LES ORRES 10-11 May 2021

Smart Mountain for tomorrow

GEOMATIC TECHNIQUES FOR THE OPTIMIZATION OF SKI RESOURCES

I. Aicardi, S. Angeli, N. Grasso, **A. LINGUA**, P. Maschio

OVERVIEW

The PITER ALPIMED INNOV project

- Motivation
- Proposed Framekork
- Snow depth measurement using multitemporal drone acquisitions
- Snow groomer tracking
- Some partial remarks

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The PITER ALPIMED INNOV project

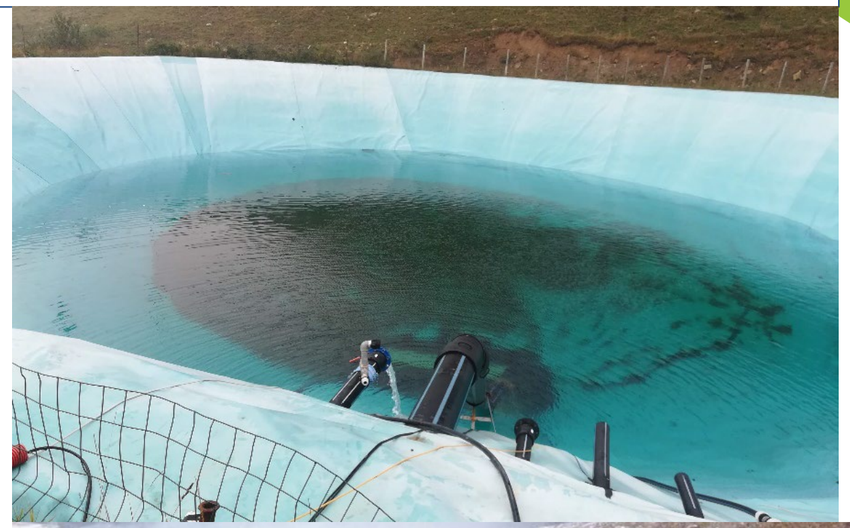
AIMS – WP 4.1.2:
Optimisation of the use of water and energy efficiency for artificial snow on ski tracks

Interreg ALCOTRA
Fonds européen de développement régional
Fondo europeo di sviluppo regionale
UNION EUROPÉENNE
UNIONE EUROPEA
ALPIMED INNOV

(presentation of prof. Alessandro CASASSO, this morning)

- “carbon footprint" of the artificial snowmaking;
- Water flows required for artificial snow;
- Measurement of water consumption (climate parameters);

- **Monitoring snow depth** to limit water consumption;
- **Survey of the routes of the snow groomer vehicles**, which will allow to quantify the fuel consumption.



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The PITER ALPIMED INNOV project

Case Study Areas

The objective of the PITER ALPIMED strategy is to interconnect and encourage best practices in the heart of the **Mediterranean Alps** in a sustainable way and to make its actors responsible for development in the **Franco-Italian cross-border mountain areas** between the Maritime Alps, the province of Imperia and the province of Cuneo.

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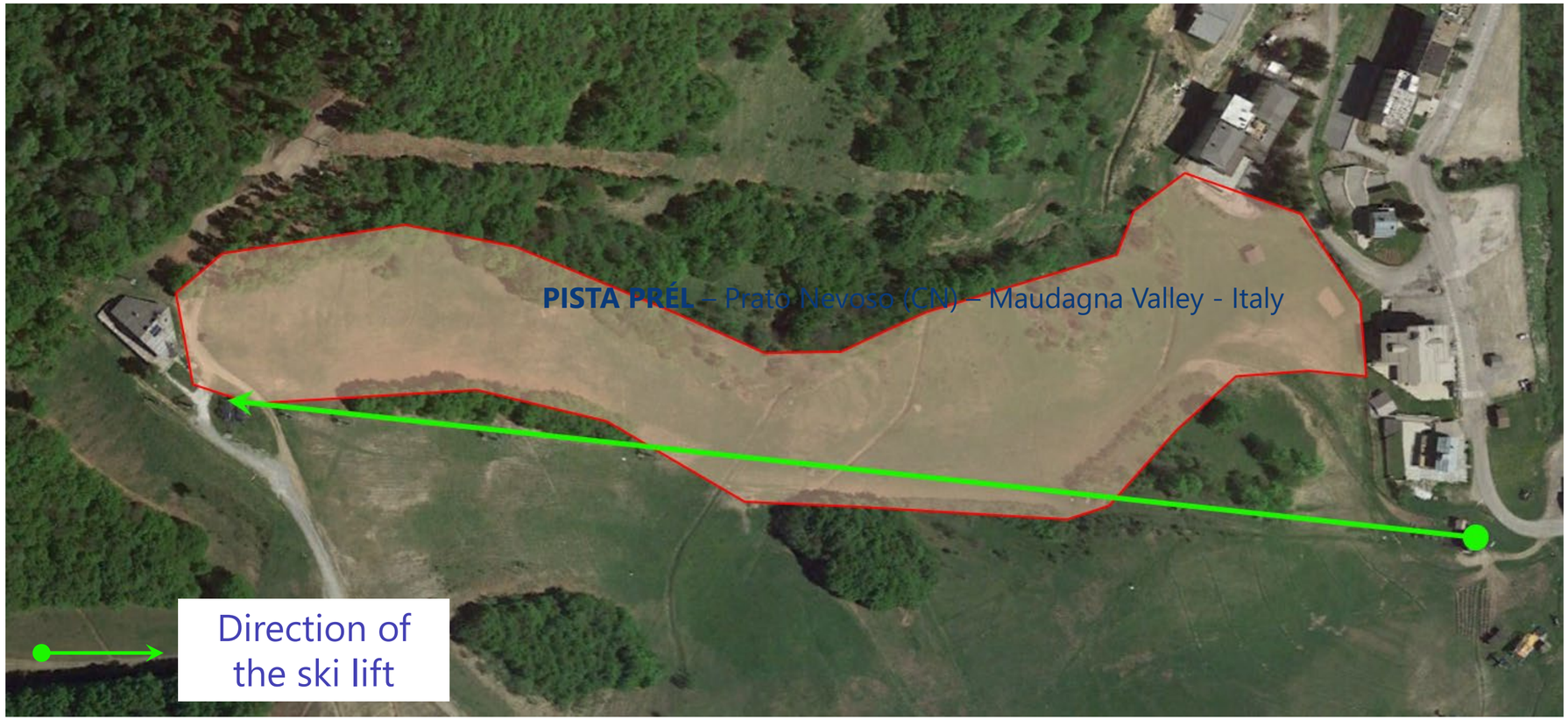
ARMAND TRACK – Limone Piemonte (CN) –Vermenagna Valley - Italy



Starting height	1582 m
Top height	1396 m
Height difference	186 m
Length	0,745 km
Avg. slope	33%
Max. slope	46%

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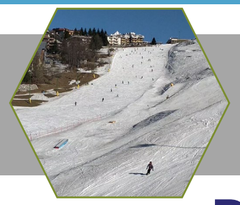
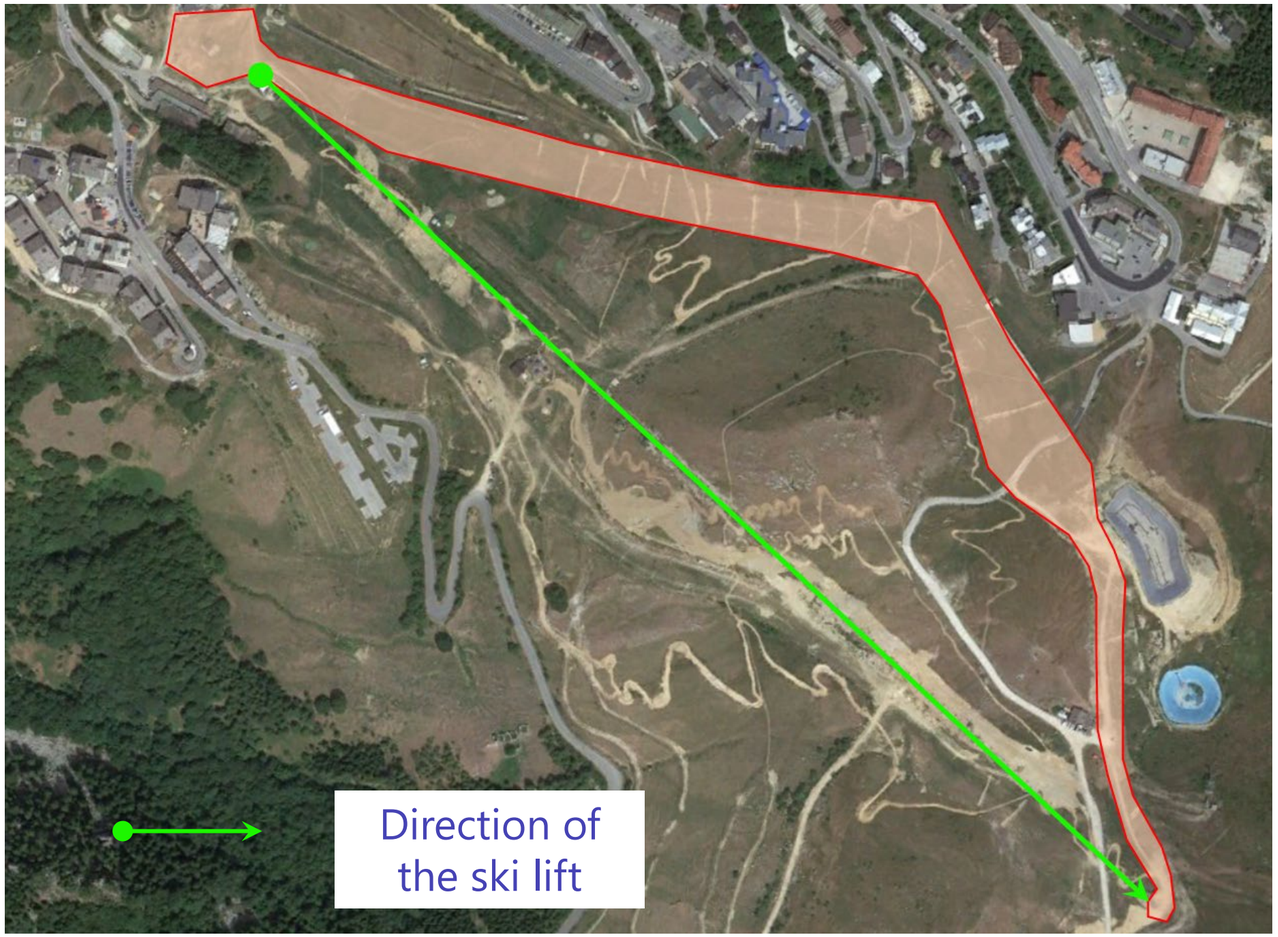


The PITER ALPIMED INNOV project

PISTA PRÉL – Prato Nevoso (CN) – Maudagna Valley - Italy



Starting height	1688 m
Top height	1461 m
Height difference	227 m
Length	1,321 km
Avg. slope	17%
Max. slope	25%

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PROPOSED FRAMEWORK

Snow depth measurement with UAV data

UAV survey of terrain

UAV survey of snow height

2 test for each case study

Image alignment
Georeferencing with marker
Generation of
dense cloud, DSM, orthofoto

Point cloud classification
DTM extraction

Comparison DTM height:
Terrain/Snow height
Estimation of snow depth (Raster)

Snow Cat tracking and snow depth

ement with GNSS data

Kinematic GNSS survey

Lever arms measure with TS

Real-Time

Validation

Snow depth estimation: difference between GNSS and DTM of terrain

Coordinate projection on Raster «snow difference» and depth extraction for each position

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SNOW DEPTH MEASUREMENT

UAV data acquisition

- Execution of **flights** with UAVs:
  - DJI Phantom 4;
  - DJI Mavic 2 Pro;
  - DJI Mavic Mini.
- **Marker** laying and measurement of the sample with RTK technique;

Nadir + Oblique strips
Avg. GSD ~ 2 cm

DJI Phantom 4 Pro

DJI Mavic 2 Pro

DJI Mavic Mini

Characteristics of UAVs

	DJI Phantom 4 Pro	DJI Mavic 2 Pro	DJI Mavic Mini
Take-off weight	1388 g	907 g	249 g
Flight autonomy	30 min	31 min	30 min
Flight distance	14 Km	18 Km	16 Km
Sensor	1" CMOS 20 MP	1" CMOS 20 MP	1/2.3" CMOS 12 MP
Camera focal length	24 mm f/2.8-11	28 mm f/2.8-11	24 mm f/2.8

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SNOW DEPTH MEASUREMENT

UAV data acquisition epochs

N.	Dataset	Image Res. [px]	N. GCPs	N. CPs	N. Images
1	ALP No snow	5472 x 3648	41	14	About 1200
2	ALP snow- I test	5472 x 3648	10	5	About 400
3	ALP snow- II test	4000 x 2250	13	10	About 450
4	PPN No snow	5472 x 3648	36	12	About 1100
5	PPN snow - I test	4000 x 2250	28	10	About 450
6	PPN snow - II test	4000 x 2250	34	10	About 400

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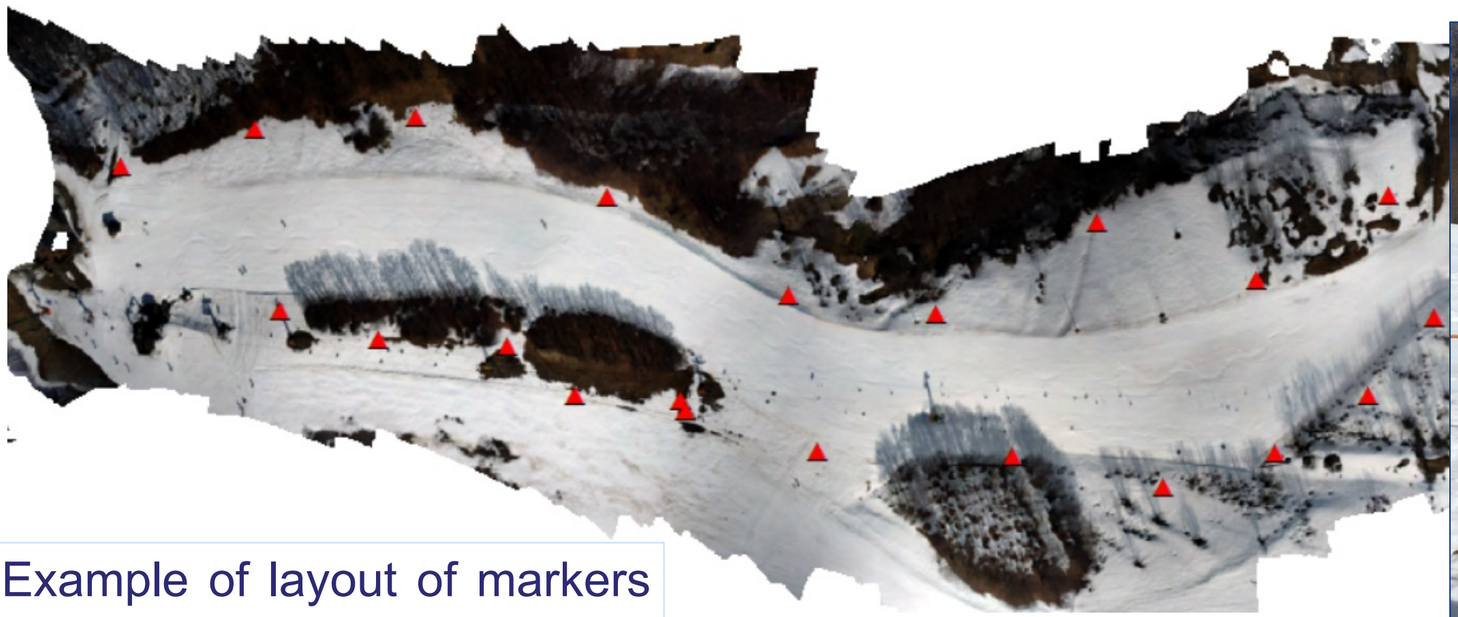
SNOW DEPTH MEASUREMENT

UAV data acquisition

- Execution of flights with UAVs;
- **Marker** laying and measurement of the same with RTK technique.



Example of layout of markers on the Armand Track

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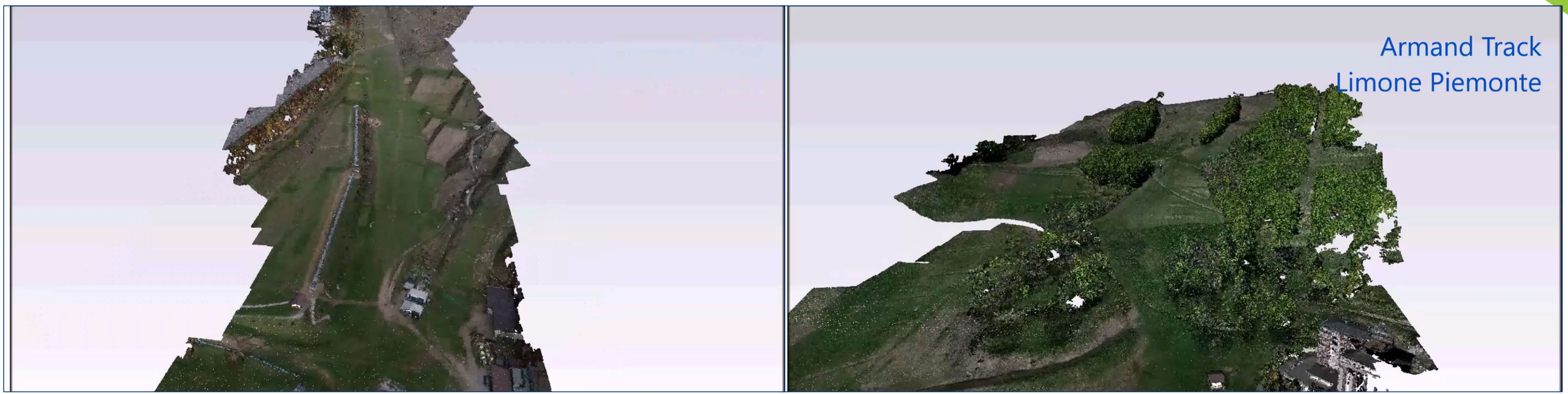
SNOW DEPTH MEASUREMENT

Structure from Motion photogrammetric processing



Generated Multitemporal 3D models

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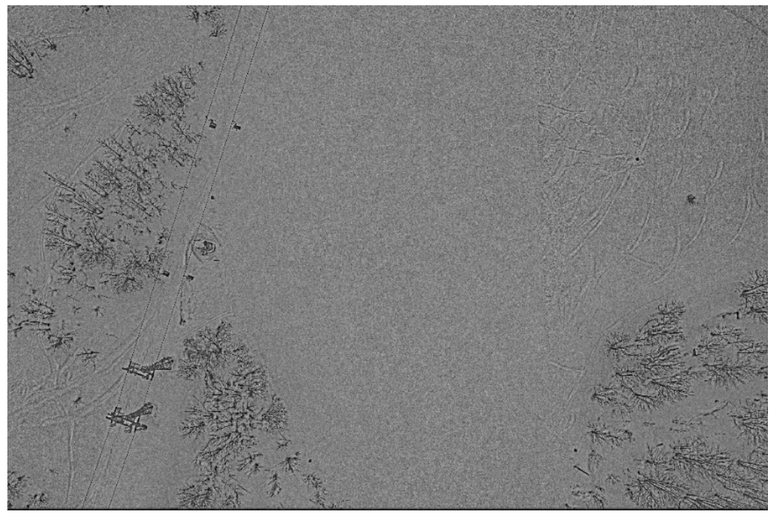
SNOW DEPTH MEASUREMENT

I Test on Armand Track (Limone Piemonte) in presence of snow

- Uniform light (no shadows) and snow beaten by the snow cat = **Uniform texture of the snow**

Original image

White balance



Wallis filter

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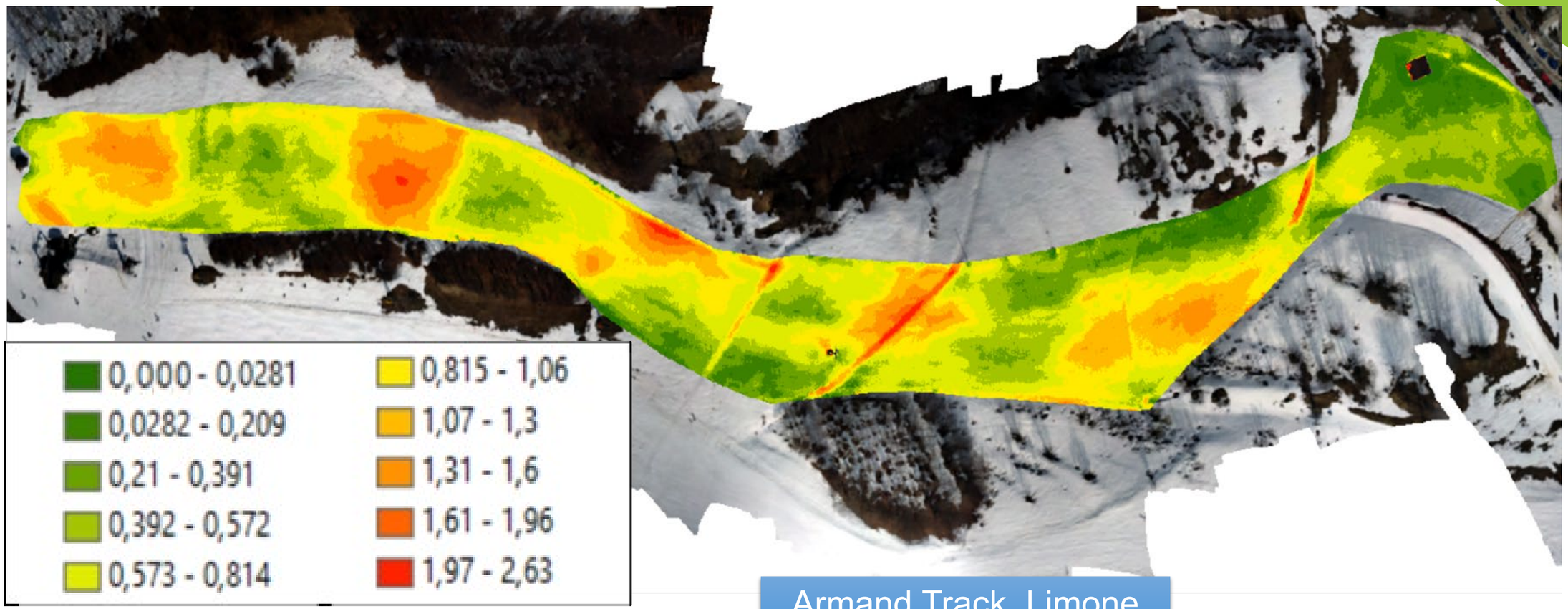
SNOW DEPTH MEASUREMENT

Snow depth estimation

Difference in Height between the DTM of the snow-free terrain and the DTM of the snow altitude



Armand Track, Limone Piemonte (II Test)

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Snow Groomer tracking and snow depth measurement with GNSS data

Real-Time

Kinematic GNSS survey

Lever arms measure with TS

Snow depth estimation: difference between GNSS and DTM of terrain

Validation

Coordinate projection on Raster «snow difference» and depth extraction for each position

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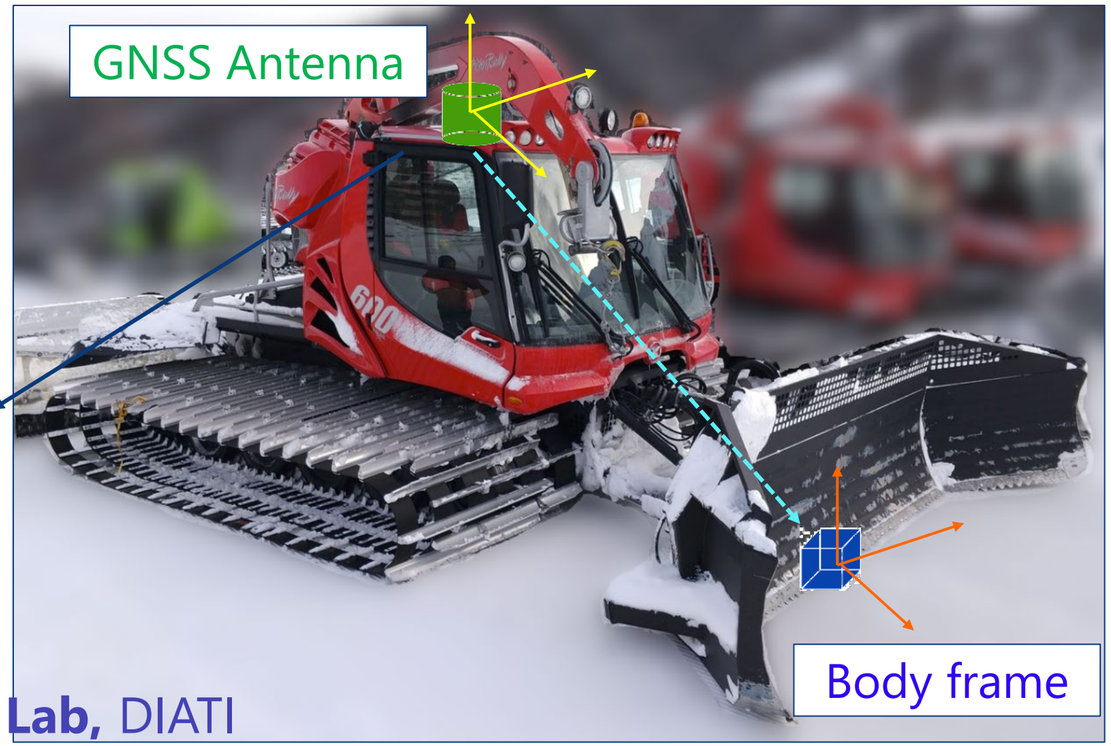
SNOW GROOMER TRACKING

GNSS sensor placement and lever arm calibration (Armand Track)

- Placement of the **GNSS system** and **measurement of the lever arms** between the GNSS antenna and the lower central point of the blade of the snow groomer, with the total station;
- GNSS tracking of the snow groomer.



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SNOW GROOMER TRACKING

Data Acquisition (Armand Track)

- Placement of the GNSS system and measurement of the lever arms between the GNSS antenna and the lower central point of the blade of the snow groomer, with the total station;
- **GNSS tracking** of the snow groomer.

GNSS Receiver	Tersus Precis BX-306
Image	
Weight	23g
Constellations	GPS L1/L2, GLONASS G1/G2, BeiDou B1/B2
Position update rate	1Hz-20Hz

GNSS Antenna	Tersus AX3702
Image	
Weight	374 g
Constellations	GPS L1/L2, GLONASS G1/G2, BeiDou B1/B2

Corrections obtained **via radio** from a **base station** placed on a known point for accurate real-time positioning.

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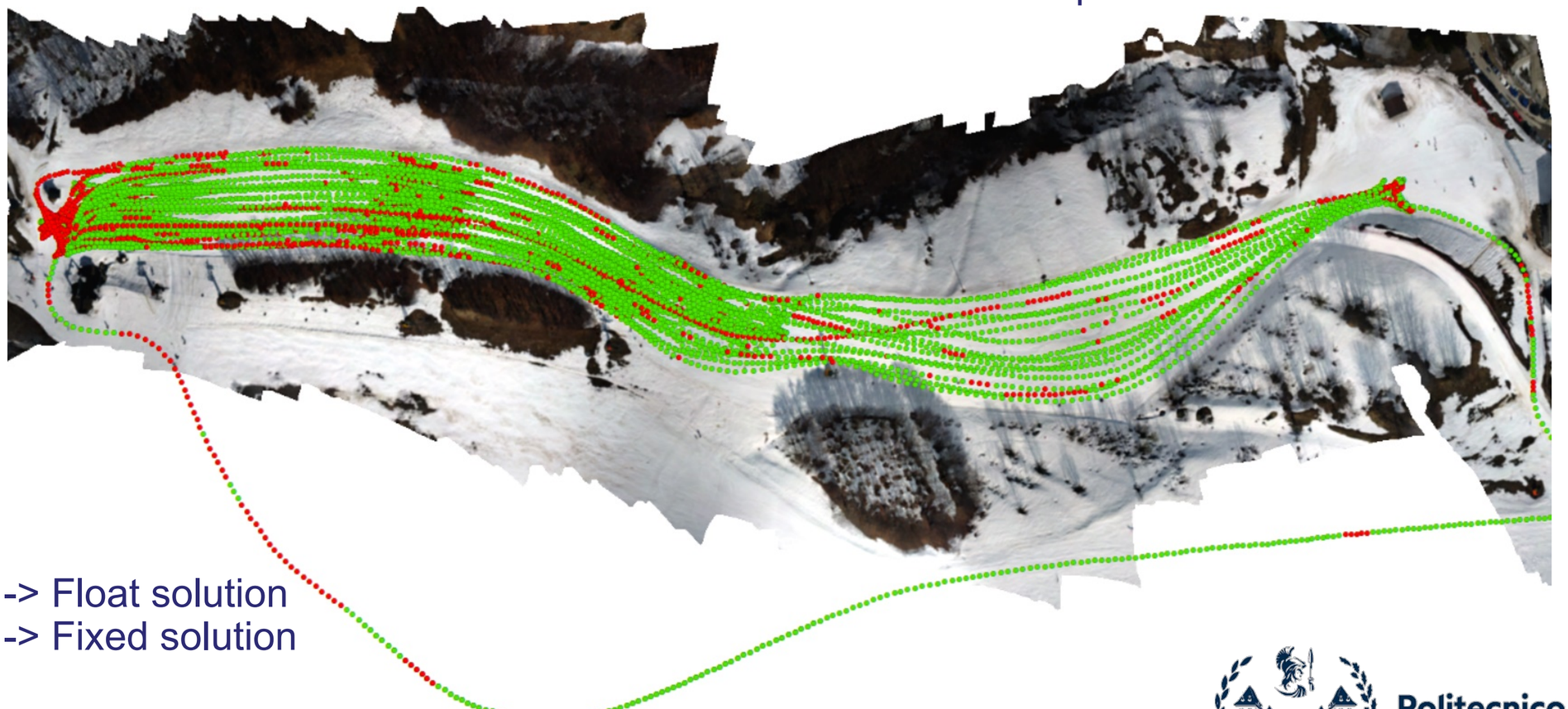
SNOW GROOMER TRACKING

GNSS data processing and analysis

- **Solution with the Tersus BX-306**: mean standard deviation values **< 1 cm** horizontal components
  mean standard deviation values ≅ **1 cm** vertical components

- **Ratio test**:

22% Float solution
78% Fixed solution



● -> Float solution
● -> Fixed solution

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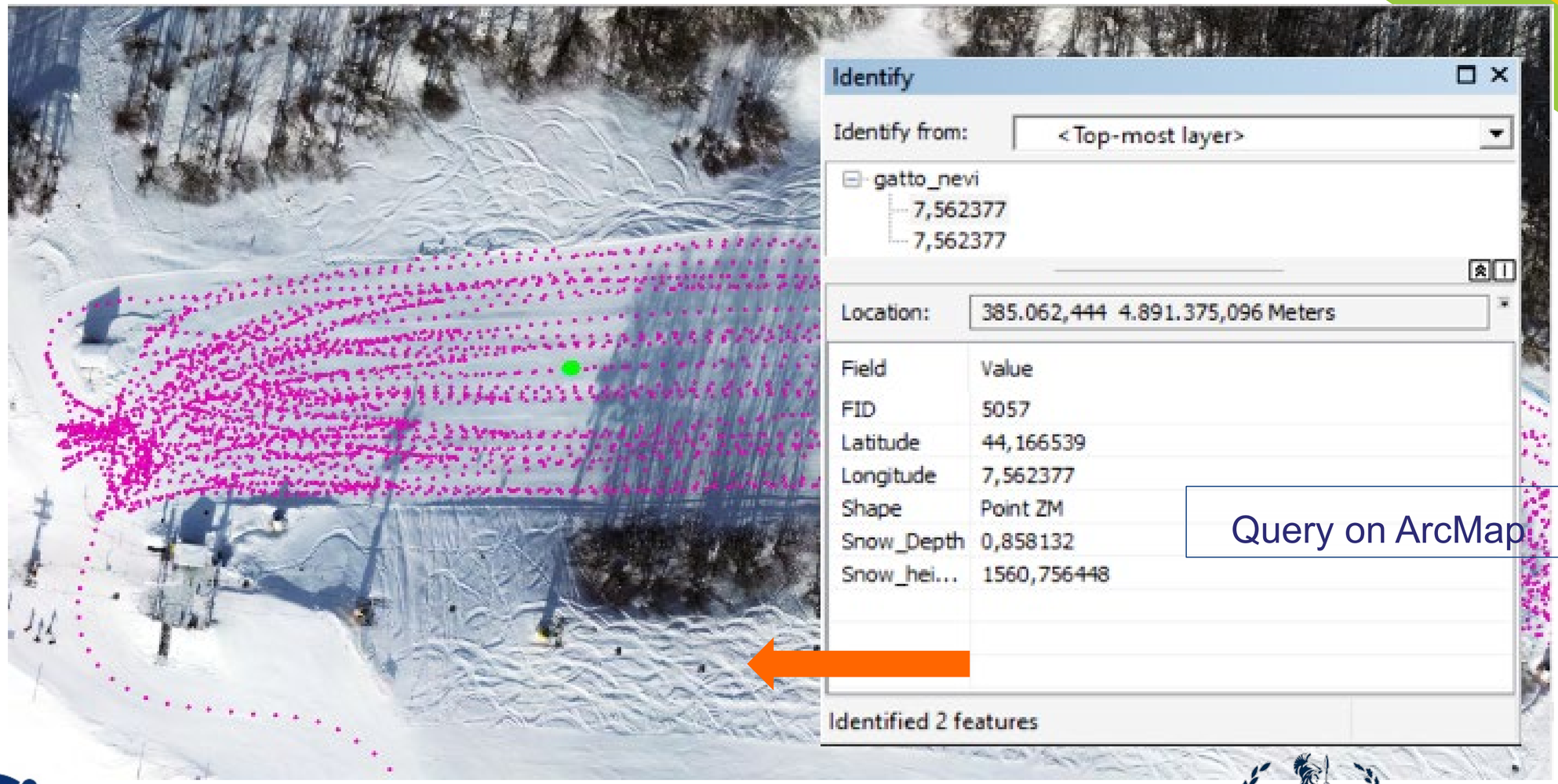
SNOW GROOMER TRACKING

Estimation of the snow depth

Snow thickness as difference between the height of the bottom of the blade and the height of the reference terrain (DTM)



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FINAL REMARKS

- The research work is part of the **Alpimed-INNOV Project** and is aimed to provide a complete framework for the snow depth estimation using **low cost** solution.
- From **aerial images**, it is possible to model the ski slopes and estimate the thickness of the snow cover with good accuracy
- Results depend on the light conditions of the environment and on the uniformity of the snow **->** need to evaluate the use of different sensors, such as **multi/hyperspectral cameras.**
- **Double-frequency mass-market GNSS sensors** could be considered as valid alternative to more expensive receivers in the snow groomer tracking.
- Future works will be aimed towards obtaining a **real-time** estimation of snow thickness.

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THANK YOU FOR YOUR ATTENTION

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