336	0.8345	POLYGON((75.8167242321344 26.8733207785854, 75.8167176061793 26.8733489746176, 75.8166109717956 26.8733288215324, 75.8166175977765 26.8733006255047, 75.8167242321344 26.8733207785854))	7.529380000000003
26.87332	75.81667	34.6336	0.8345	POLYGON((75.8167242321344 26.8733207785854, 75.8167176061793 26.8733489746176, 75.8166109717956 26.8733288215324, 75.8166175977765 26.8733006255047, 75.8167242321344 26.8733207785854))	6.803980000000024

Sample data for building footprint with photon data with building heights

DIGITAL TWIN MODEL



Way Forward

- High-Resolution Data Integration
- Advanced Remote Sensing Techniques
- Refinement of Digital Surface Model

Thank You...