Large-Scale Geo-Data Mining for Good

Conrad Albrecht and team*

* in particular thx to: Chenying Liu, Levente Klein, Marcus Freitag, Yi Wang

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Agenda

Big Geo-Data Remote Sensors: an eye on our planet across the spectrum I

Urban Forests:
a source of wellbeing that deserves attention & planning II.a
Klein, Zhou, Albrecht (ICML 2021), Albrecht et al. (IGARSS 2022, accepted),
Klein, Albrecht, Marianno (2022 ESA Living Planet Symposium)

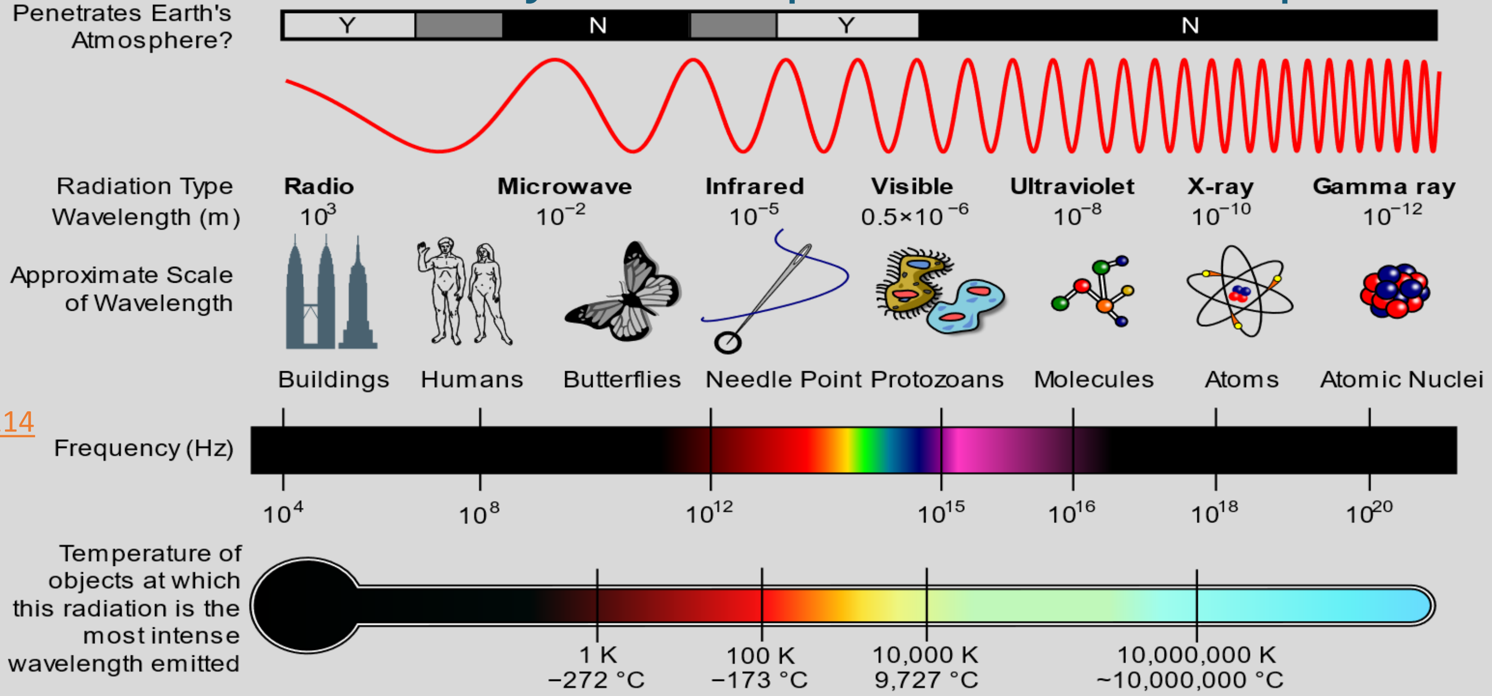
Archeology top-down:
discover traces of and learn from our ancestors keeping intact the environment II.b
Albrecht et al. (IEEE BigData 2019), Albrecht & Pankanti (2020 AAAS symposium),
students of Albrecht group @ Zhu lab (2022 German-Israeli archeology challenge winners)

Earth Observation analytics: challenges & perspectives III

plenum & discussion IV

credit: eol.jsc.nasa.gov

I Big-Geo Data Remote Sensors: eye on our planet across the spectrum

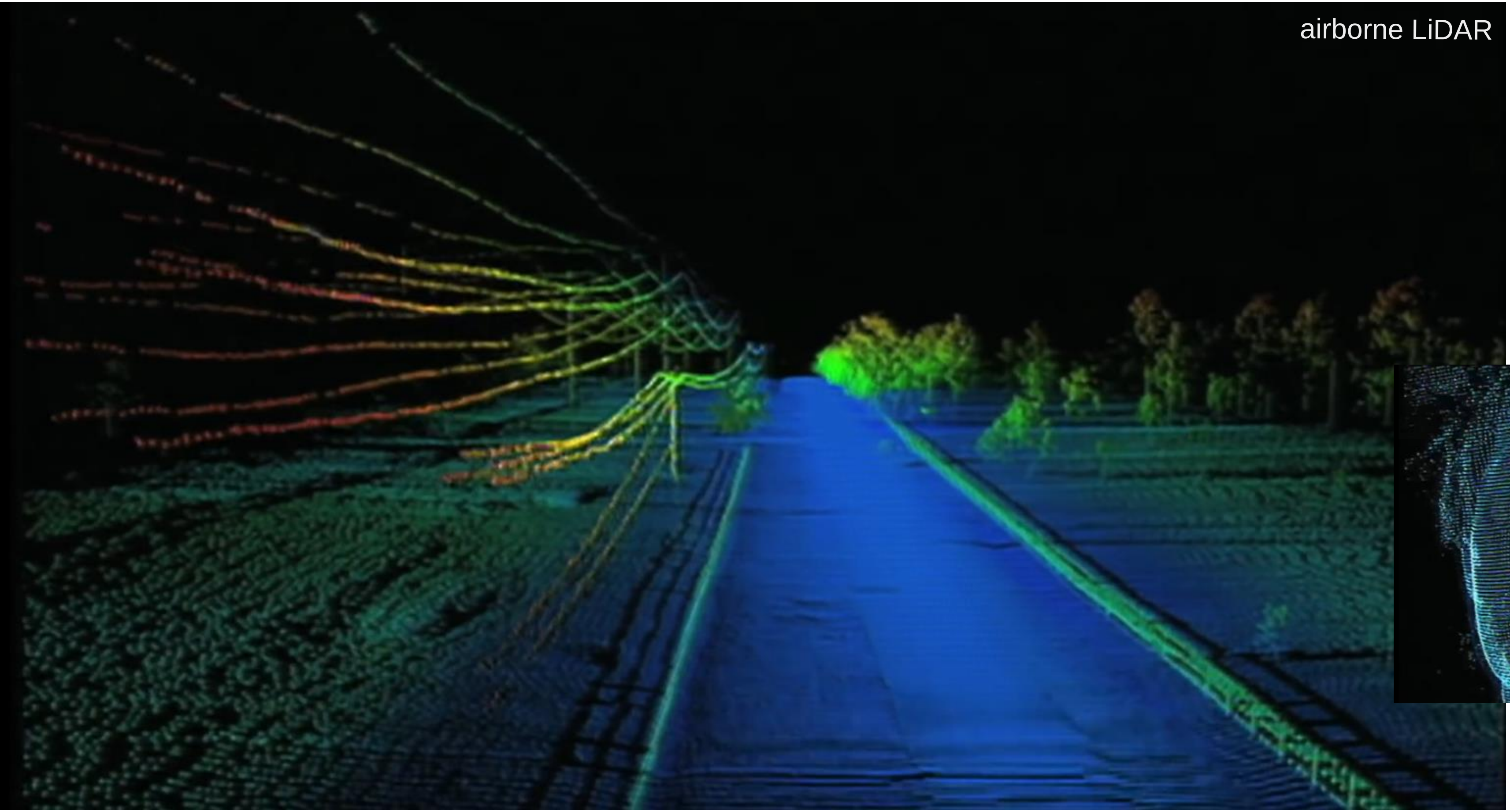


source of figure elements: https://wikipedia.org and https://svs.gsfc.nasa.gov/13114

Radar: record phase and amplitude of microwave-like generated signal bouncing off Earth’s surface (including its polarization)

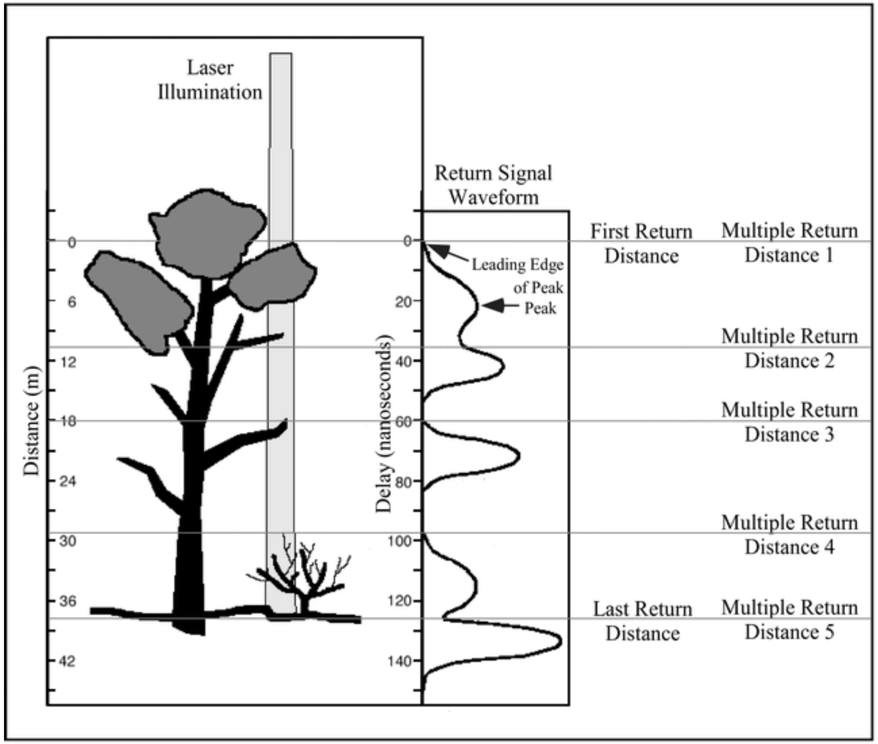
optical: multi- & hyperspectral imaging by absorption of sunlight reflected by Earth’s surface (including infrared and thermal radiation)

I Big-Geo Data Remote Sensors: LiDAR laser technology in the arts



track & screenshots: copyright by Radiohead – House of Cards (source: YouTube)

I Big-Geo Data Remote Sensors: LiDAR worth the effort?



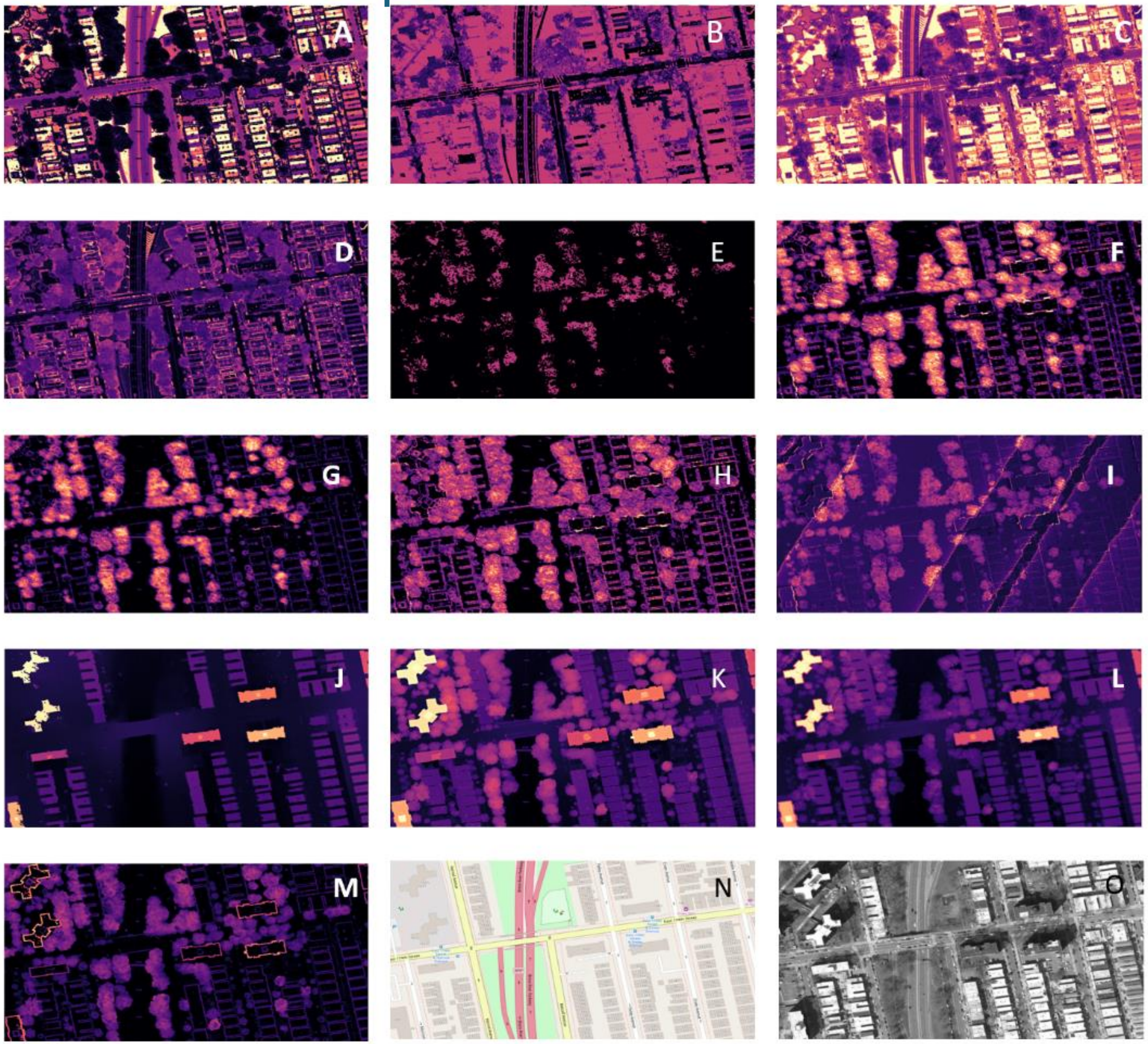
LiDAR cartoon: Lefsky et al. (2002), *Elon on LiDAR screenshots*: YouTube clip Elon Musk says losers use LiDAR. [Explanation video]

view onto Manhattan with Central Park, New York City, as in my seat after take-off from EWR …

II.a Urban Forests (in NYC): From raw 3D LiDAR point cloud statistics …

POINT CLOUD STATISTICS

attribute	statistics	Fig. 2 index
reflectance r	minimum r_-	A
	maximum r_+	B
	mean $\overline{r}$	C
	standard deviation $r_\triangle$	D
count c	minimum c_-	E
	maximum c_+	F
	mean $\overline{c}$	G
	standard deviation $c_\triangle$	H
	sum $\sum$	I
elevation e	minimum e_-	J
	maximum e_+	K
	mean $\overline{e}$	L
	standard deviation $e_\triangle$	M



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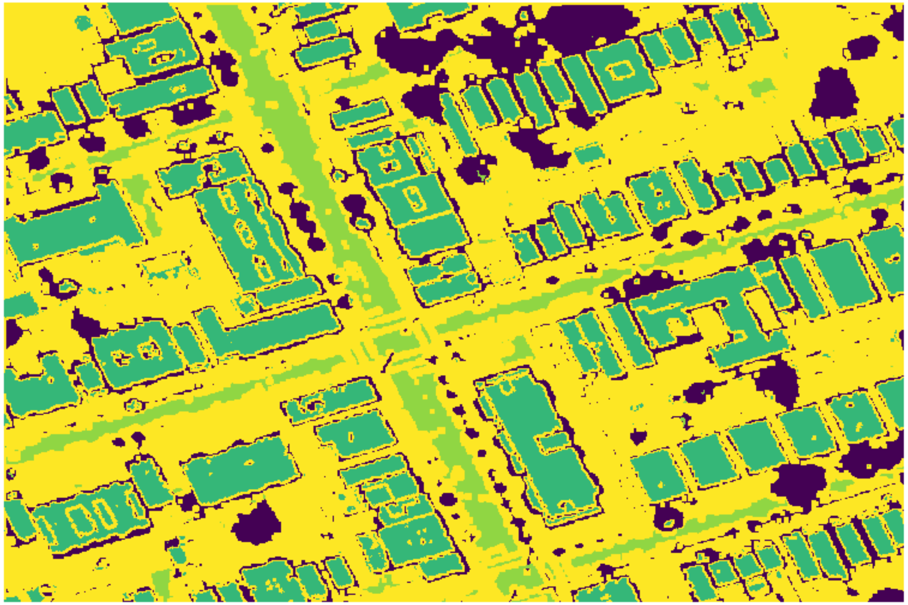
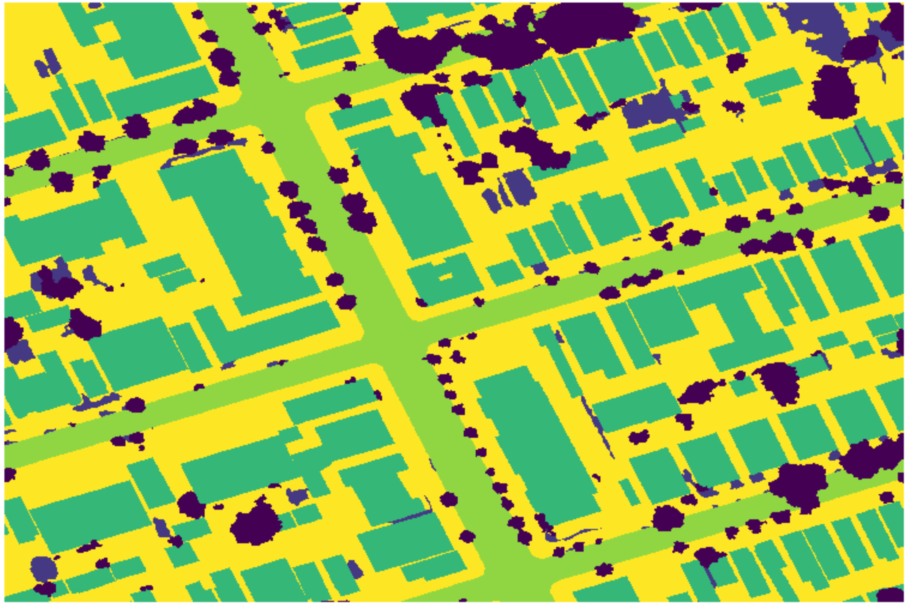
II.a Urban Forests (in NYC): … to tree identification …

LABELING RULES FROM LIDAR STATISTICS

class	pseudo (R,G,B)	binary classification rule
buildings	$\left(e_-, e_\Delta, e_+\right)$	$e_- > \langle e_- \rangle \wedge e_\Delta < \langle e_\Delta \rangle \wedge e_+ > \langle e_+ \rangle$
vegetation	$\left(c_+, e_\Delta, c_\Delta\right)$	$c_+ > \langle c_+ \rangle \wedge e_\Delta > \langle e_\Delta \rangle \wedge c_\Delta > \langle c_\Delta \rangle$
roads	$\left(r_-, \overline{r}, e_-\right)$	$r_- > .1 r_{\max} \wedge \overline{r} < .6 r_{\max} \wedge e_- < .1 e_{\max}$

II.a Urban Forests: … for long-term tree damage by Hurricane Sandy …

(a) 2011: one year before storm

(b) 2013: one year after storm

(c) 2015: 3 years after storm

scene definition	sample reference (lat, lon)	vegetation state description	relative change 2011 → 2013	2013 → 2015
suburban close to shore	$(40.579, -73.947)$	*damaged*	-14%	-5%
urban close to shore	$(40.580, -73.958)$	*little damage*	-3%	+4%
suburban inland	$(40.599, -73.967)$	*undamaged*	+.5%	+3%

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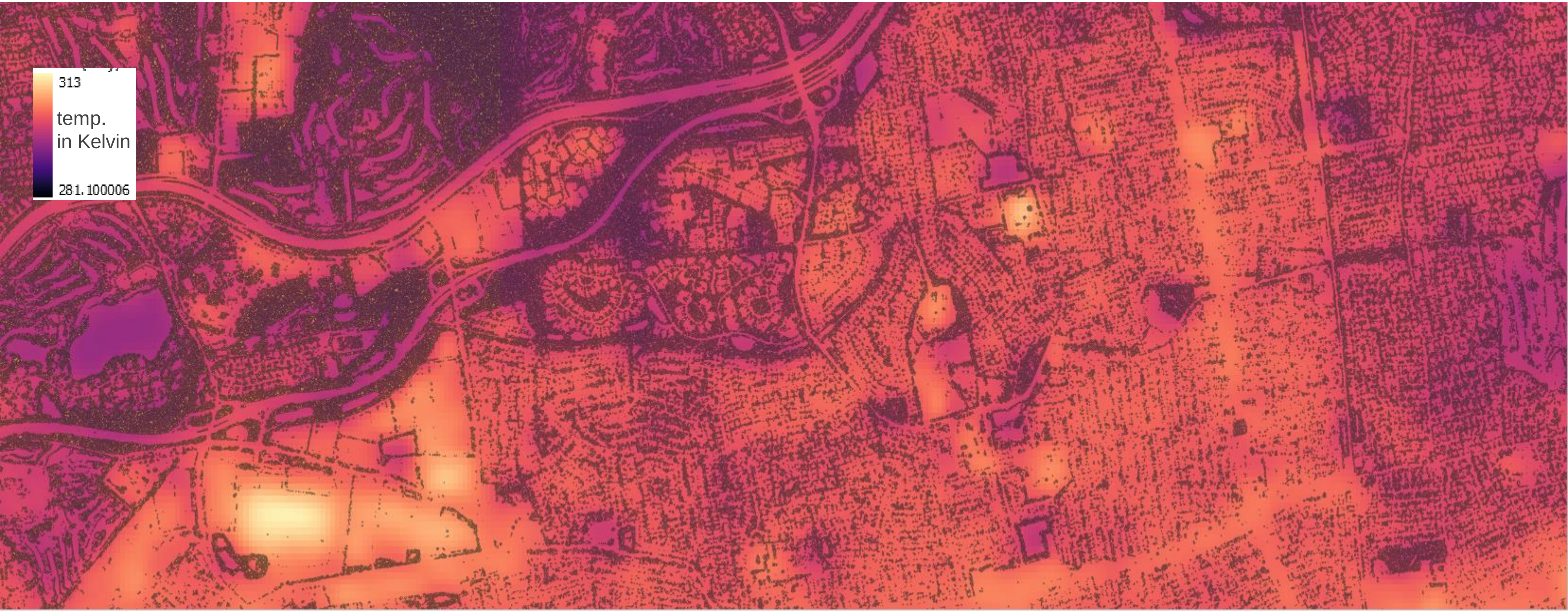
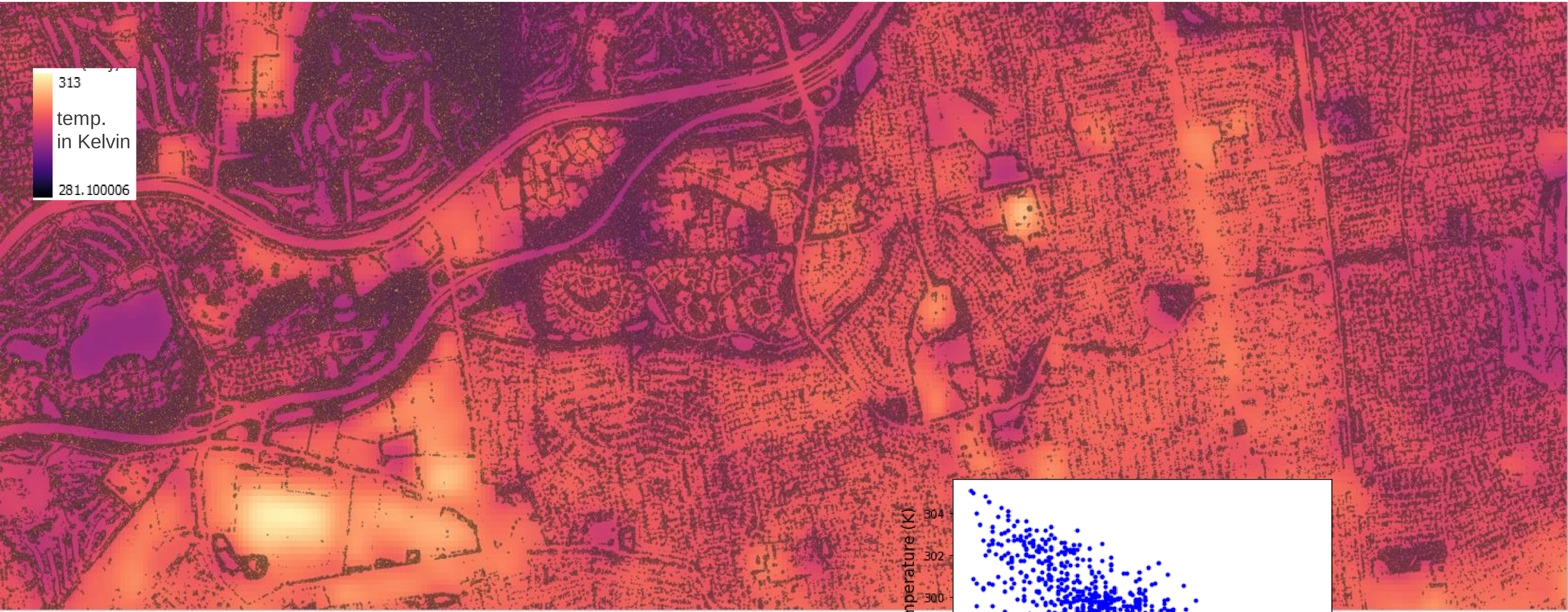
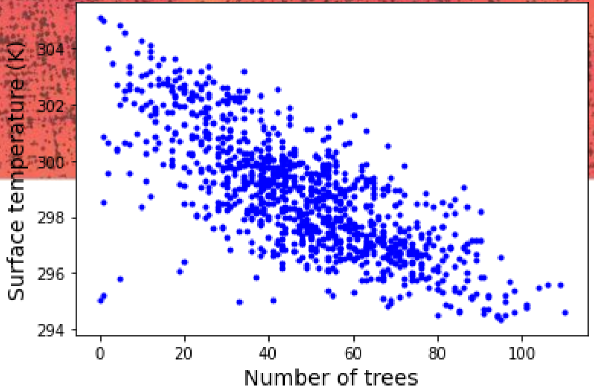
II.a Urban Forests: … or heat island identification & urban planning



sensor fusion:
Landsat 8 satellite's thermo-**optical** sensor + vegetation identified by airborne **LiDAR** survey

II.a Urban Forests: … or heat island identification & urban planning





sensor fusion:
Landsat 8 satellite's thermo-**optical** sensor + vegetation identified by airborne **LiDAR** survey

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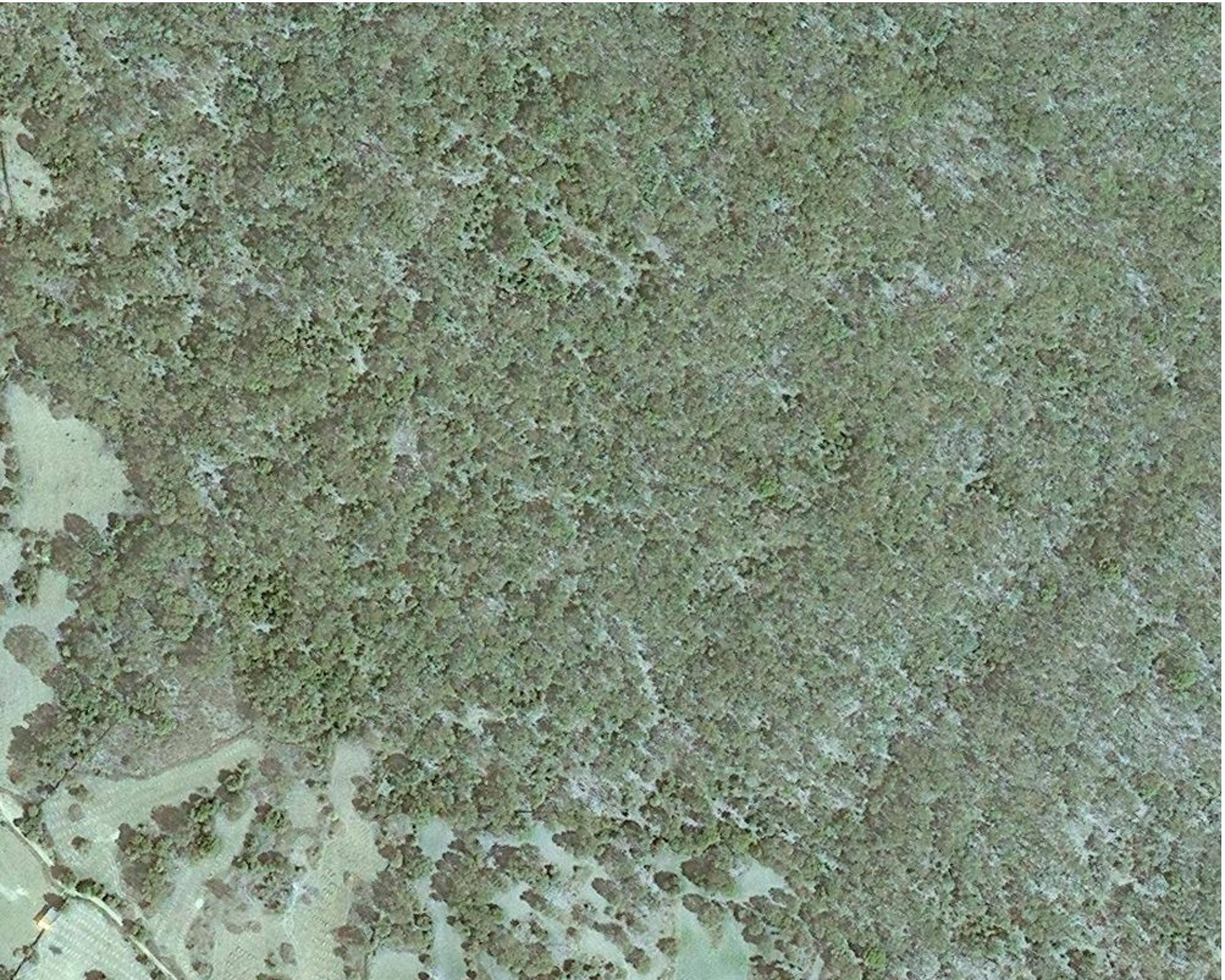
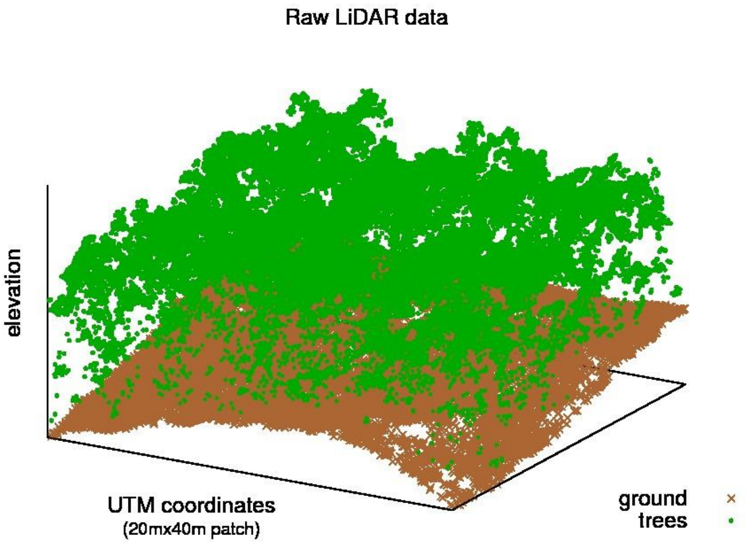
credit: Prof. Chris Fisher, Colorado State University

II.b Archeology top-down: Digitally uncovering ancient urban infrastructure …



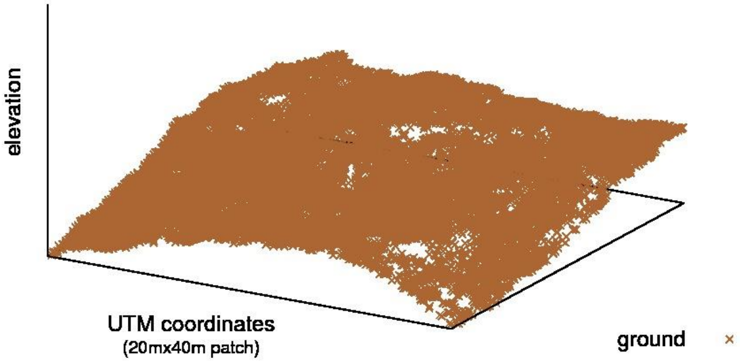


classify 3D LiDAR point cloud into tree data vs. bare ground laser reflections

Colorado State University

IBM Research

II.2 Archeology top-down: Digitally uncovering ancient urban infrastructure …



virtually remove trees to obtain rasterized digital elevation model

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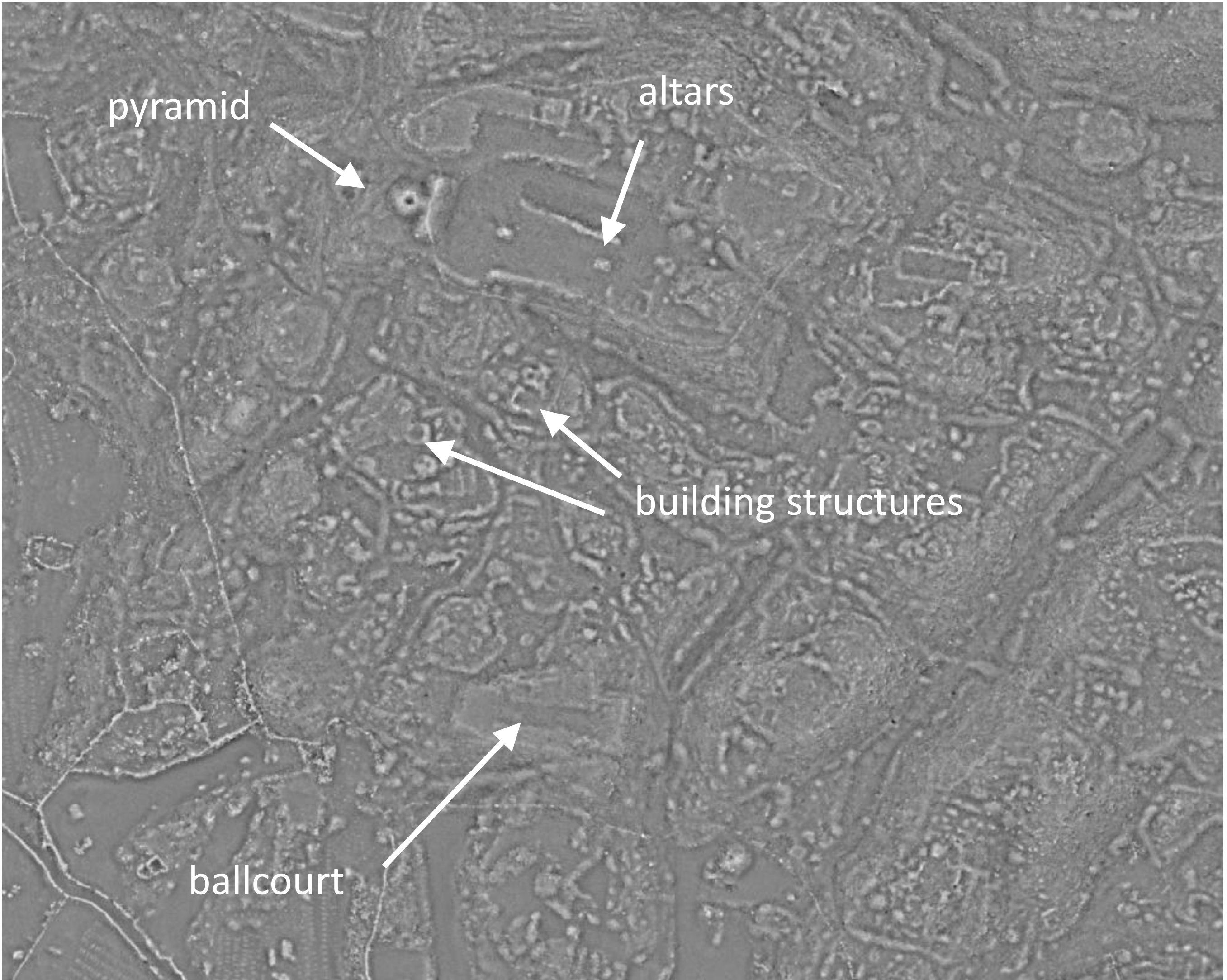
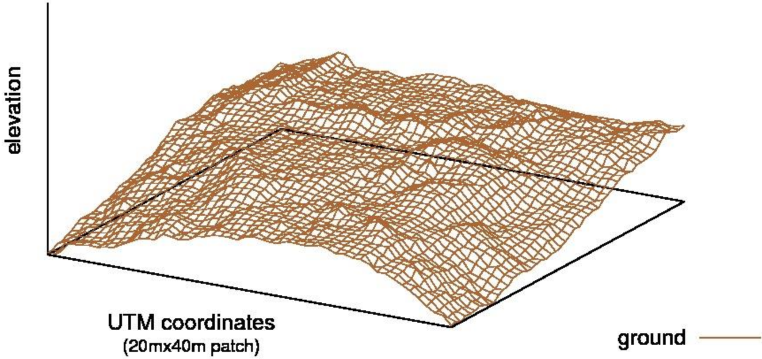
II.b Archeology top-down: Digitally uncovering ancient urban infrastructure …





(machine-learning aided) identification of local terrain structures in collaboration with archeologists

Colorado State University

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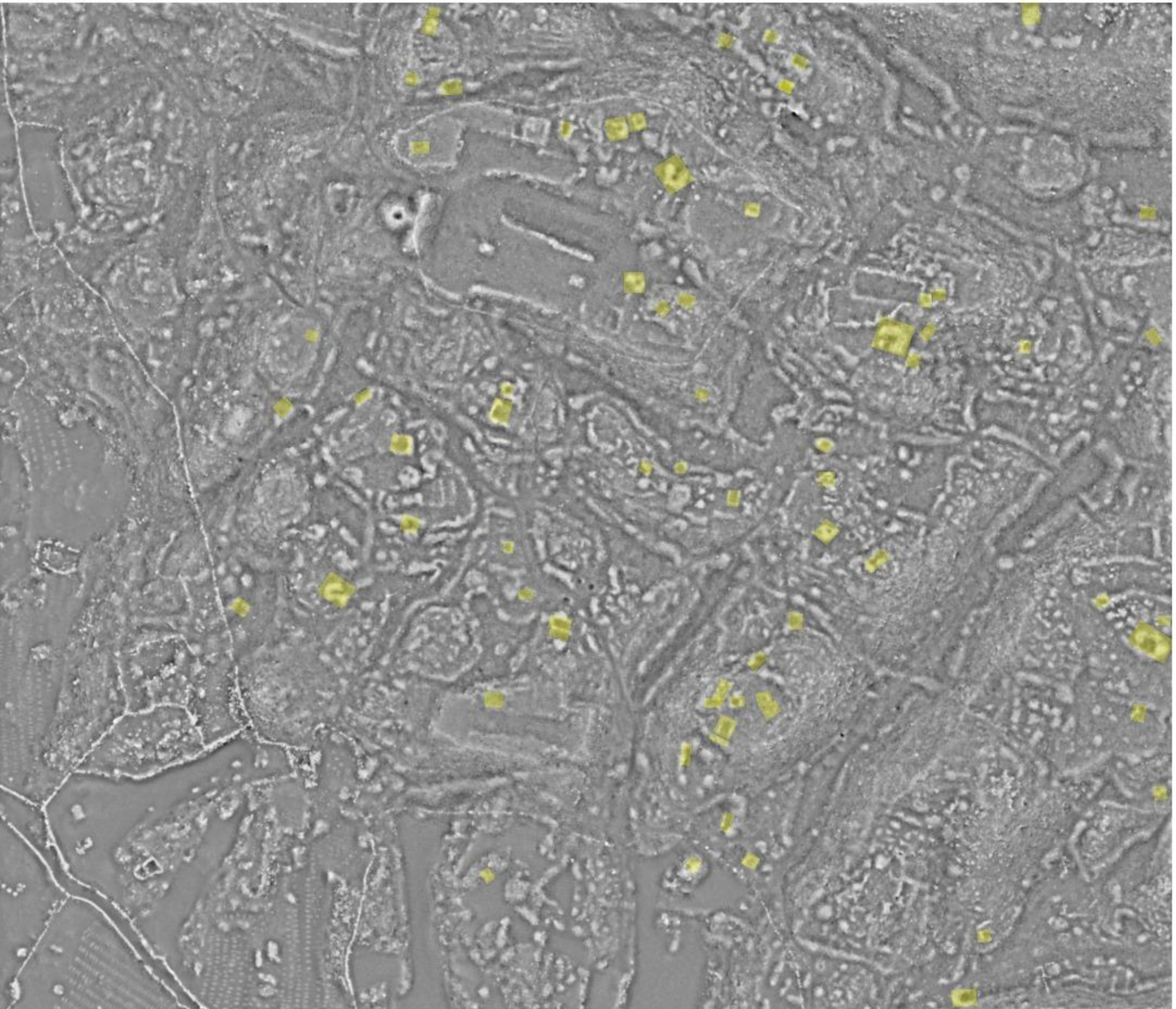
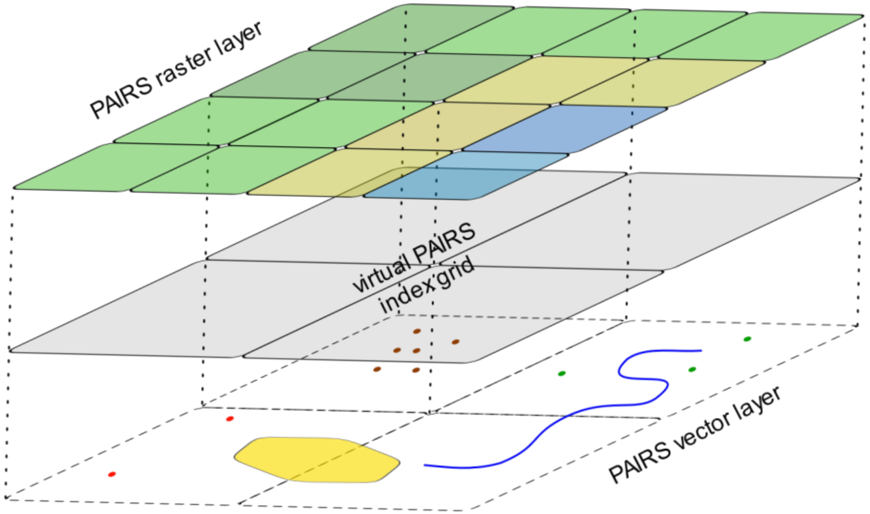
II.b Archeology top-down: … and indexing it into a scalable geo-data platform





technical resources:

- https://doi.org/10.1109/LAGIRS48042.2020.9165675
- https://eartharxiv.org/repository/view/1782

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II.b Archeology top-down: Ancient agriculture in Israeli's Negev desert …

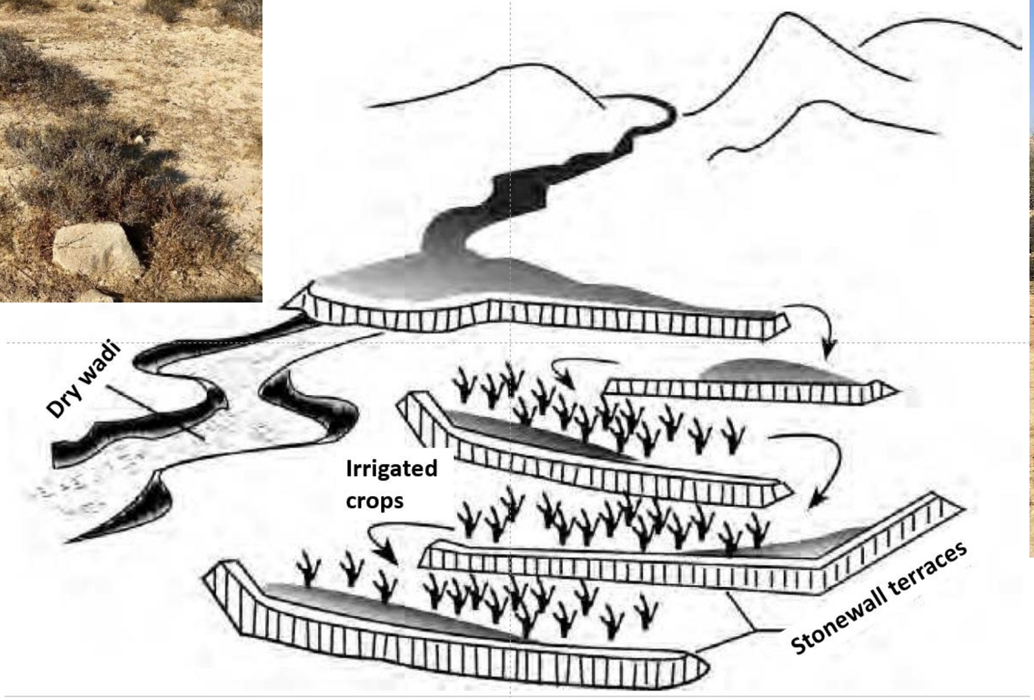

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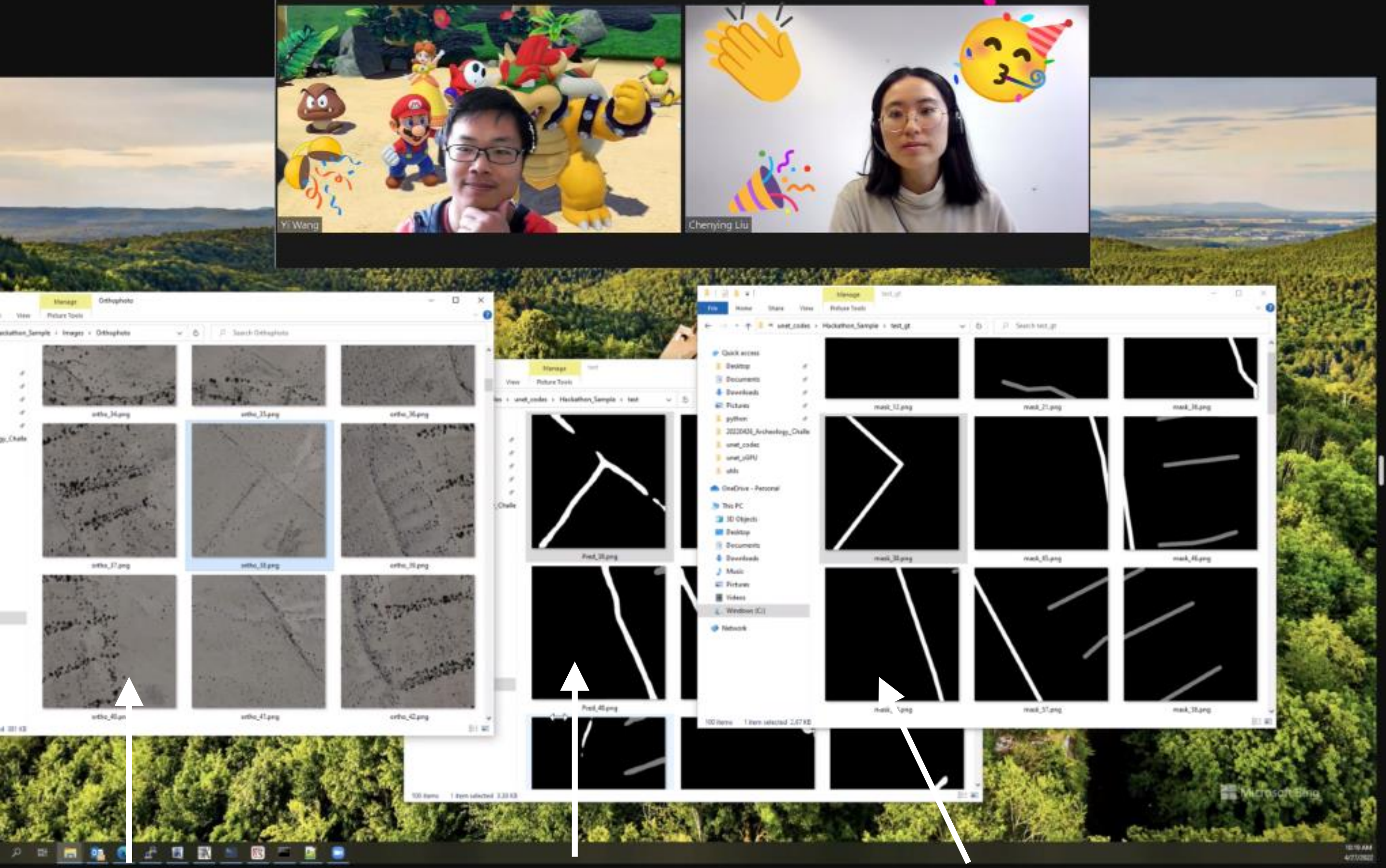
illustration credit to [*https://idsi.net.technion.ac.il/challange_background*](https://idsi.net.technion.ac.il/challange_background)

II.b Archeology top-down: … unvealed by talented AI PhD students

… from fusion of multi-spectral (optical) drone imagery + LiDAR features



drone imagery

Artificial Neural
Network results

ground truth image
segmentation masks

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III Challenges & Perspectives:
Towards a Digital Twin for Social, Economic & Environmental Good

terrabyte

by virtue of artificial intelligence applied to massive amounts of earth observation data ...

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:archeology

collect rainforest LiDAR, preserve & educate about our ancient heritage

:urbanization

improve local climate of urban spaces through unification with nature

:ecology

automatize geo-data analytics for environmental management
in harmony with human land use and agricultural needs

IV. plenum & discussion

1.

How to leverage machine learning and remote sensing to improve the local climate in (mega)cities for the wellbeing of its urban population; and how to address ethical concerns?

DLR

Alexander von Humboldt

TUM

source: https://upload.wikimedia.org/wikipedia/commons/3/32/Hotel_Therme_Rogner_Bad_Blumau_Kunsthaus.jpg

2. Does artificial intelligence in earth observation have the capacity to help preserve the Amazon rainforest (led by fair principles incorporating the "perspectives of all stakesholders" such as endangered species, local farmers, archeologists, and governments)?

3. What are the current limitations of these technologies vis-a-vis protection of human rights & ethics; and how to overcome such limitations?

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source: https://upload.wikimedia.org/wikipedia/commons/f/f6/Shade_Cacao_Plantation%2C_Ixcacao_Mayan_Chocolate%2C_Belize.JPG

4.

How do we transparently implement AI-based environmental management inspired by the United Nation's Sustainable Development Goals?

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source: https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2018/08/E_2018_SDG_Poster_with_UN_emblem.png