POLITECNICO DI TORINO
DIATI
Department of Environment, Land and Infrastructure Engineering

ISE-NET
Innovative Solutions for the Environment

Spin off del Politecnico di Torino

Hydro-geomorphometric study of a mountain basin in the north-west of Italy.

An analysis through Terrestrial Laser Scanner, Drones and GIS techniques for the water resources management and the natural hazard prevention

Eng. Muriel Lavy

CENTER FOR GEOGRAPHIC ANALYSIS
HARVARD UNIVERSITY

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Politecnico di Torino

SCHOOL OF ENGINEERING

SCHOOL OF ARCHITECTURE

CAMPUS IN TURIN

SCHOOL OF SPEC. MASTERS

AUTOMOTIVE & DESIGN

Research areas

Departments

DIATI

Department of Environment, Land and Infrastructure Engineering

Study the **technologies** which deal with **safeguarding**, **protecting** and **managing** **the environment and land**, the sustainable use of **resources**, as well as the optimal and eco-compatible development of **infrastructures** and transport systems.

Research Group

- Eng. Enrico Suozzi, PhD
- Eng. Gianpiero Amanzio, PhD
- Eng. Stefano Crepaldi, PhD
- Geol. Raffaella Ghione
- Eng. Muriel Lavy
- Eng. Federico Marchionatti, PhD
- Eng. Nicole Nota
- Eng. Ye Zhao, PhD

Prof. Geol. Marina De Maio

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Eng. Enrico Suozzi, Ph.D.

CEO

Prof. Geol. Marina De Maio

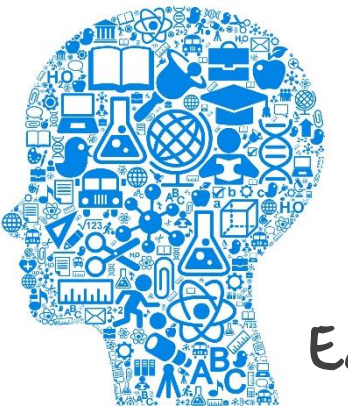
Scientific Supervisor
Associate Professor
Applied Geology

Arch. Emilio Misuriello

Commercial
More than 20 years experience in the field of information systems planning.

GeosLab
Sistemi Informativi Territoriali

Mobile Mapping

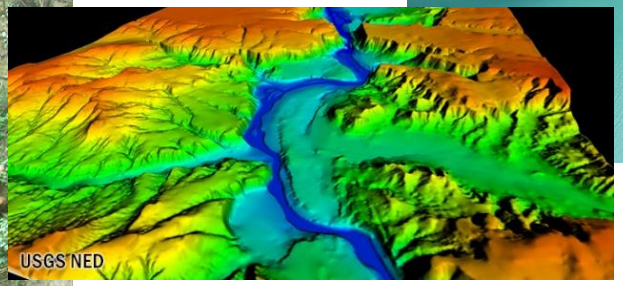


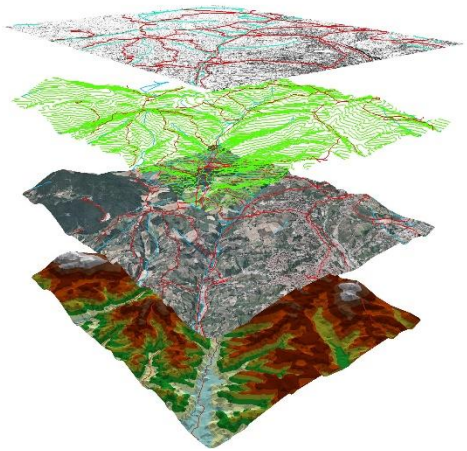
Field of research

Environmental engineering

Applied geology & Hydrogeology

Geospatial analysis & GIS





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Natural Phenomena

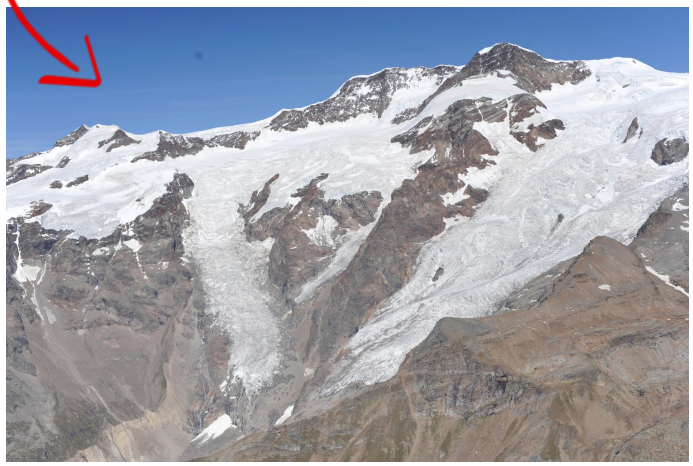
Climate Change

Water Resources

Mountain environment

Hydrogeological-Hydraulic Risk

Glacial Evolution



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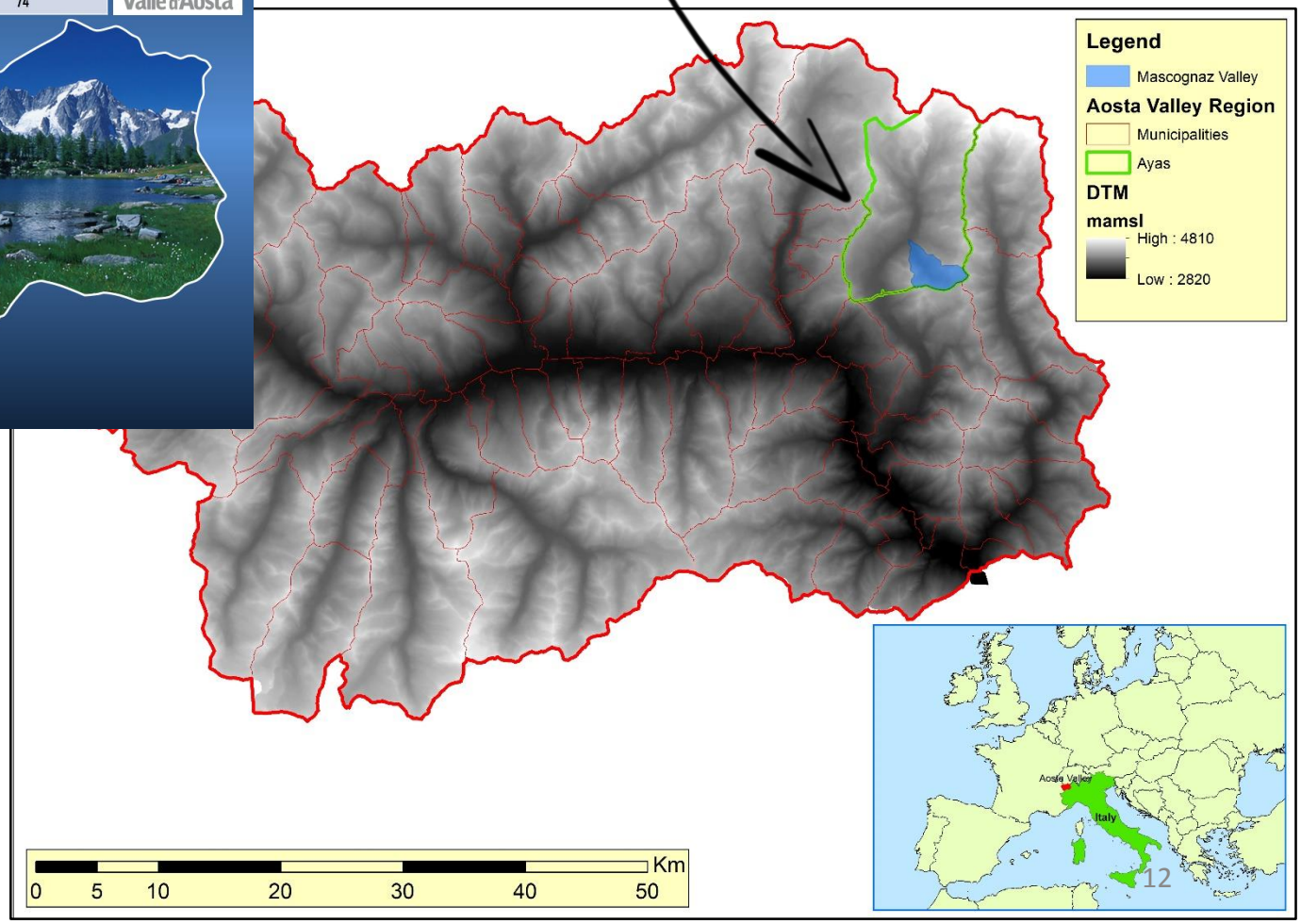
Where ?

Test Site

Mascognaz Valley



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MASCOGNAZ VALLEY
N
Mascognaz_1
Mascognaz_2
Meteorological Station
✓ 10 km²
✓ 1830 m → 3030 m asl
Legend
Aosta Valley Region
Municipalities
Ayas
Meteorological station
Springs
Mascognaz 1
Mascognaz 2
Basin
0
2 500
5 000
Meters

Observed Phenomena

Natural resources

- Climate change
- Groundwater & surface water
- Snow melting recharge

Environmental Hazard

- Snow avalanche
- Landslide
- Glacial fall
- Hydraulic instability

Video time…

How to access?

Multi-parametric Probes

what we have

Meteorological Station

sensors

sommer MESS-SYSTEMTECHNIK

- Snow Scale
- Snow Pack Analyzer
- Snow Depth
- Thermometer
- Hygrometer

rotronic LEADING IN HUMIDITY MEASUREMENT

OTT Corr-Tek

Corr-Tek Idrometria Srl

- Pluvio2
- Parsivel
  Enhanced precipitation identifier
- CWS (All in one)

OTT

- Thermometer
- Hygrometer

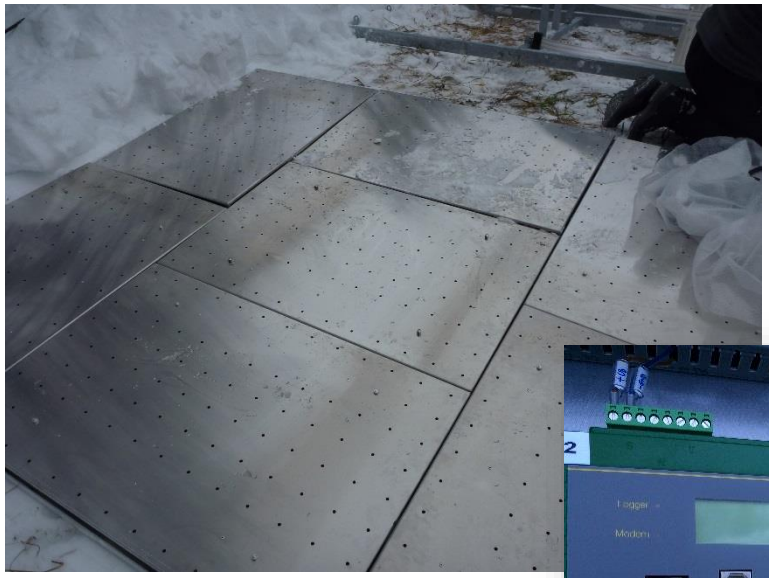
rotronic LEADING IN HUMIDITY MEASUREMENT

- Gonio-Anemometer
- Barometer

YOUNG

- Buried Rain Gauge → LSI LASTEM
- Albedometer
  Measure global and reflected solar irradiance → LAMBRECHT METEOROLOGICAL INSTRUMENTS GERMANY

Snow Scale

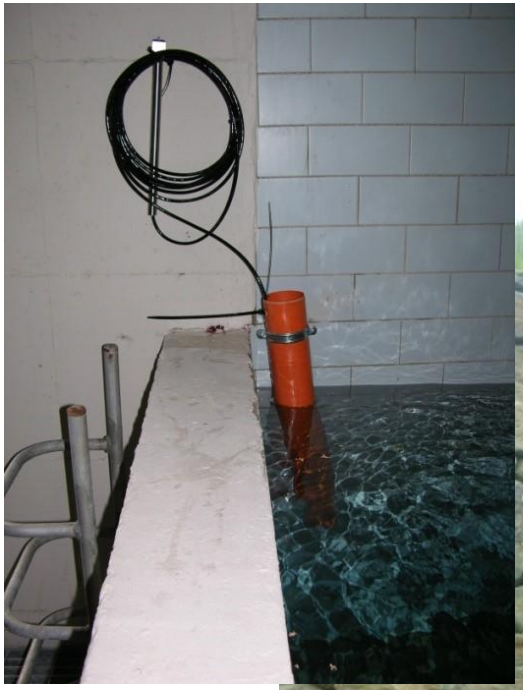


Snow Depth USH8

Buried Rain Gauge

Snow Pack Analyzer

Springs & Multiparameter probes

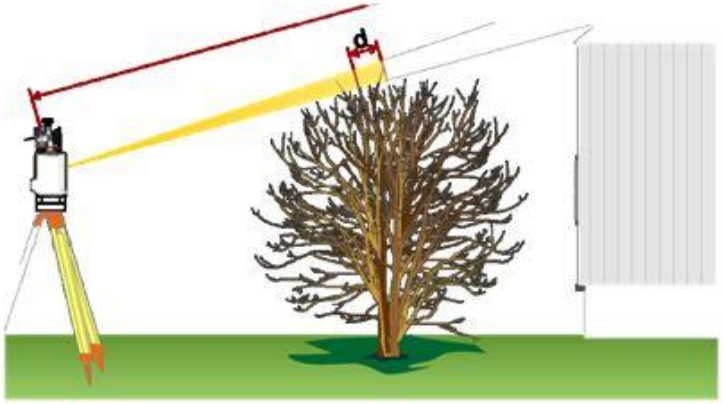


- ❑ Water Level
- ✓ Temperature
- ➢ Electrical conductivity

Terrestrial Laser Scanner

What is a Laser Scanner?

Instrument able to acquire the *spatial coordinates* of a given region or surface of an object in an *automatic* way, *systematic* and with a *high speed*.

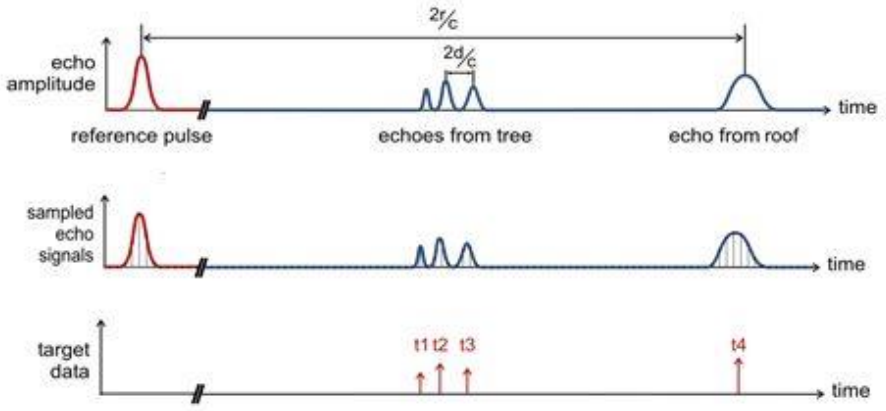


The laser beam is deflected by a mechanism of rotating mirrors and oscillating, varying the azimuth angle and zenith angle in discrete steps, illuminating the ground of contiguous points.

How does it work?

It is based on *time-of-flight* distance measurement using an infrared laser.

The system is capable of measuring even *thousands of points per second*.

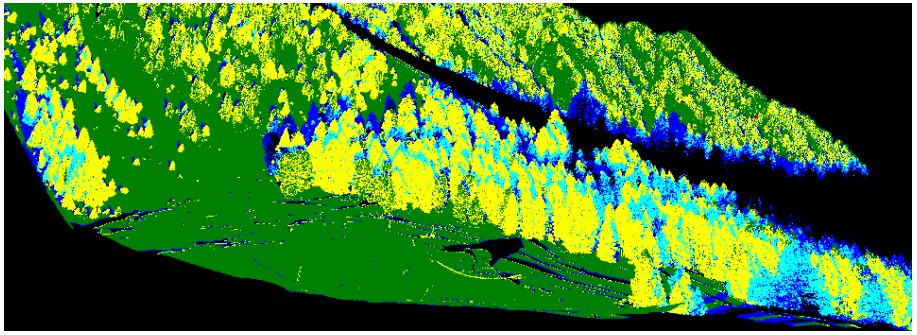


Terrestrial Laser Scanner

RIEGL
LASER MEASUREMENT SYSTEMS

Main Features

- Eye safe operation in laser: **Class 1**
- Long range: up to **4000 m**
- High **speed** data acquisition up to 222,000 means./sec
- **Multiple Target** capability - Unlimited number of targets
- Built-in calibrated **digital camera**
- high accuracy, high precision ranging based on echo digitization and online waveform processing



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GPS

Leica Viva GS10 and GS25

GNSS technology

RTK data-processing

Performance

Accuracy

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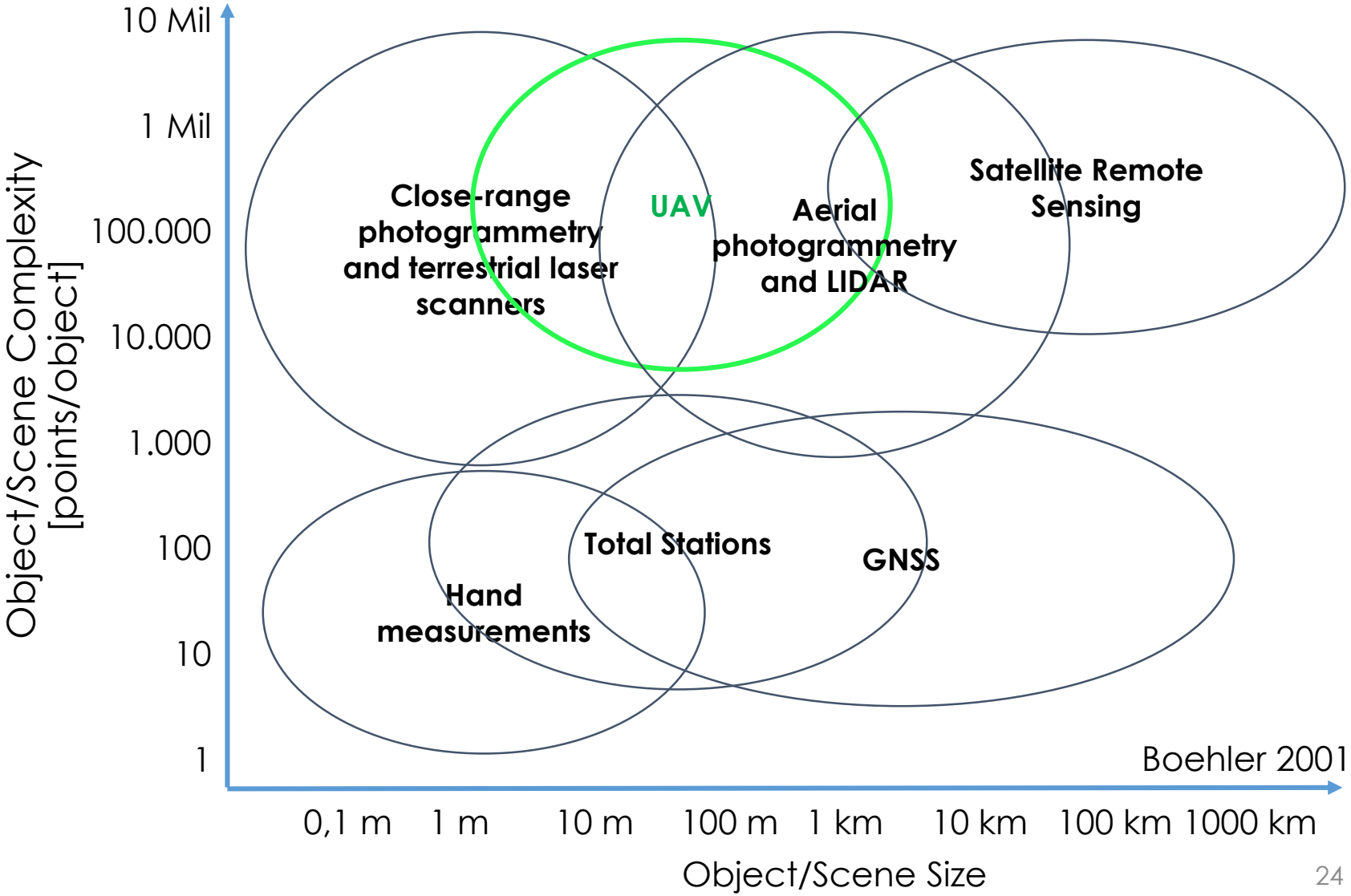
Unmanned Aerial Vehicles

When Can You Use Them?



UAV Drone

- ✓ **Multirotor quadcopter**
- ✓ Ready to Fly Design
- ✓ Flight time:10 to 15 min
- ✓ Camera mount

Sony NEX-7

dji

ISE-NET
Innovative Solutions for the Environment

senseFly

- ✓ **Fixed wings**
- ✓ Ready to Fly Design
- ✓ Flight time: 50 min
- ✓ Camera mount

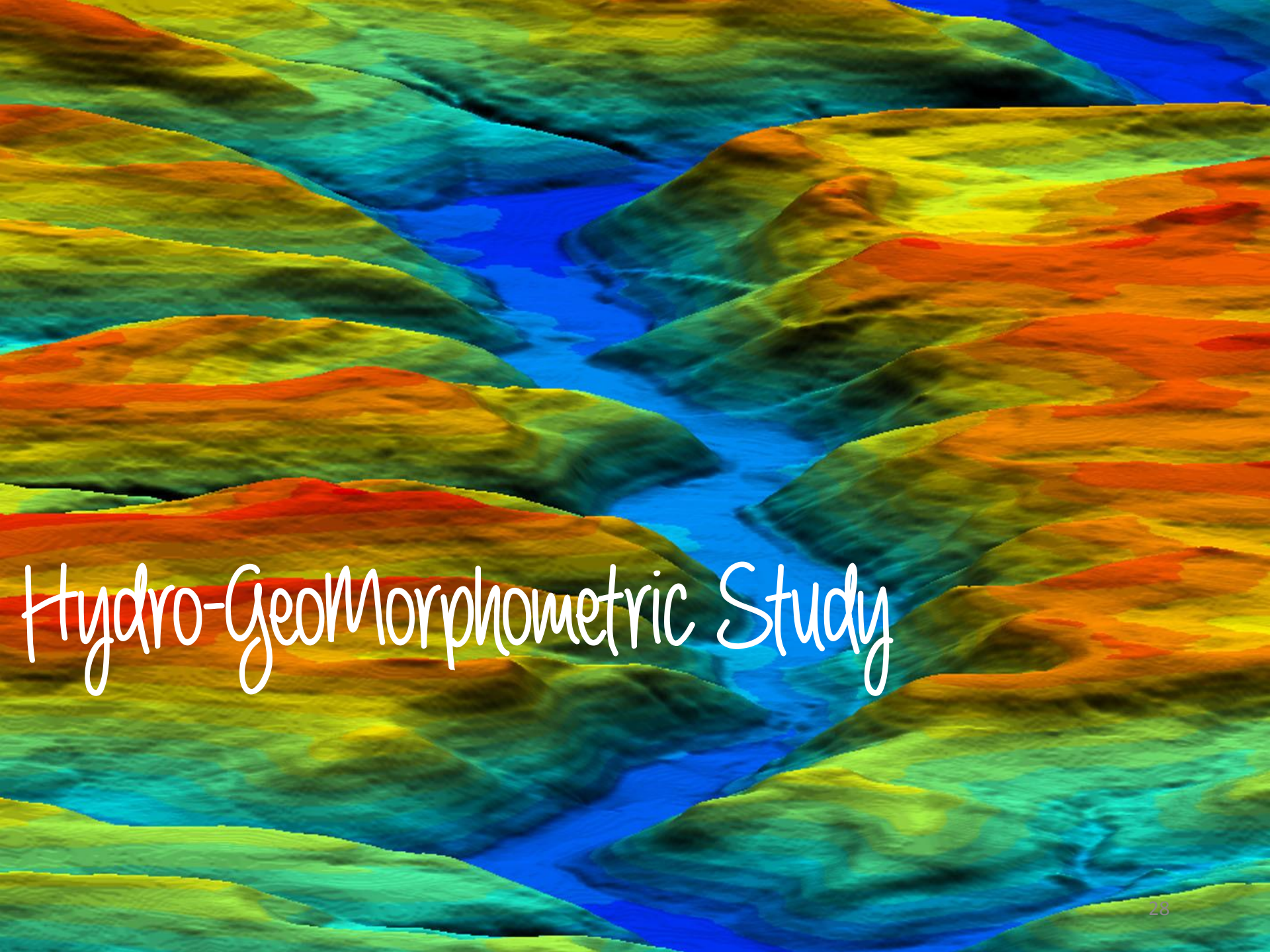
eBee
senseFly

swinglet CAM
senseFly

ARPA Valle d'Aosta

The Study…

- Terrain Surface
- Water
- Snow
- Glacier

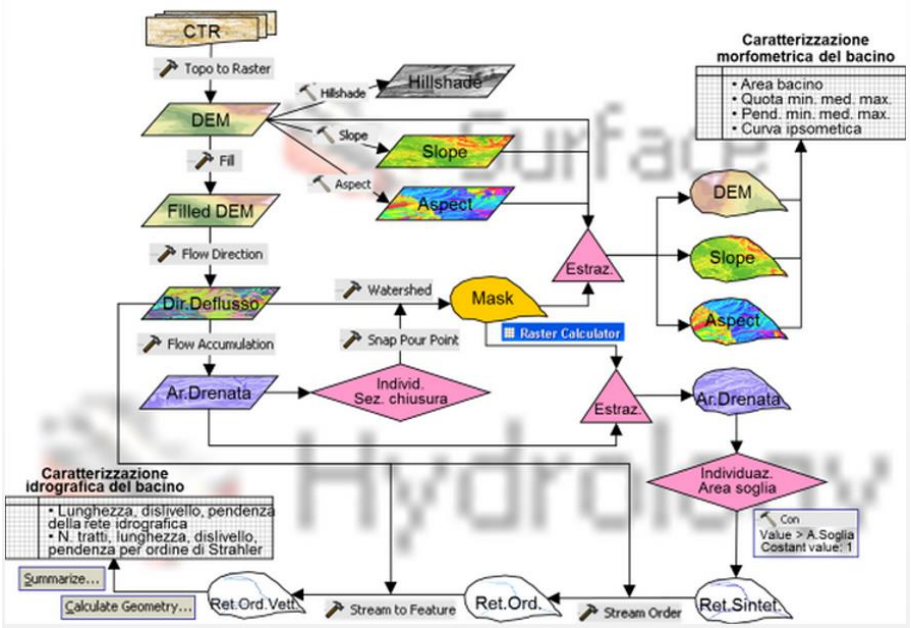

Hydro-GeoMorphometric Study

Hydro - GeoMorphometry

GIS Spatial Analysis

ArcGIS® 10.2

esri Understanding our world.



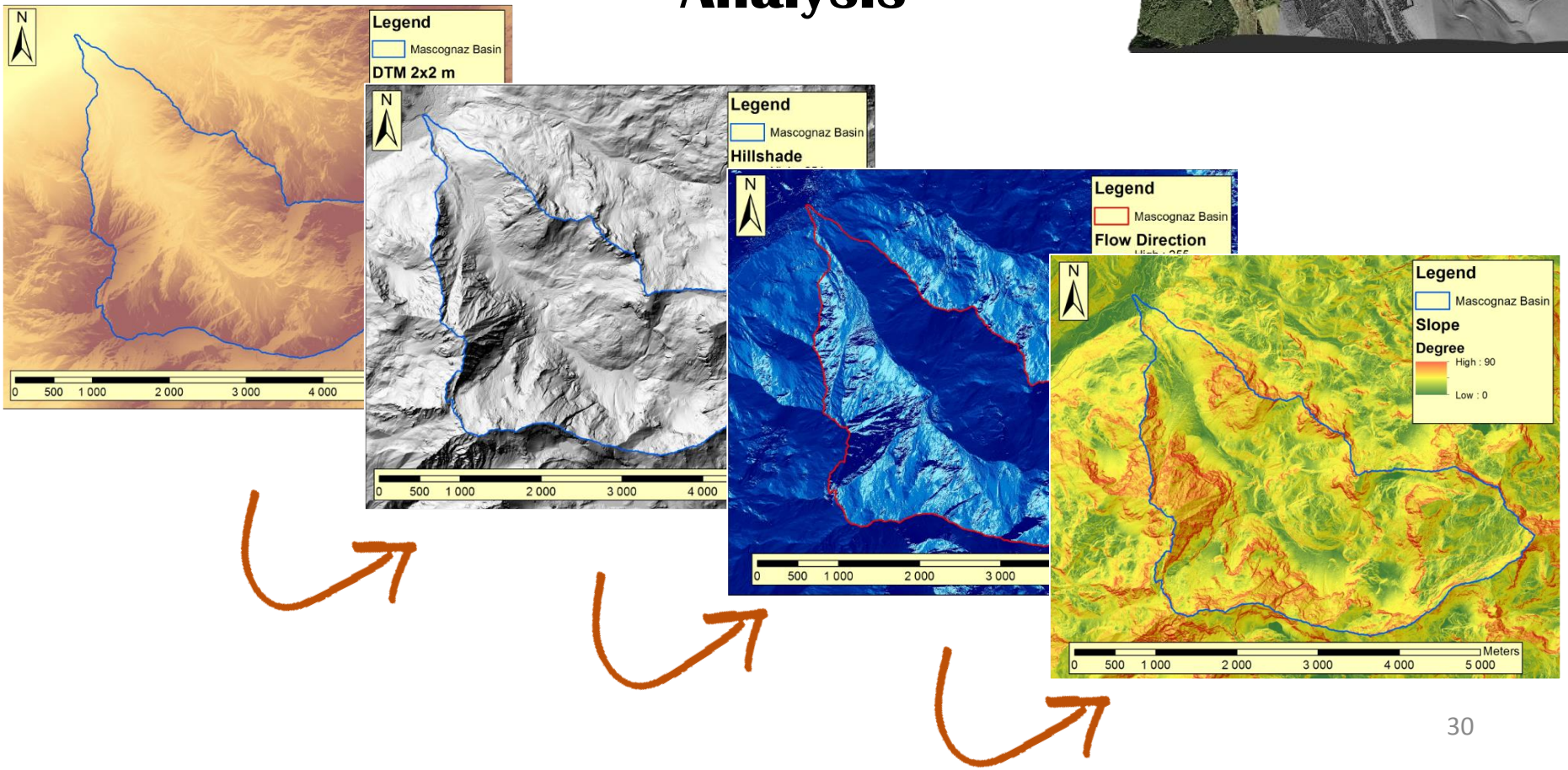
1. Morphometric Analysis
2. Hydrologic Analysis
3. Hydrographic Analysis

Hydro - GeoMorphometry

Digital Terrain Model

2m x 2m

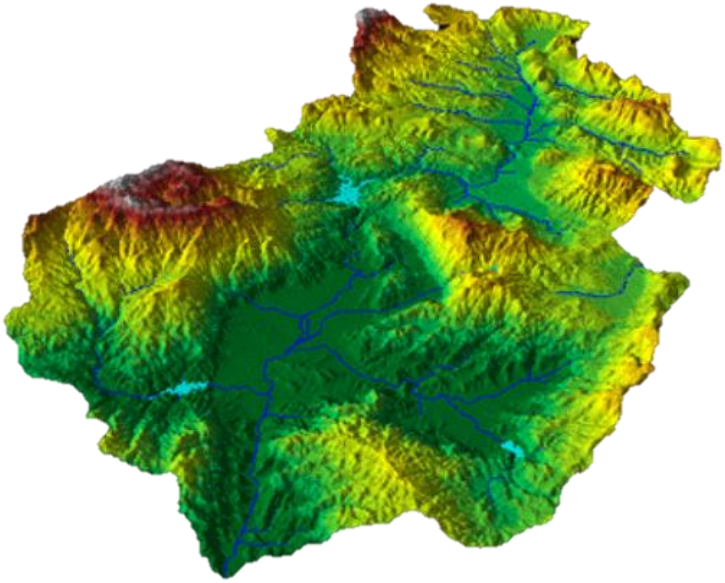
Analysis

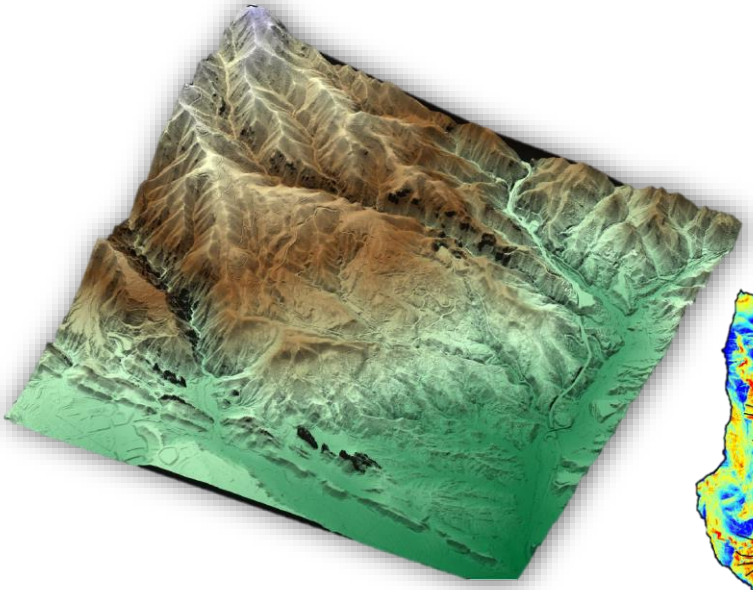


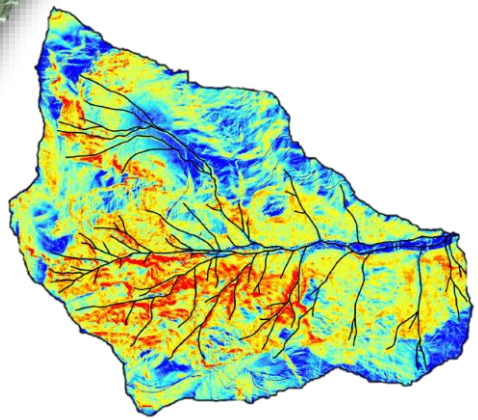
Hydro - GeoMorphometry

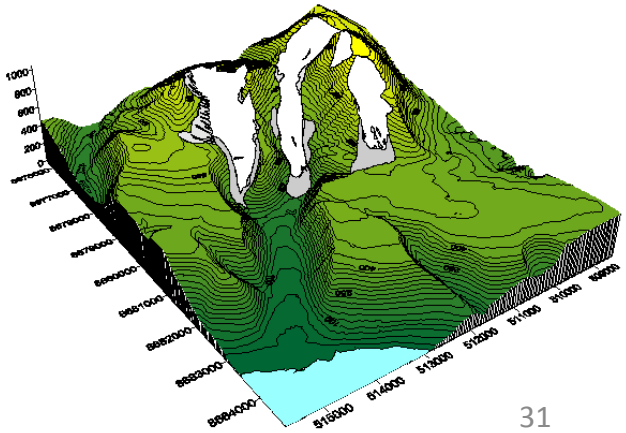
1. MORPHOMETRIC ANALYSIS

- ✓ Hillshade
- ✓ Determination of altitude and slope (min, med and max)
- ✓ Determination of aspect
- ✓ Evaluation of planimetric and effective surface





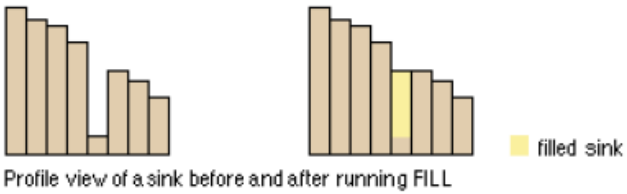




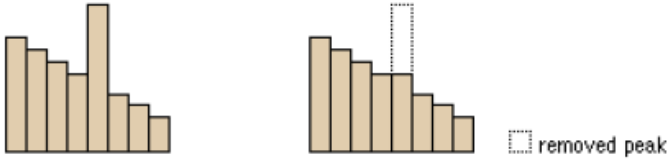
Hydro - GeoMorphometry

2. HYDROLOGIC ANALYSIS

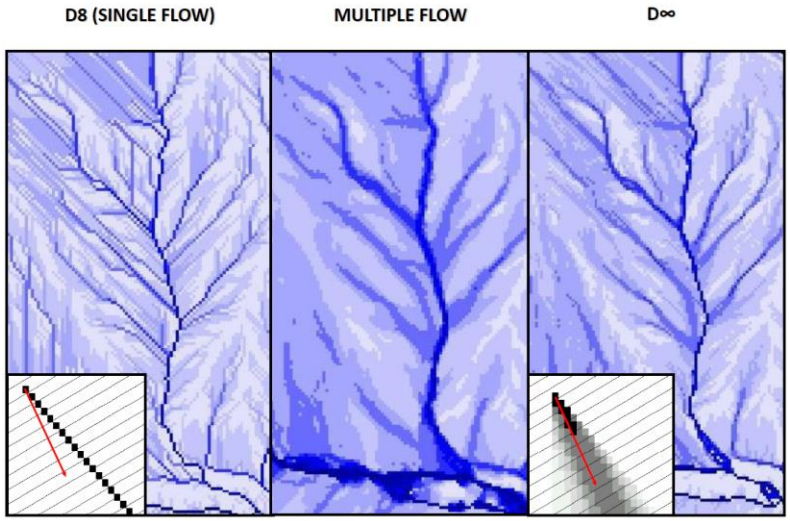
- ✓ Removal of local pit and peak (fill)
- ✓ Flow Direction
- ✓ Flow Accumulation and Drainage Area



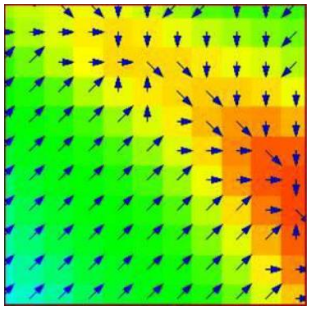
Profile view of a sink before and after running FILL

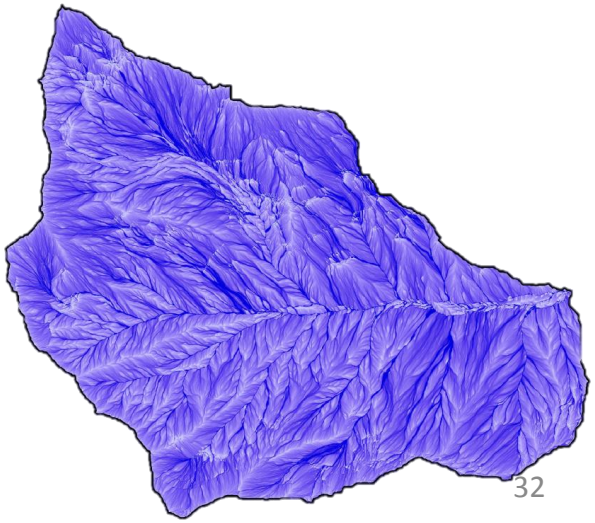


Profile view of a peak before and after running FILL



Flow Direction (ArcGIS) | Quinn et al. (1991) | Tarboton (1997)

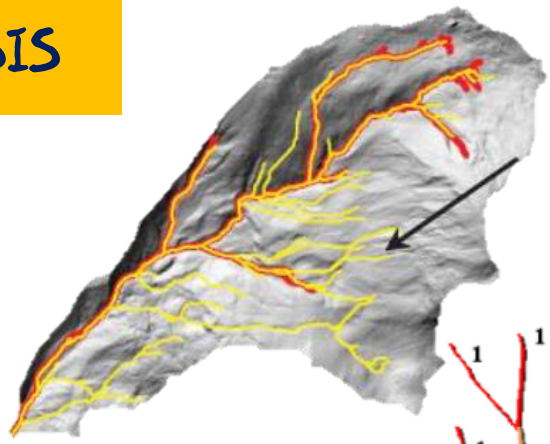


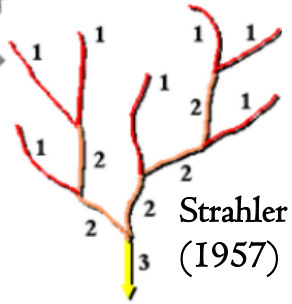


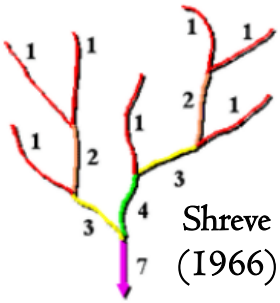
Hydro - GeoMorphometry

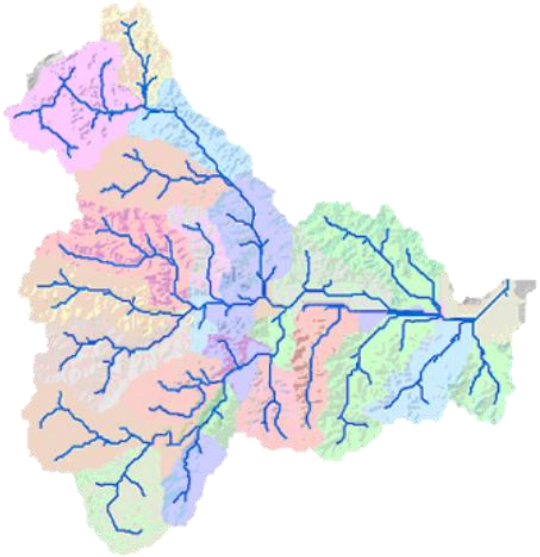
3. HYDROGRAPHIC ANALYSIS

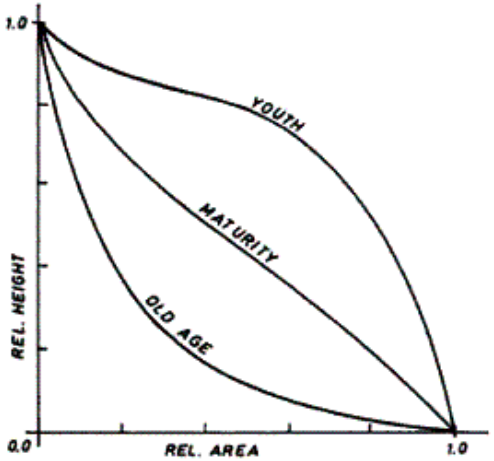
- ✓ Stream network extraction (threshold)
- ✓ Stream ordering
- ✓ Hypsometric curve construction
- ✓ Watershed delineation
- ✓ Number of sections, length, and height difference of stream network



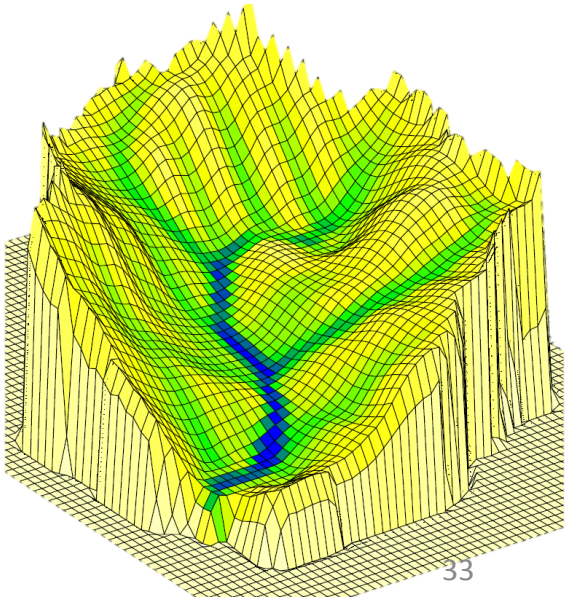




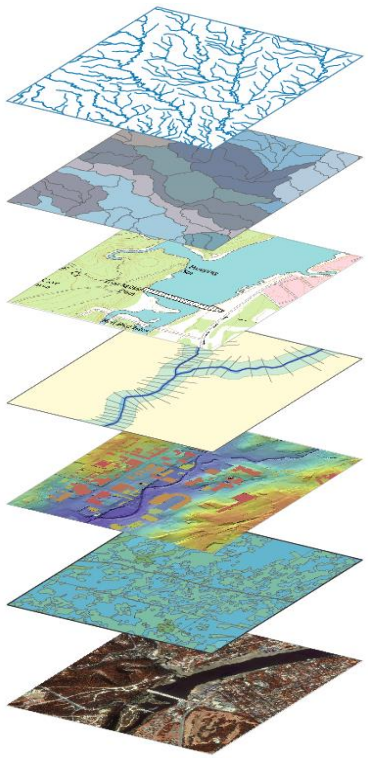




Scheidegger (1987)



Arc Hydro



Streams

Drainage Areas

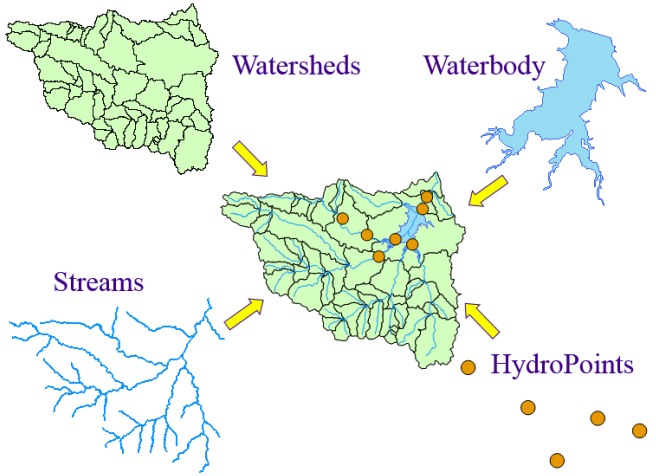
Hydrography

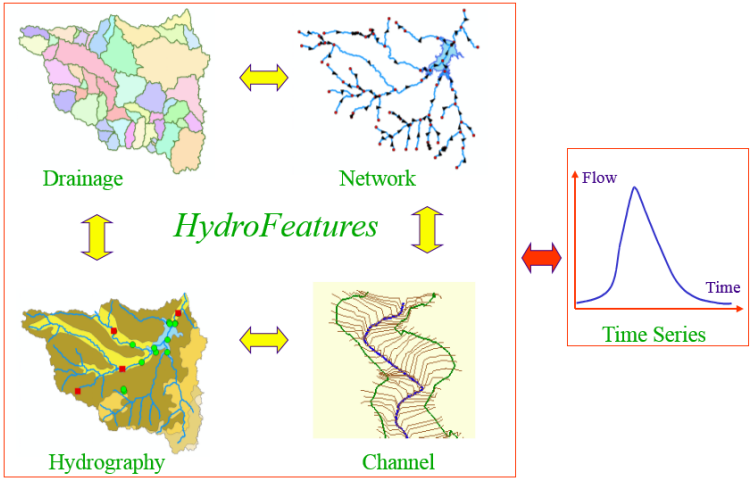
Channels

Terrain Surfaces

Rainfall Response

Digital Orthophotos





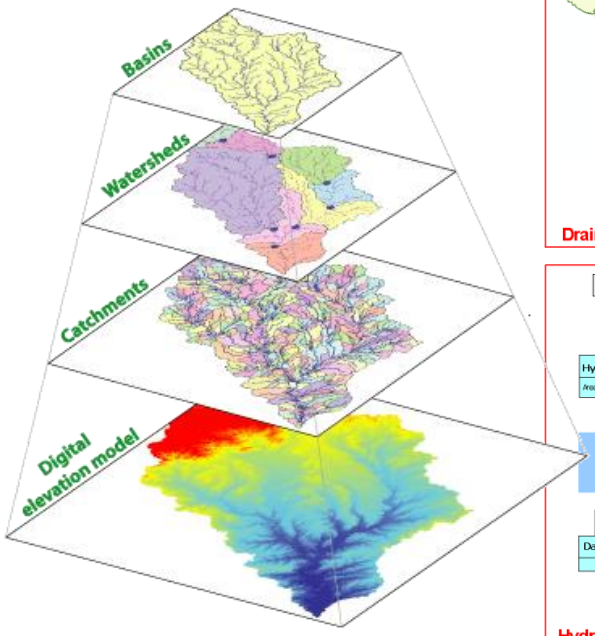
Arc Hydro

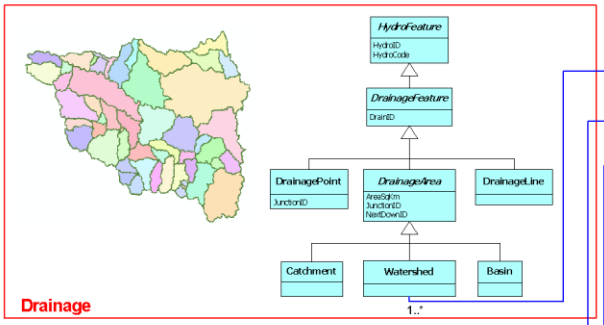
ArcGIS Hydro Data Model

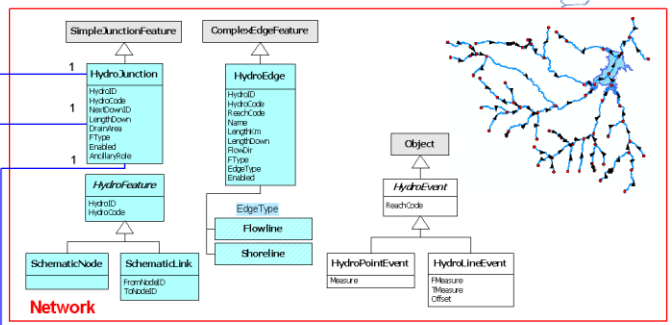
http://arconline.esri.com/arconline/datamodels/water.cfm
http://www.crwr.utexas.edu/giswr

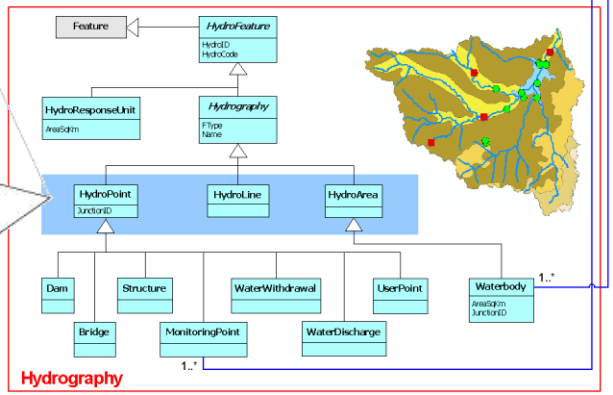
GIS in Water Resources Consortium

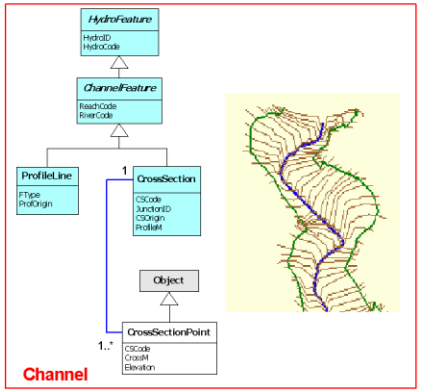
GISWR

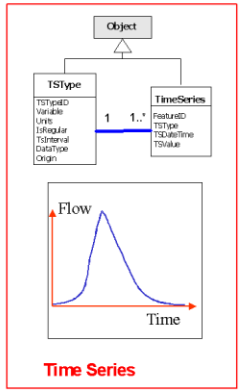




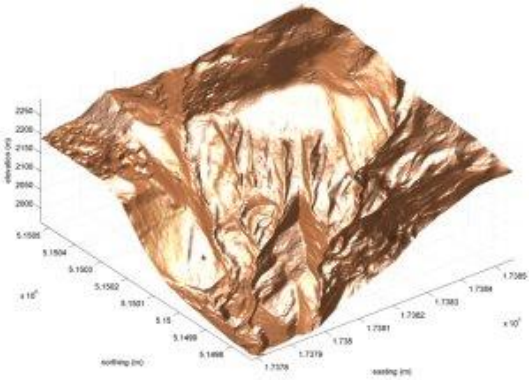








Quantitative Analysis on Surface

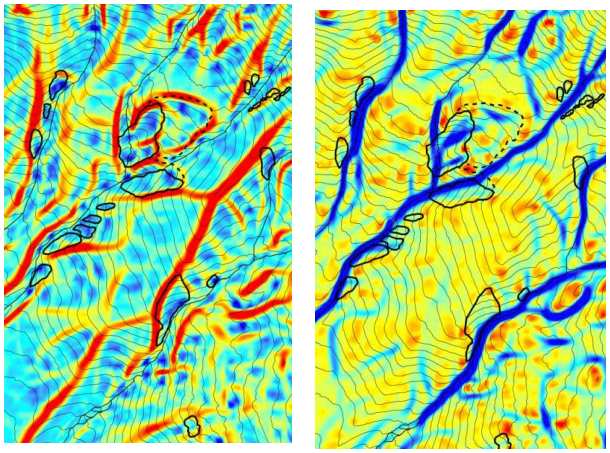


Geomorphometric Parameters

OPENNESS

Yokoyama et al.
(2002)

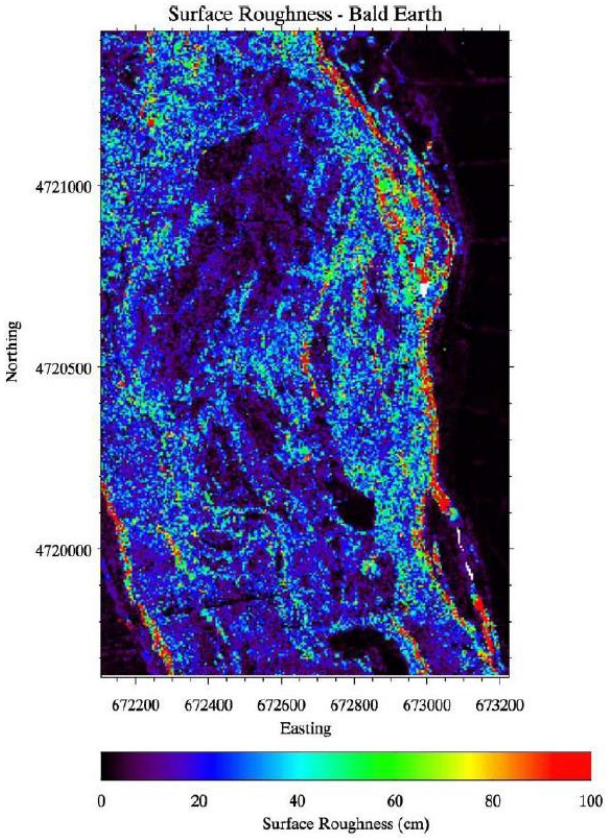
CURVATURE



MAX min

Tarolli, Sofia, Dalla Fontana
(2010)

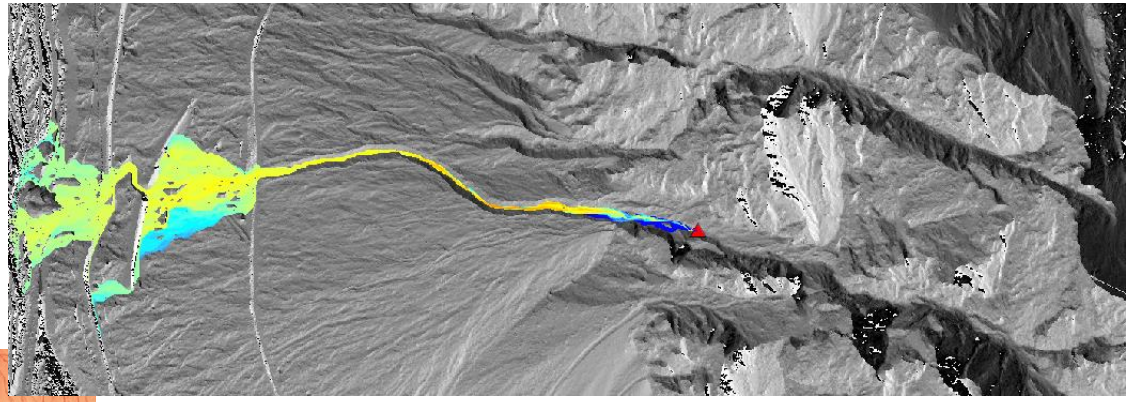
ROUGHNESS



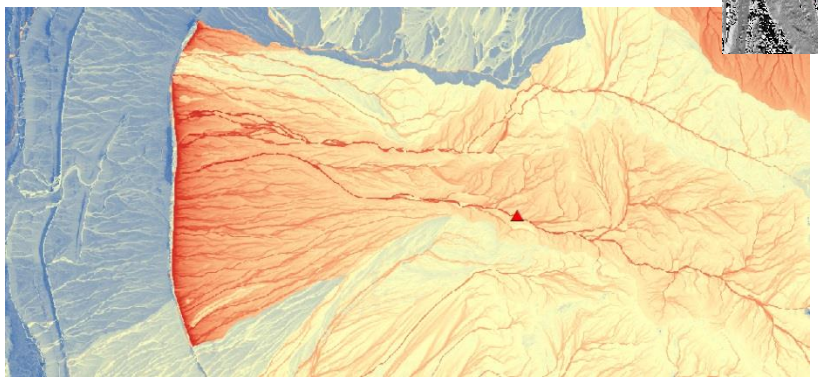
Glenn et al.
(2006)

Quantitative Analysis on Surface

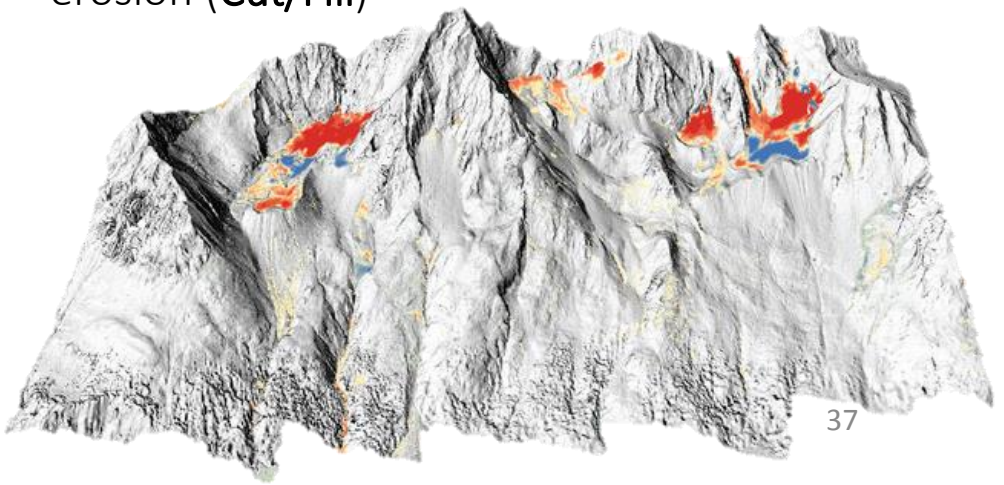
MODEL DEVELOPMENT → Geoprocessing tools + model builder



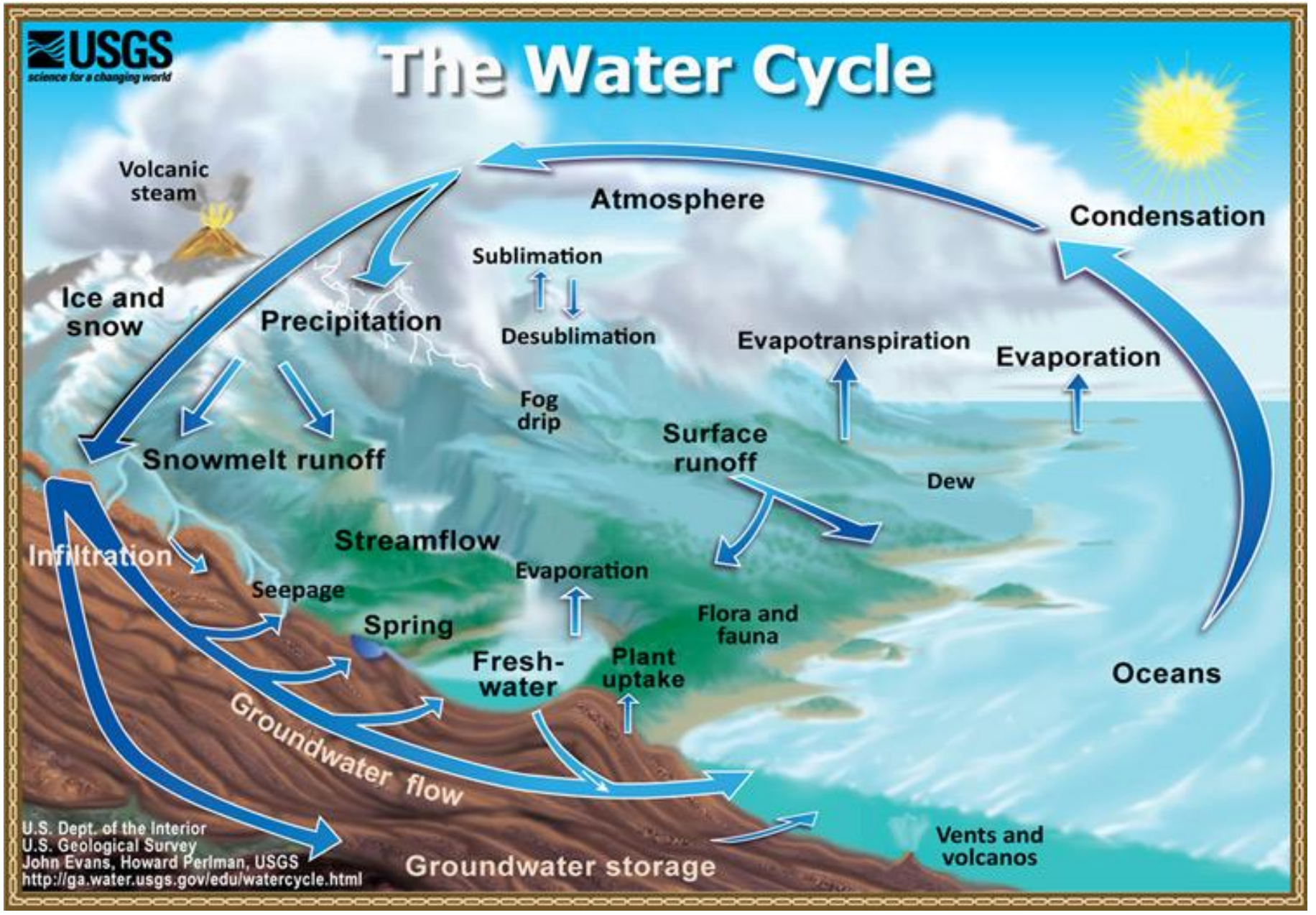
- detection of **hydraulic instability phenomena**



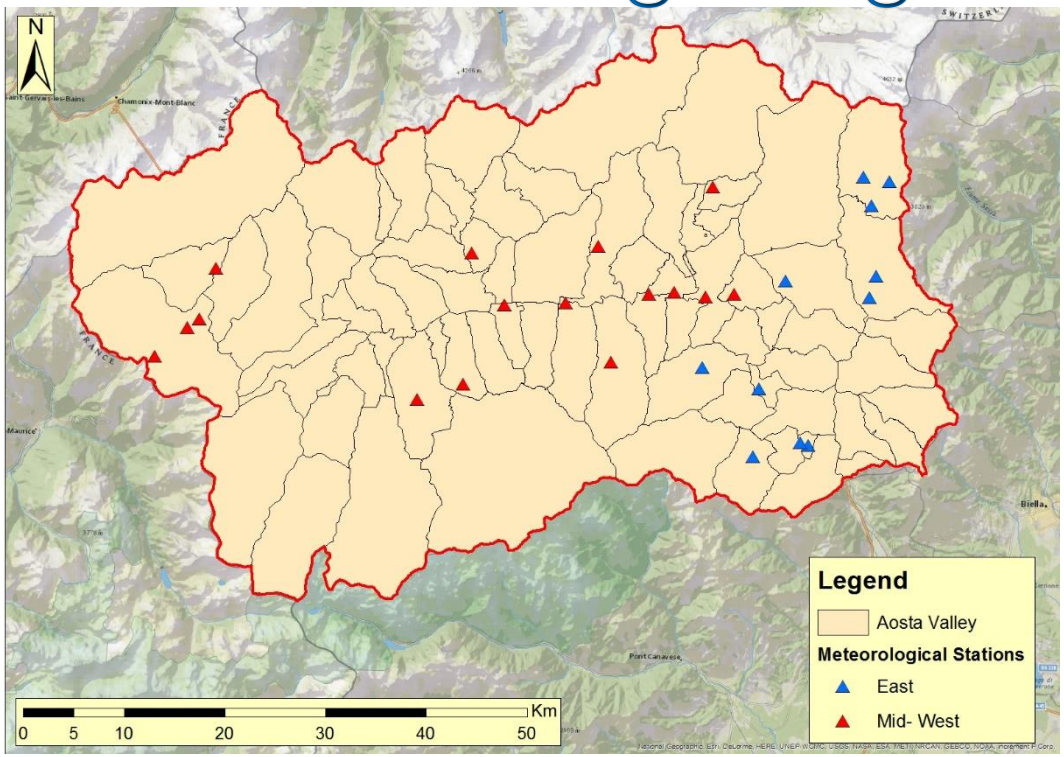
- Evaluation of area and volumes of deposit and erosion (**Cut/Fill**)




Water Study

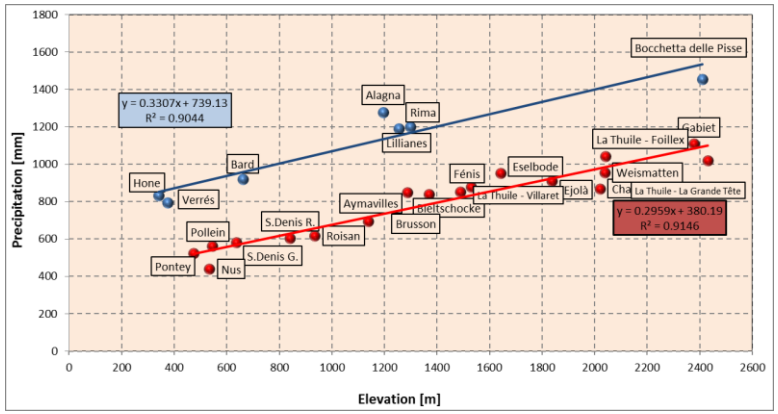

USGS
science for a changing world
The Water Cycle
Volcanic steam
Atmosphere
Condensation
Sublimation
Desublimation
Ice and snow
Precipitation
Evapotranspiration
Evaporation
Fog drip
Surface runoff
Dew
Snowmelt runoff
Streamflow
Infiltration
Evaporation
Seepage
Spring
Flora and fauna
Fresh-water
Plant uptake
Oceans
Groundwater flow
Vents and volcanos
Groundwater storage
U.S. Dept. of the Interior
U.S. Geological Survey
John Evans, Howard Perlman, USGS
http://ga.water.usgs.gov/edu/watercycle.html

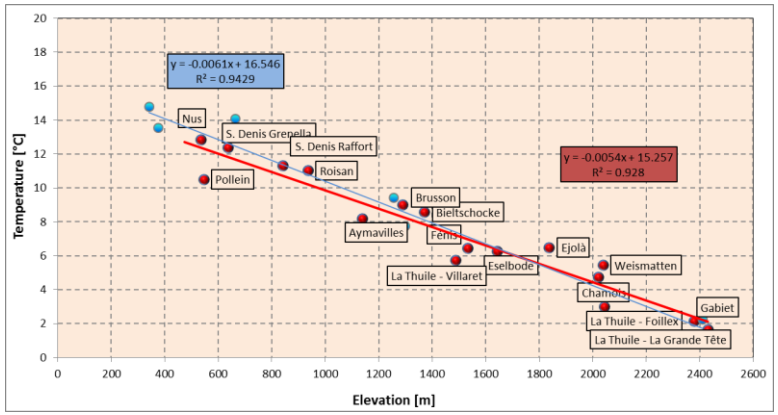
Hydrologic study



26 **meteorological stations** collecting temperature, rainfall and snowfall data

Linear Trend of **Precipitation** and **Temperature** related to **Elevation**

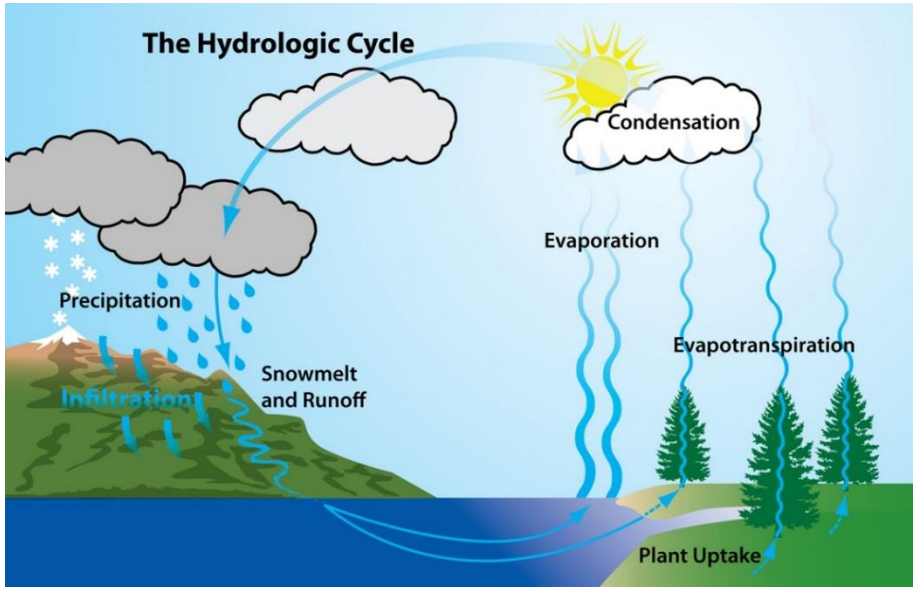




$$P = a \cdot H + b$$

$$T = -c \cdot H + d$$

Hydrological Inverse Balance



$$P = E_{tr} + I + R$$

$$E_{tr} = \frac{P}{\sqrt{0{,}9 + \left(\frac{P^2}{L^2}\right)}};$$

$$L = 300 + 25T_c + 0{,}05T_c^{\,3};$$

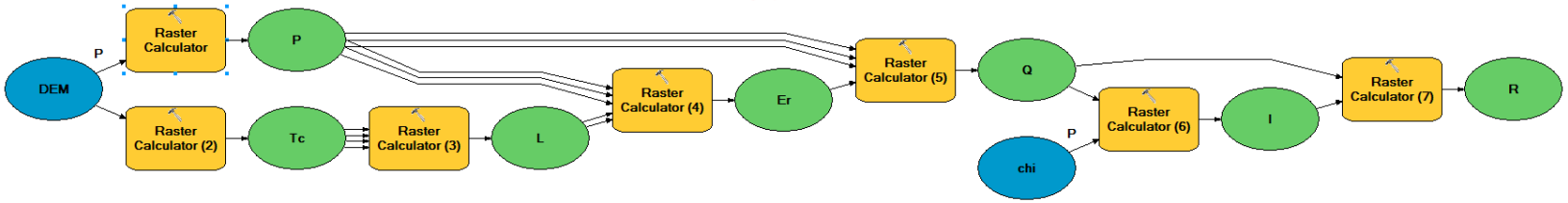
$$Q = P - E_{tr};$$

$$I = Q \cdot \chi;$$

$$R = Q - I;$$

- E_{tr} = Evapotranspiration (Turc)
- Q = Rainfall
- χ = Infiltration Coefficient
- I = Infiltration
- R = Runoff

MODEL DEVELOPMENT



Geological setting

The valley is at the contact of two basic structural Units

BED-ROCK

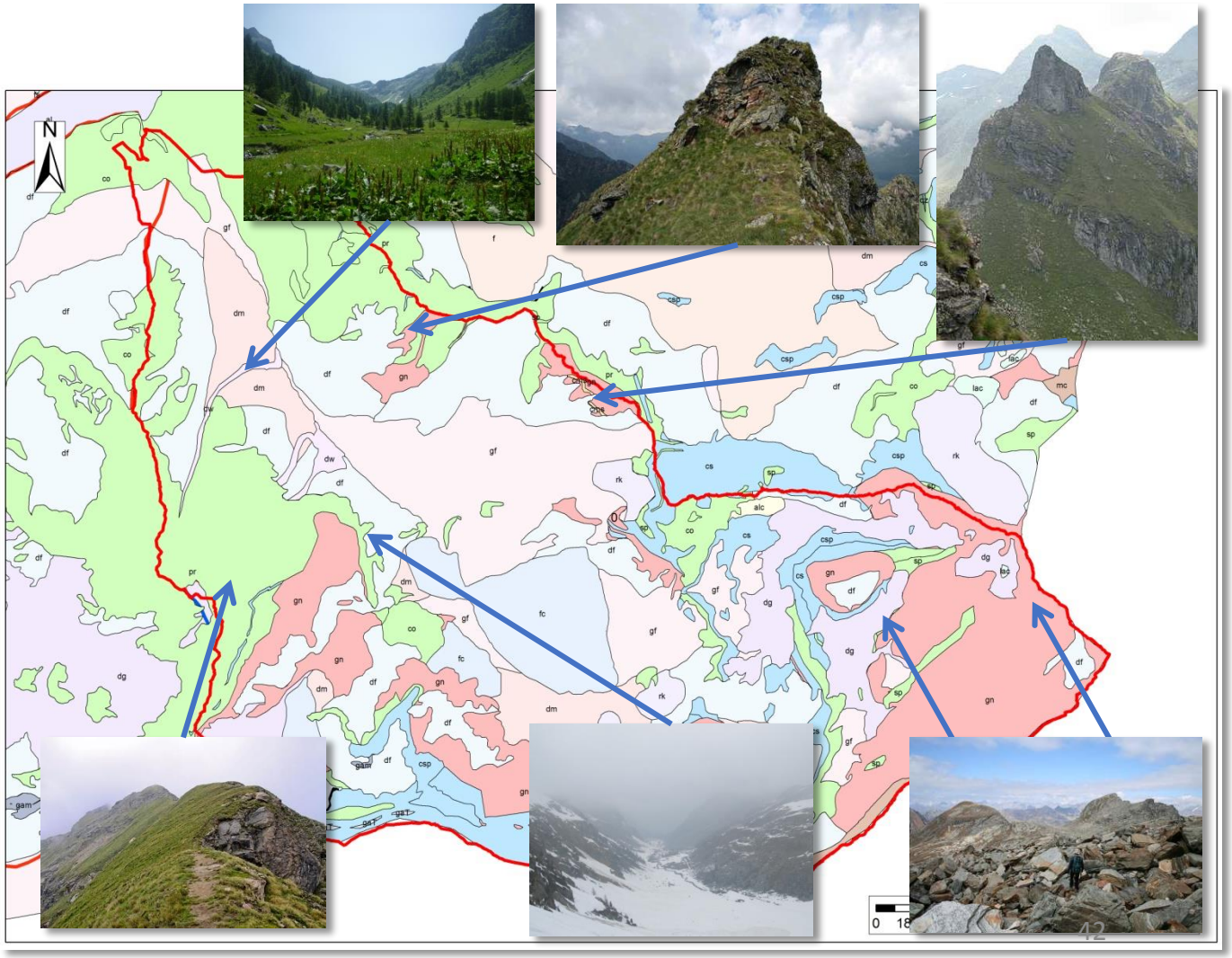
Piedmont Zone:

- Greenstones
- Calcschists

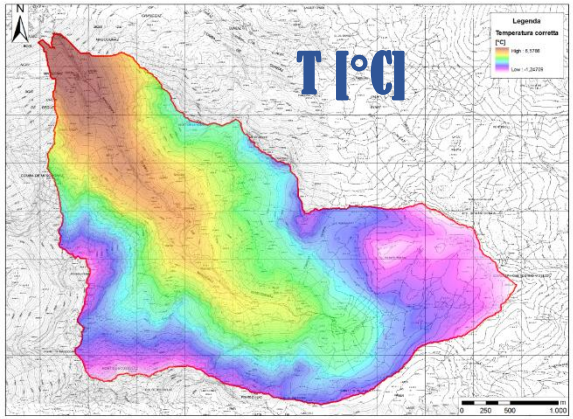
Sesia Lanzo Zone:

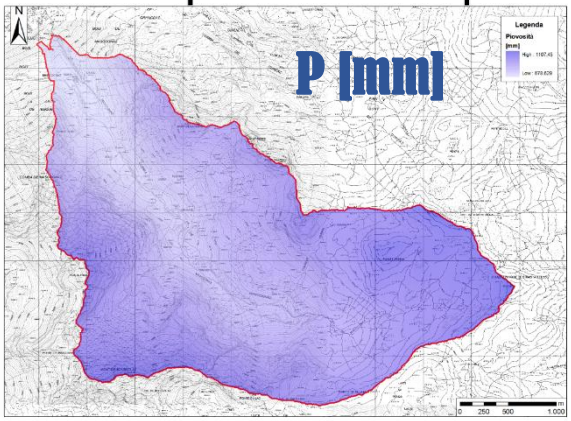
- Gneiss

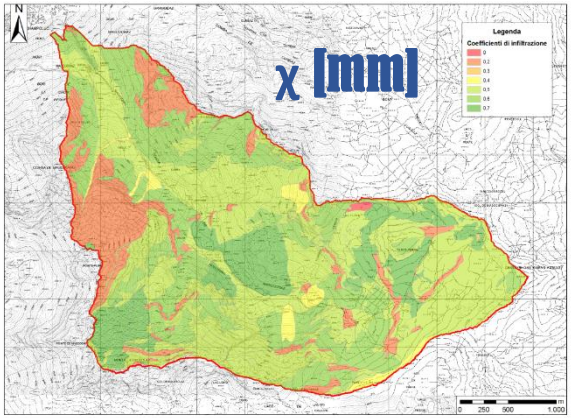
QUATERNARY MATERIAL

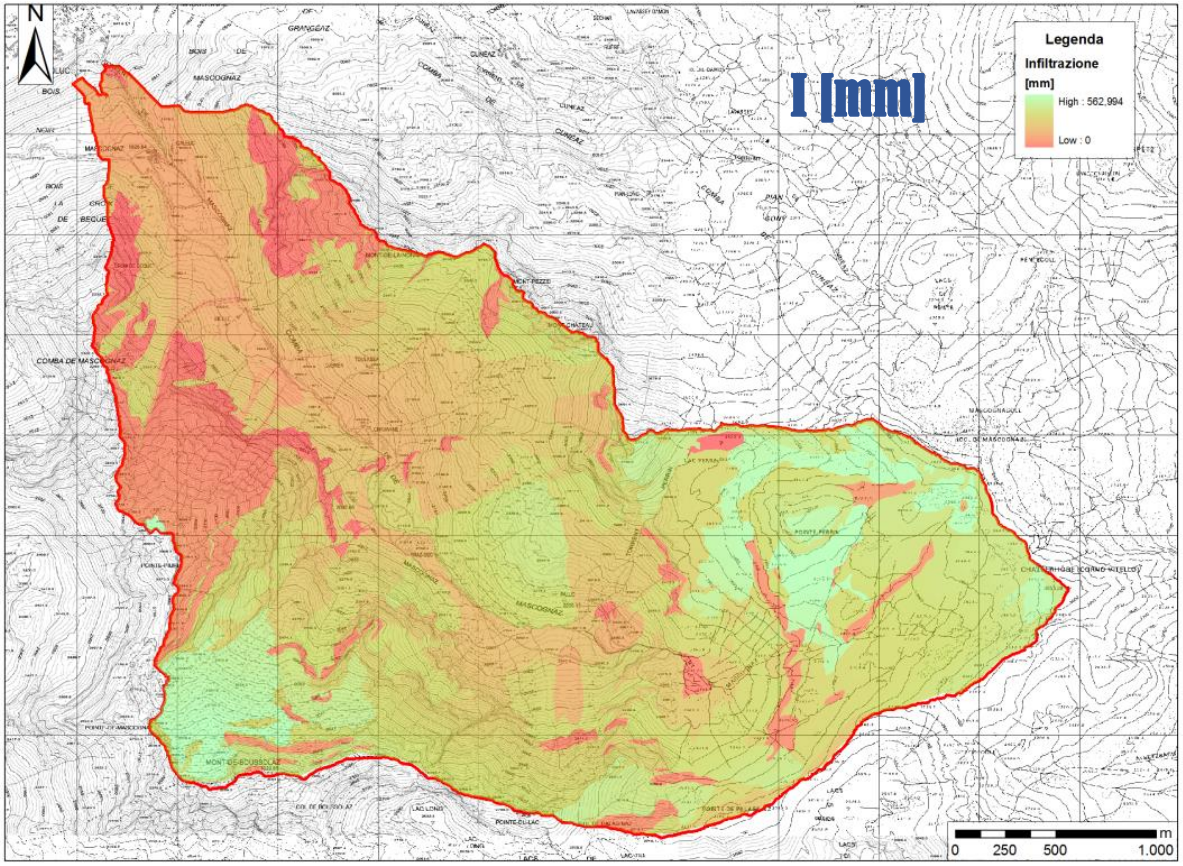


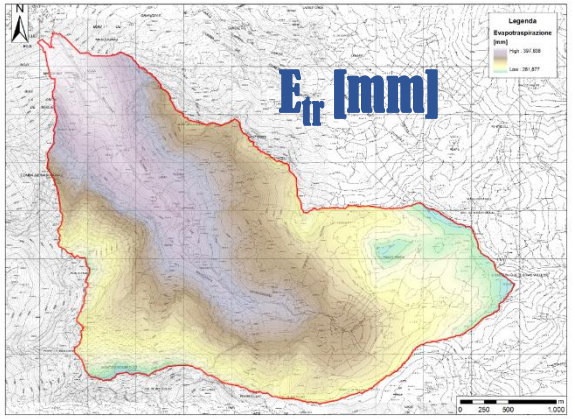
Output Maps

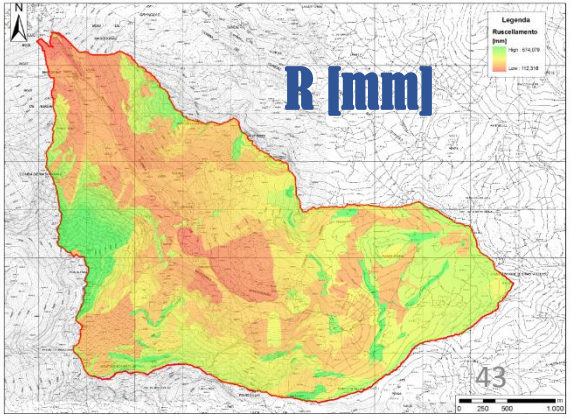

T [°C]


P [mm]


χ [mm]


I [mm]
Legenda
Infiltrazione
[mm]
High : 562.994
Low : 0
0 250 500 1.000
m


E_tr [mm]

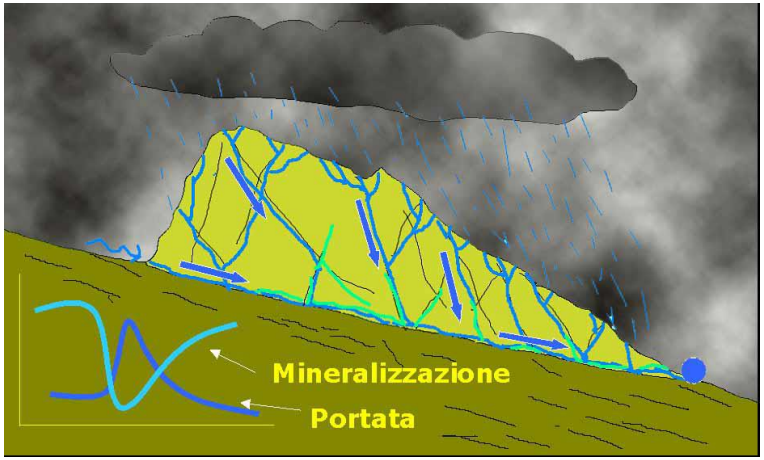

R [mm]

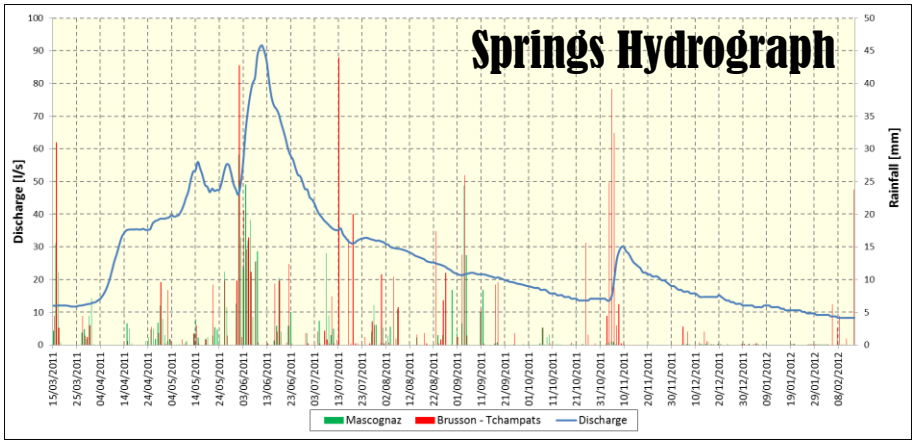
Water Balance

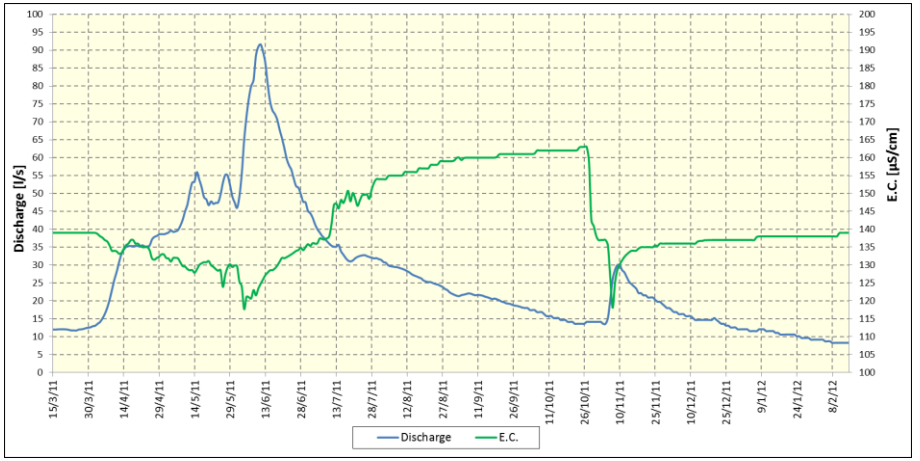
$$Rate_{in} = Rate_{out}$$

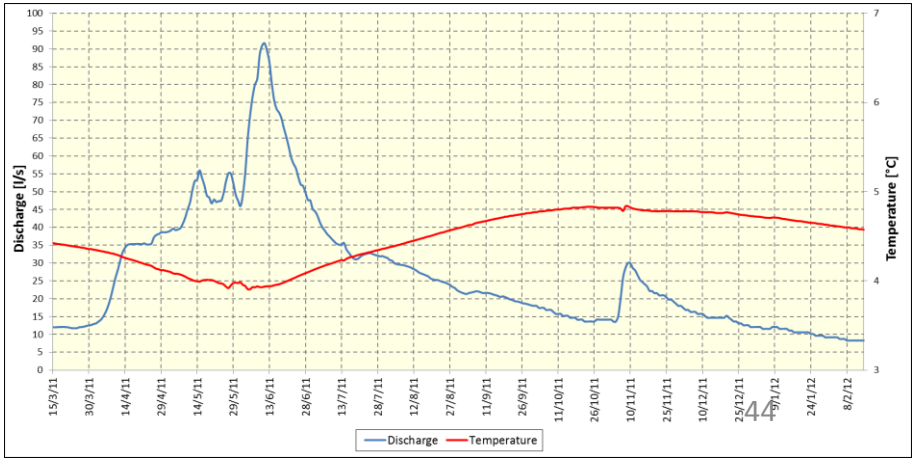
$$INFILTRATION_{in} = SPRINGS_{discharge}$$

SPRINGS BEHAVIOR

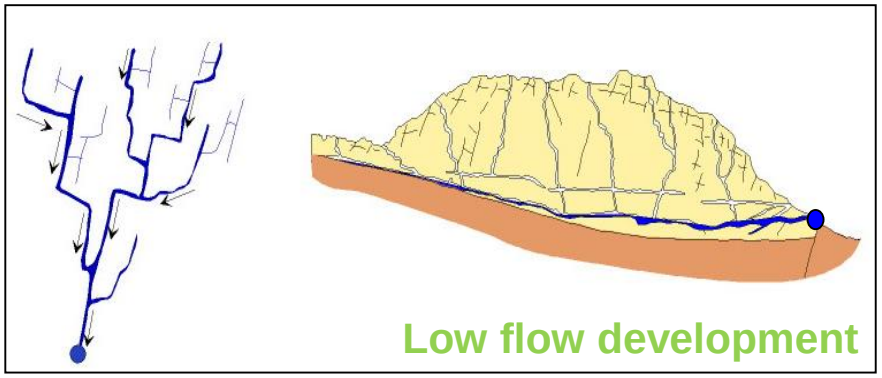




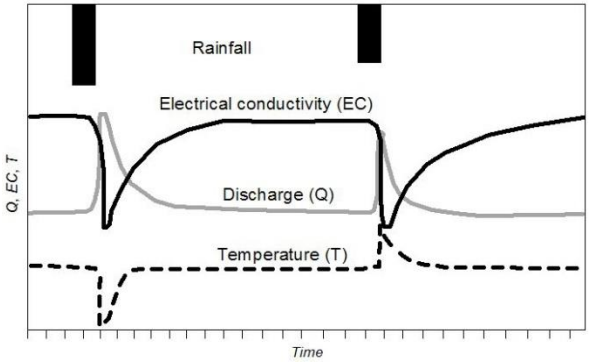


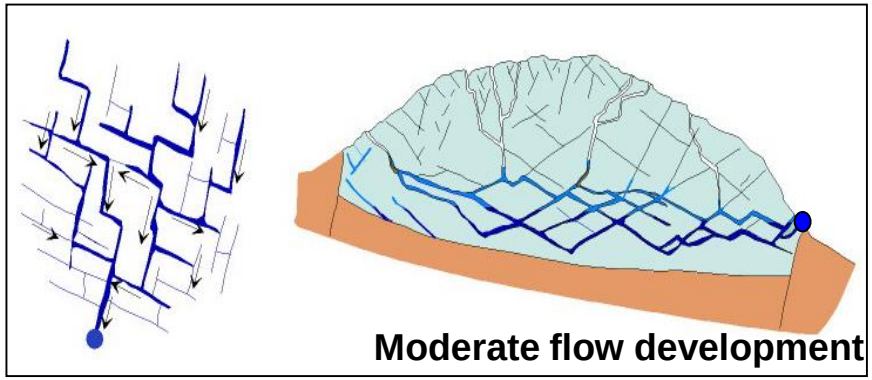


SPRINGS BEHAVIOR

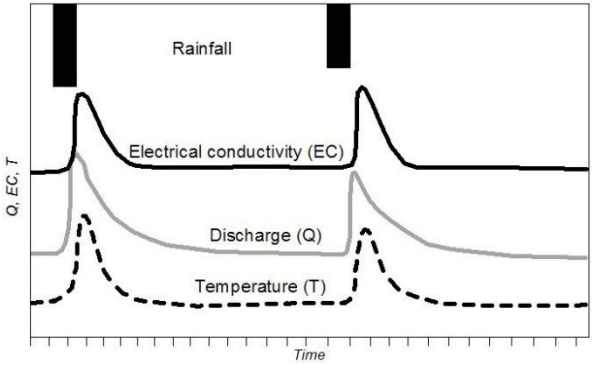


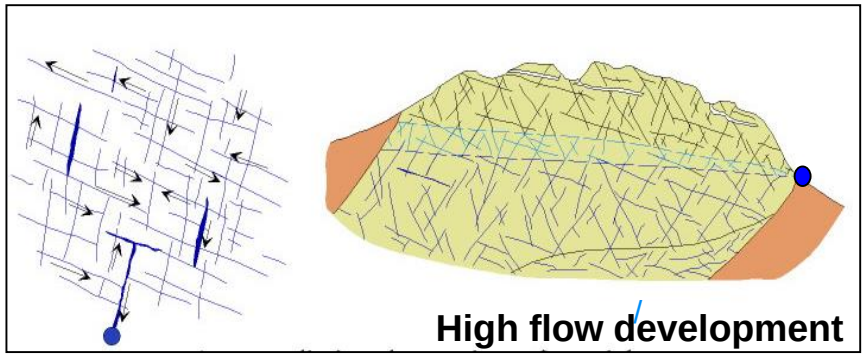
Replacement



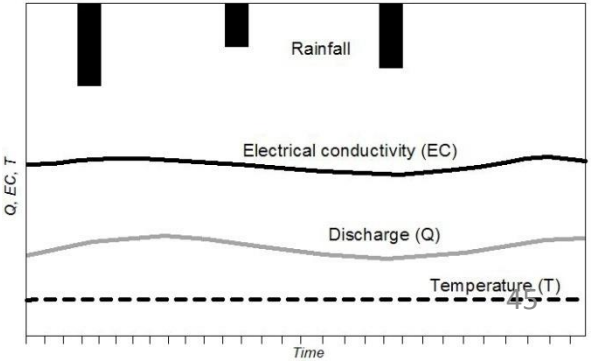


Piston



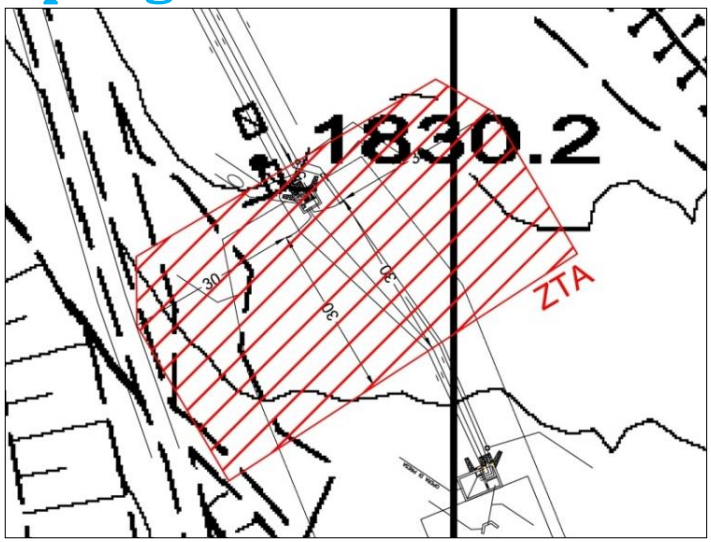


Homogenization

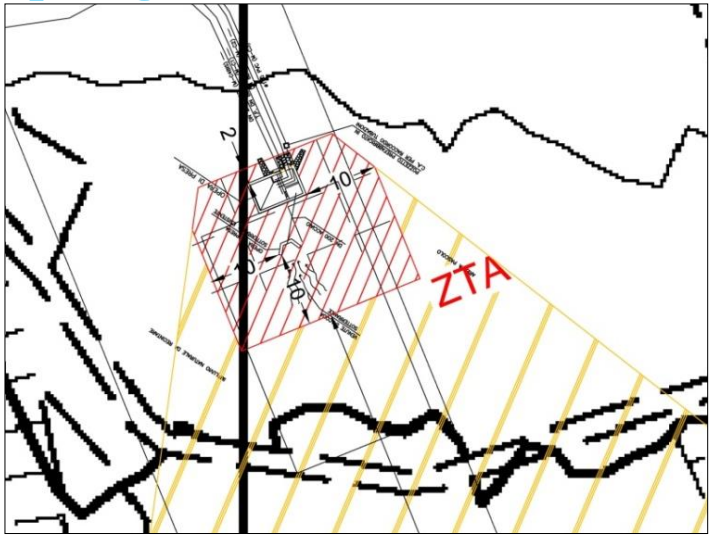


Springs Vulnerability

Spring 1

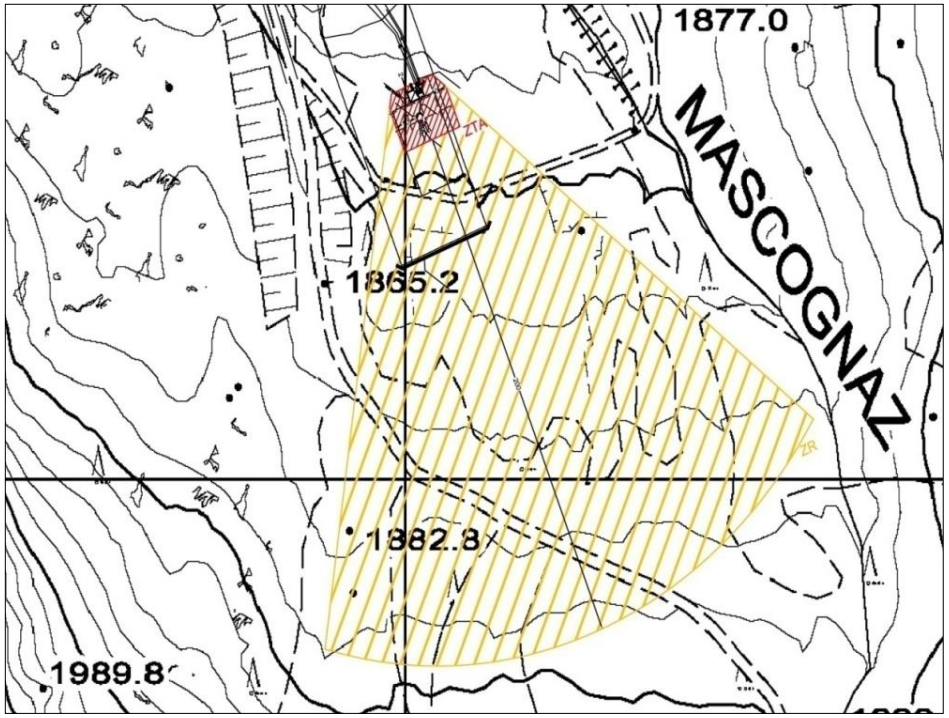


Spring 2



Delay time

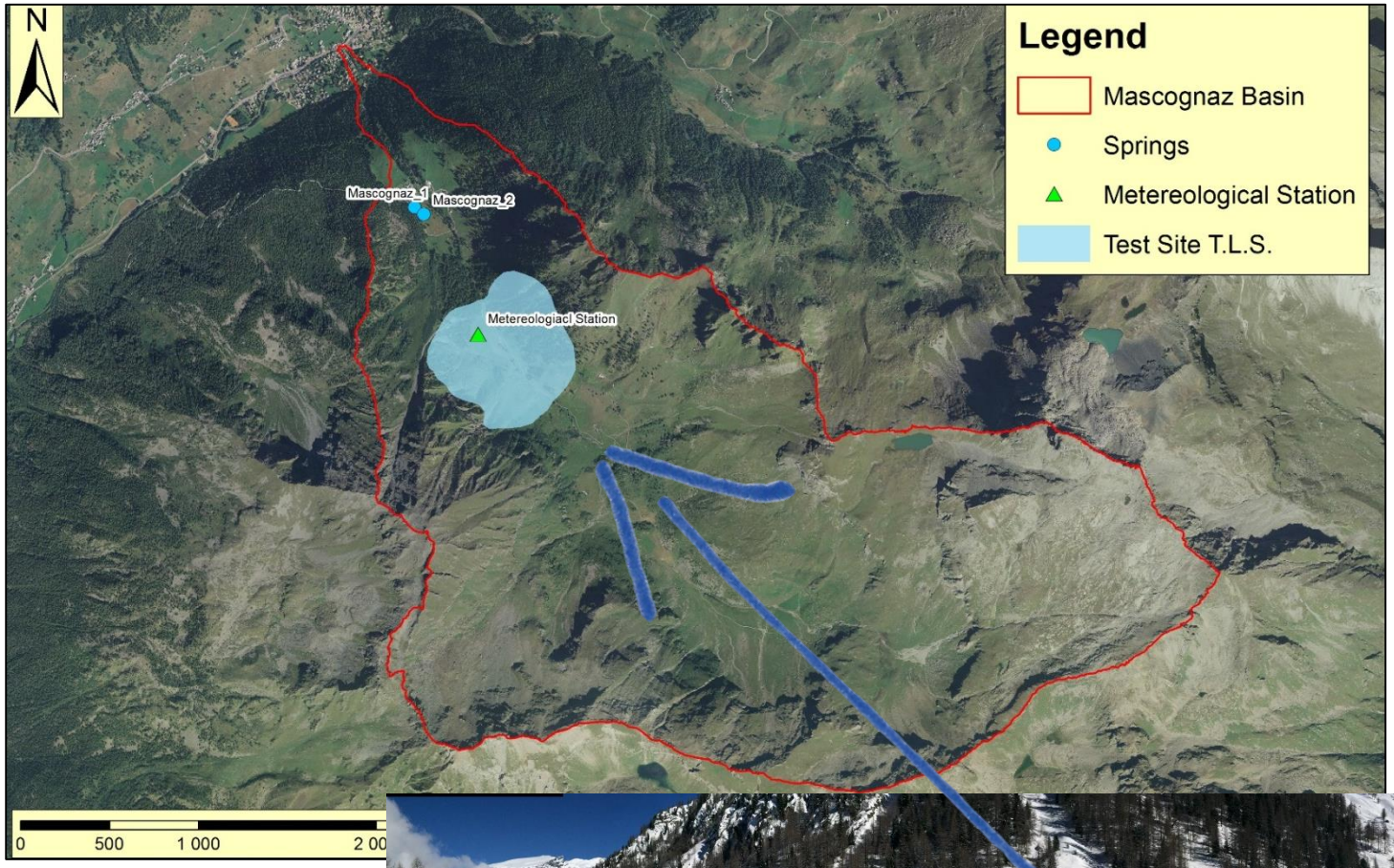
Safe protection Zone



Improve the water MANAGEMENT

Snow study

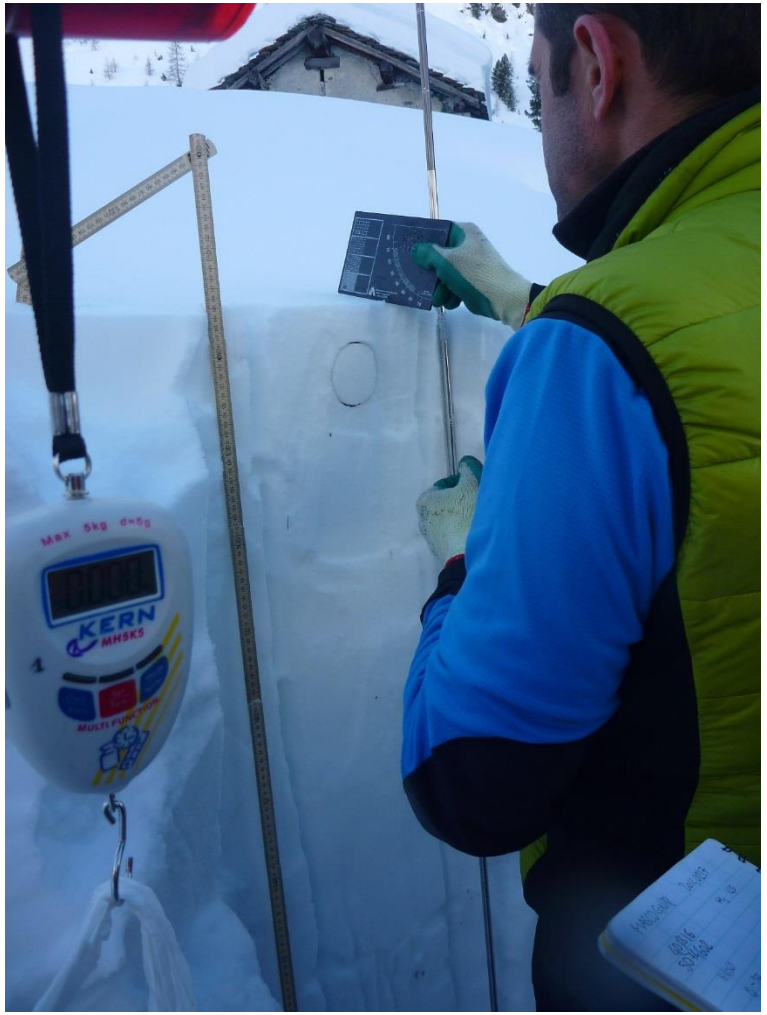
Snow pack study area



POLITECNICO DI TORINO

Manual punctual measurement

Snow pack section + stratigraphy

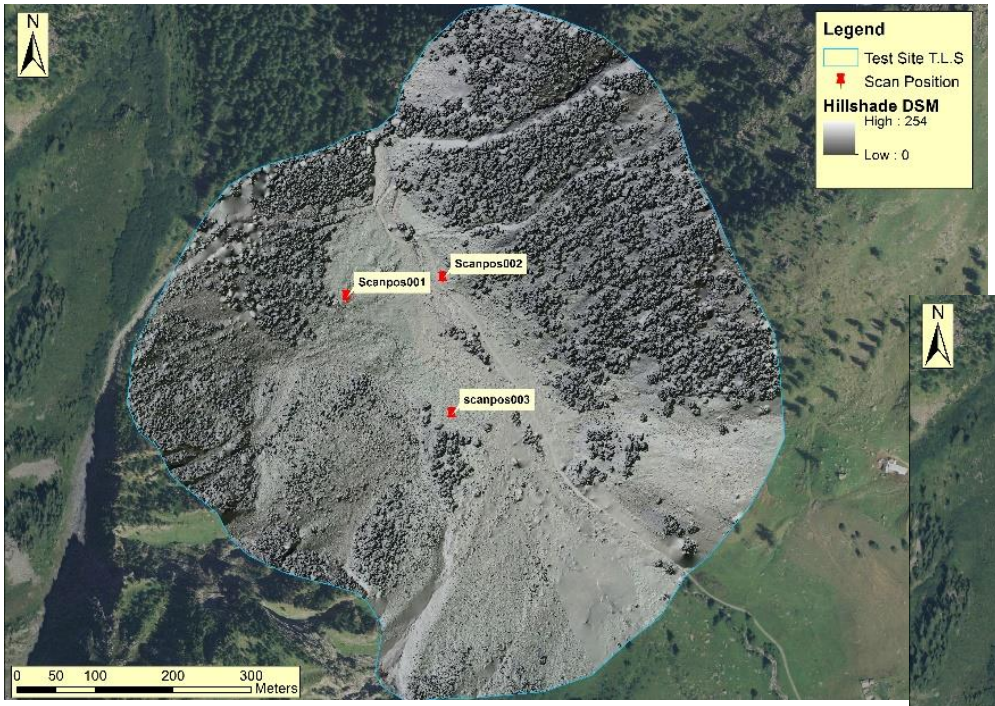


- ✓ Snow density → SWE
- ✓ Snow pack stability

TLS ACQUISITION

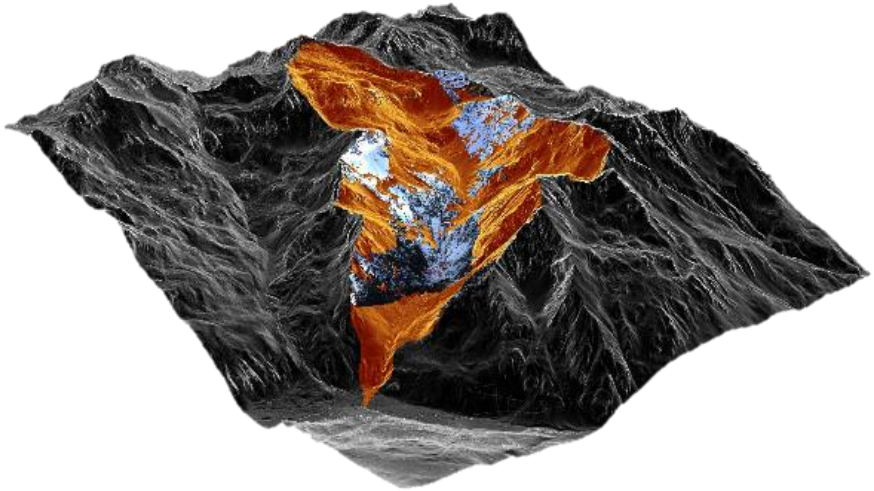
Video time…

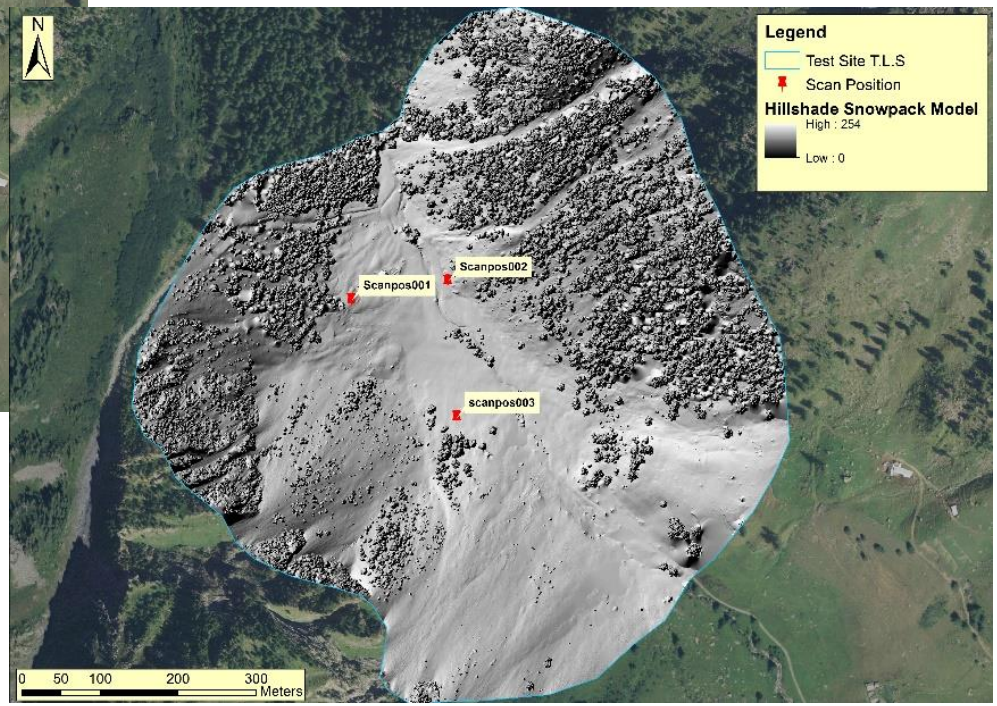
TLS ACQUISITION



DSM (0.25 m x 0.25 m)

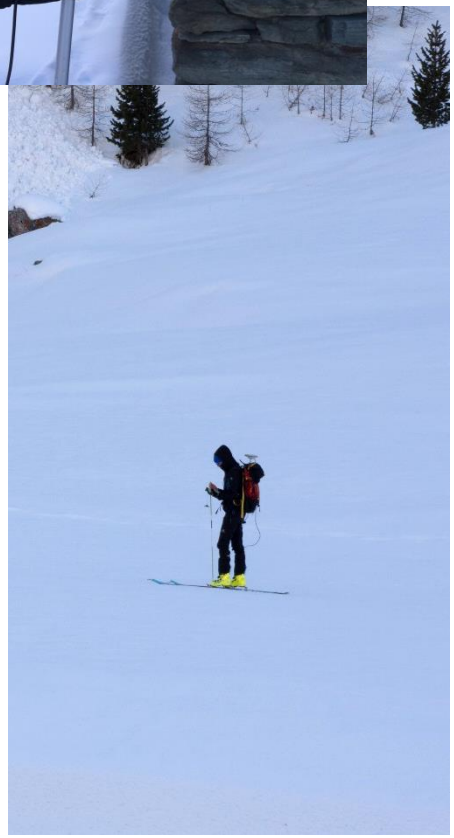
✓ partly filtered





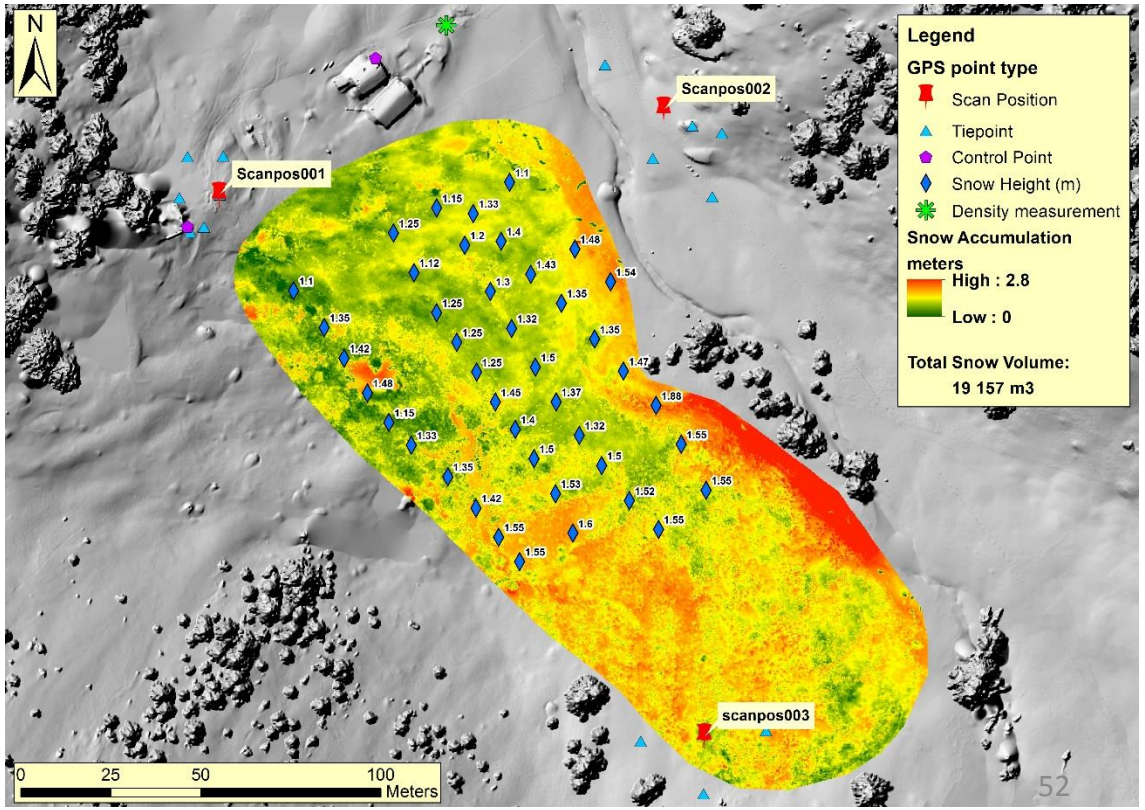
Snow DEM (0.25 m x 0.25 m)

GPS measurement

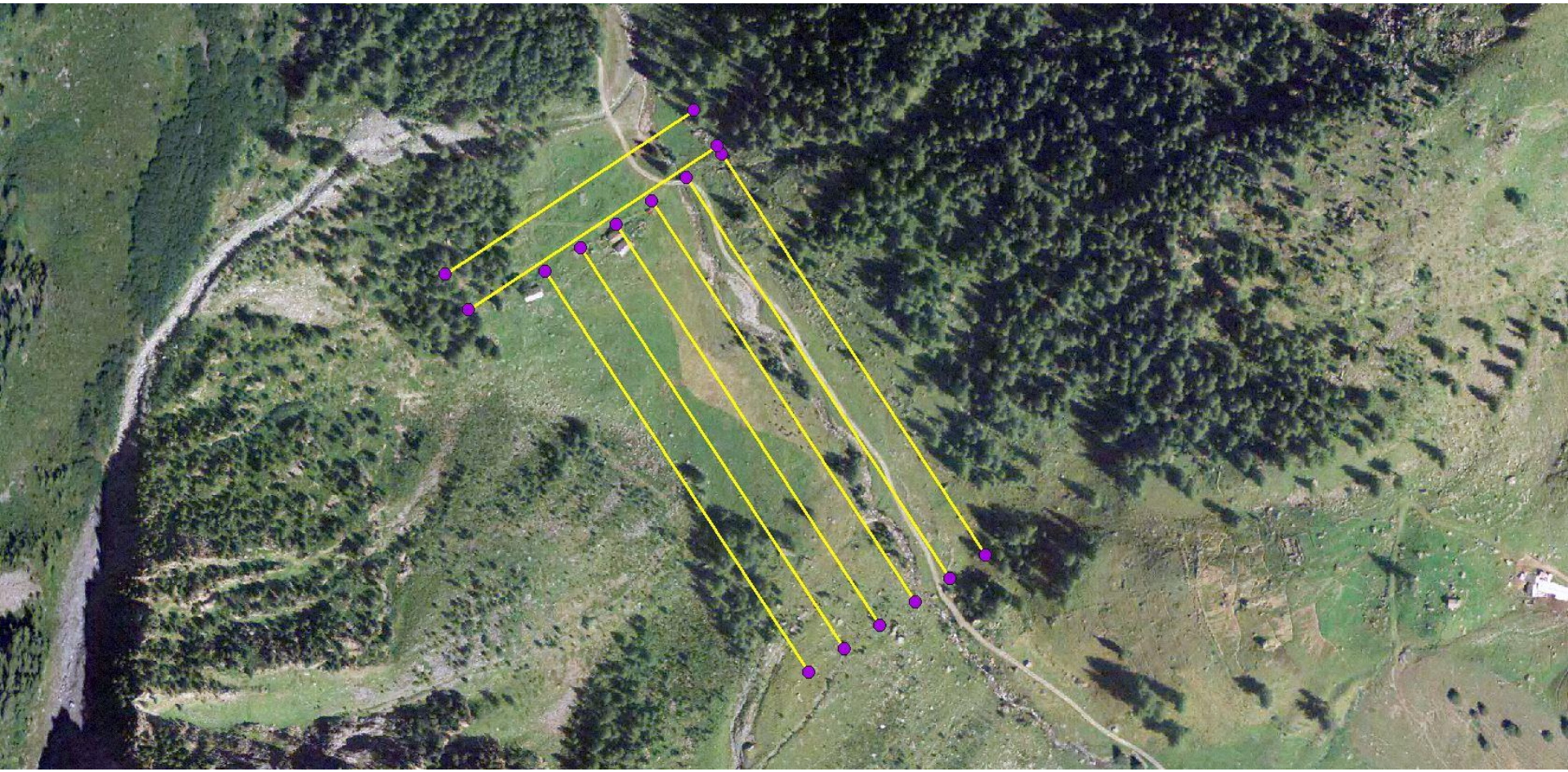


Ground Control Points:

- Snow height
- Accuracy ≈ 1 – 1.5 cm

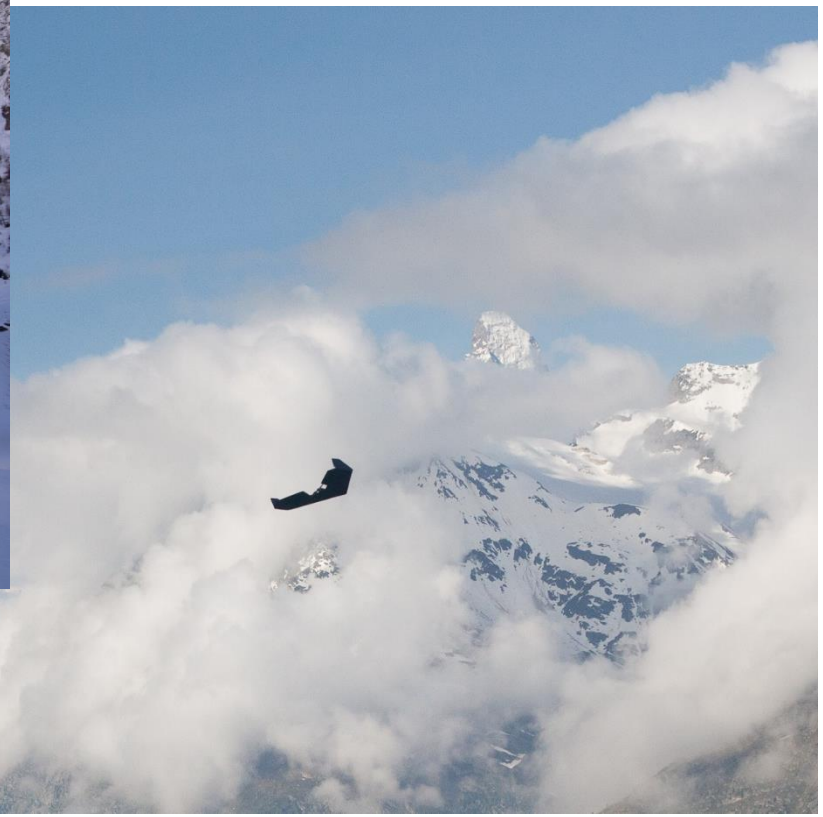


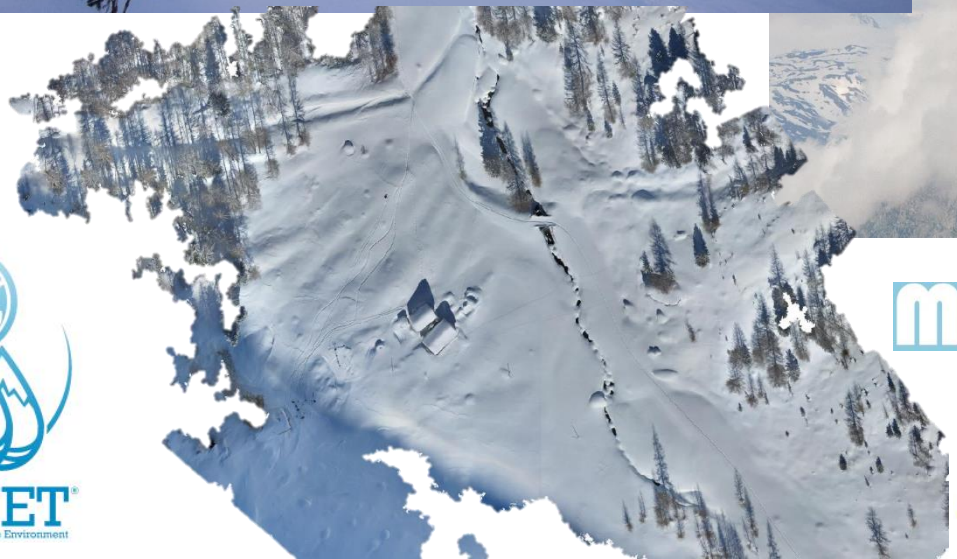
UAV & PHOTOGRAMMETRY



UAV & PHOTOGRAMMETRY

UAV & PHOTOGRAMMETRY





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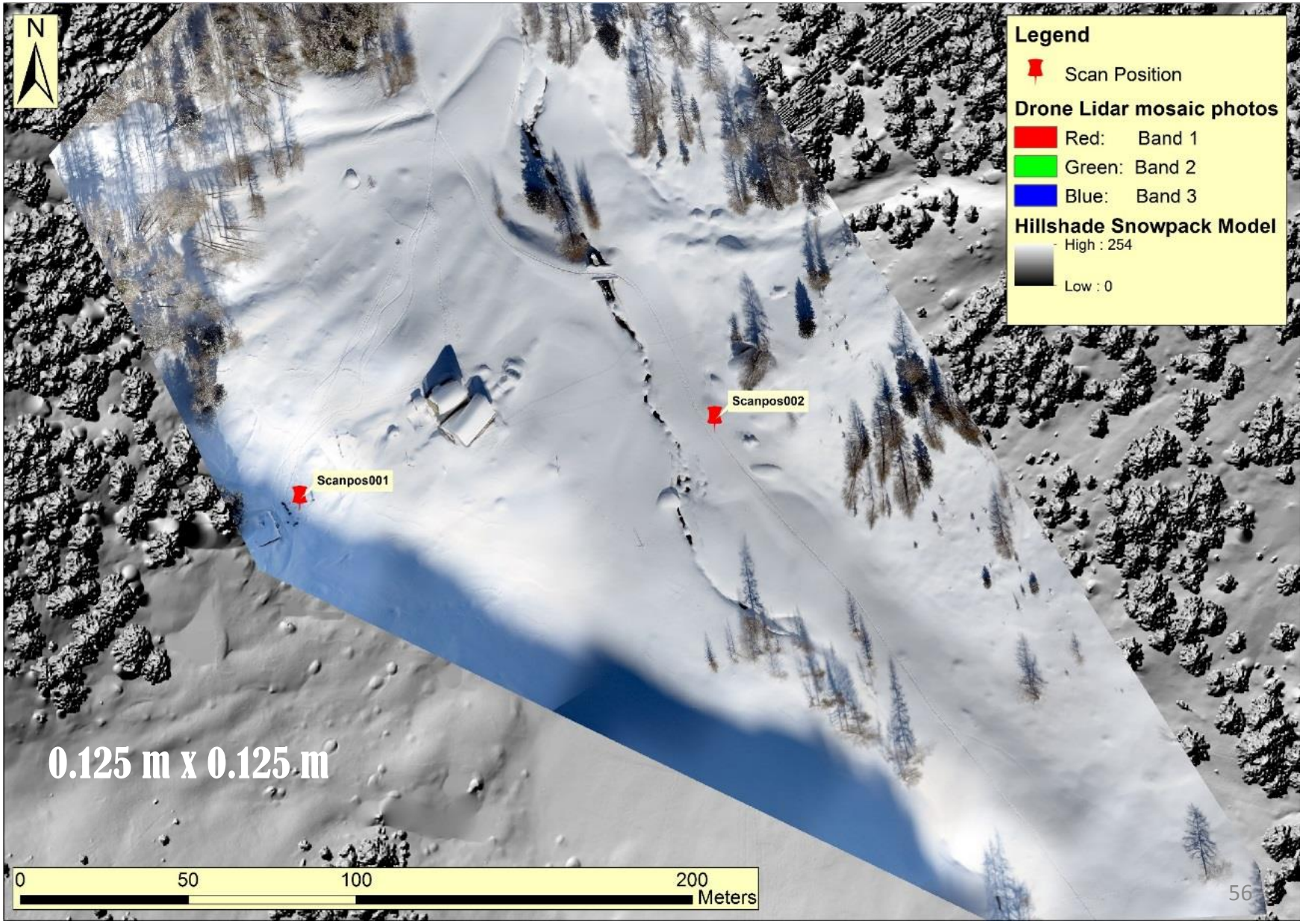
MIC MAC

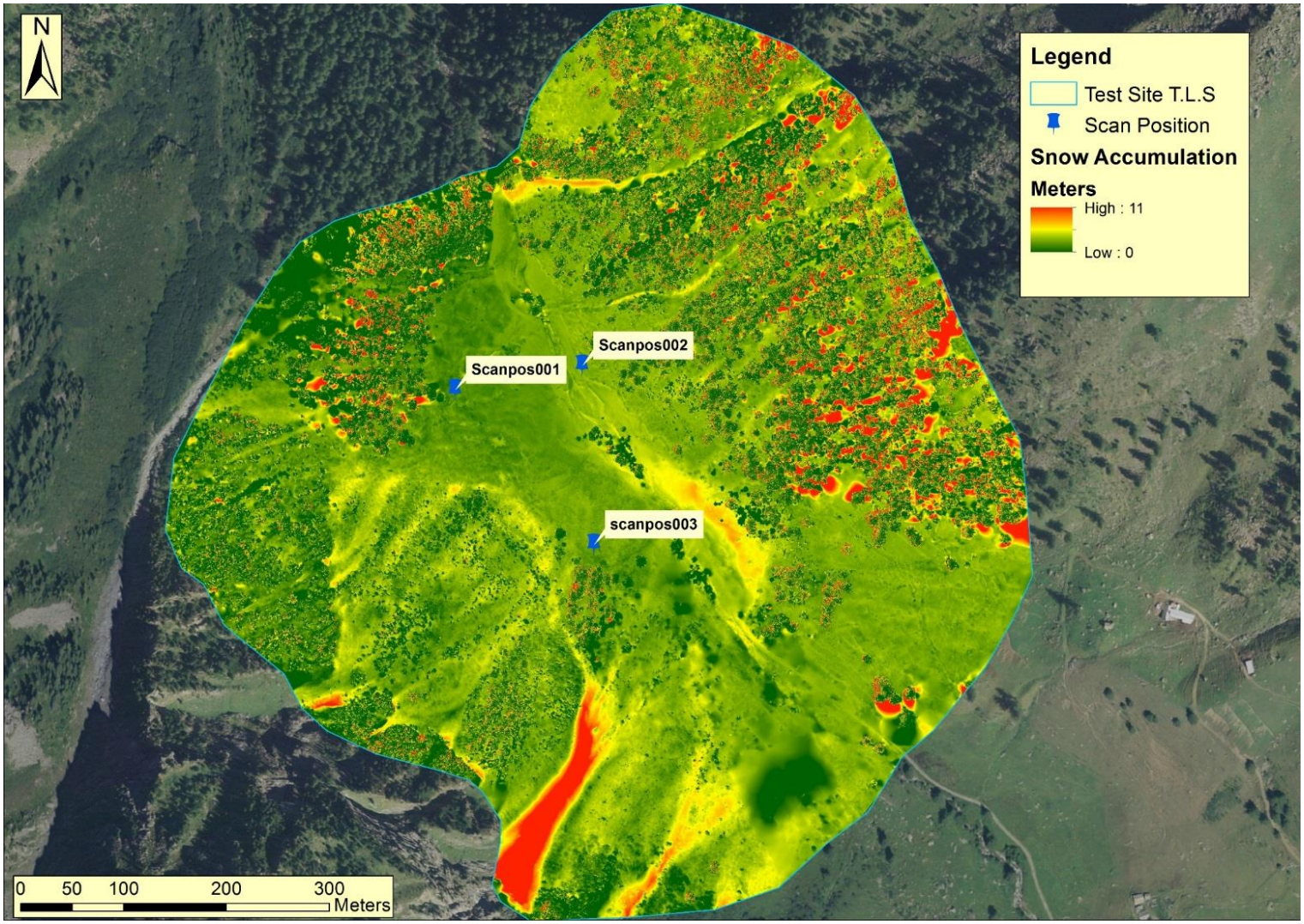
Agisoft

ARPA Valle d'Aosta

PHOTOGRAMMETRY & ORTOPHOTO



SNOW ACCUMULATION



+ Density	=	Snow Water Equivalent
+ Aspect + Hillshade	=	Snowmelt Process
+ Slope + Curvature	=	Snow Avalanche

WSL Institute for Snow and Avalanche Research SLF

Swiss Federal Institute for Forest, Snow and Landscape Research WSL

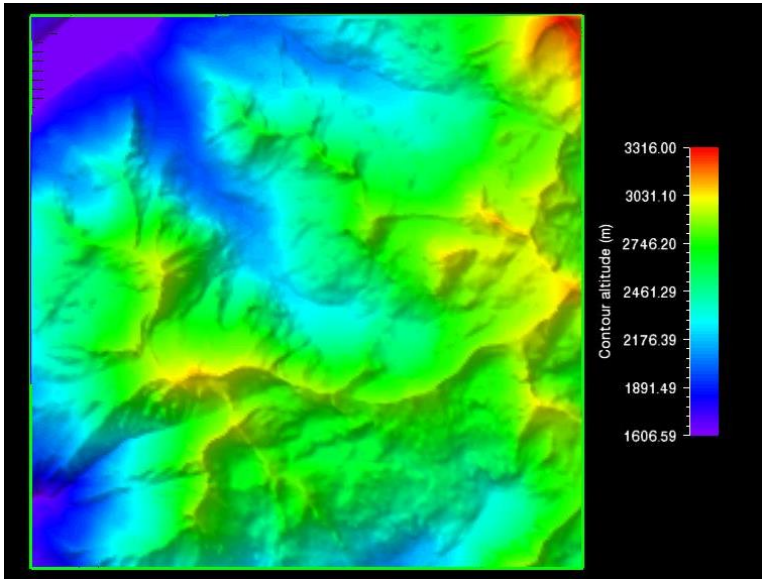
RAMMS

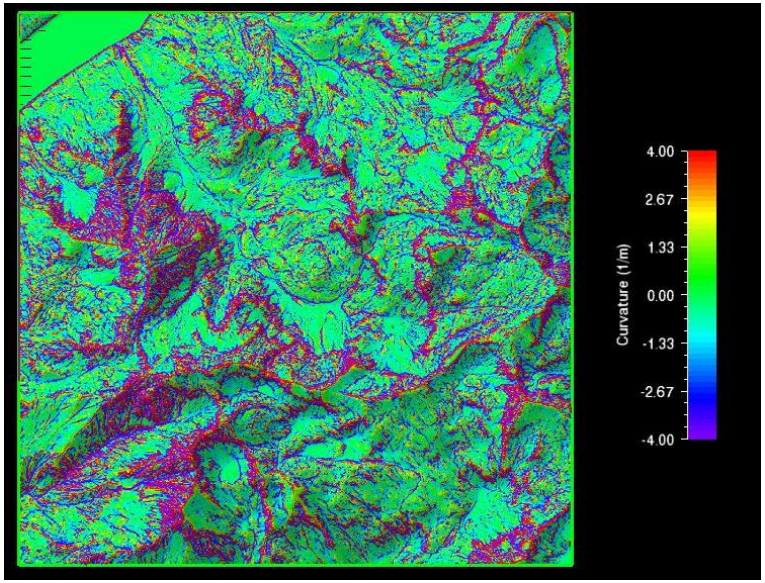
Rapid Mass Movement Simulation

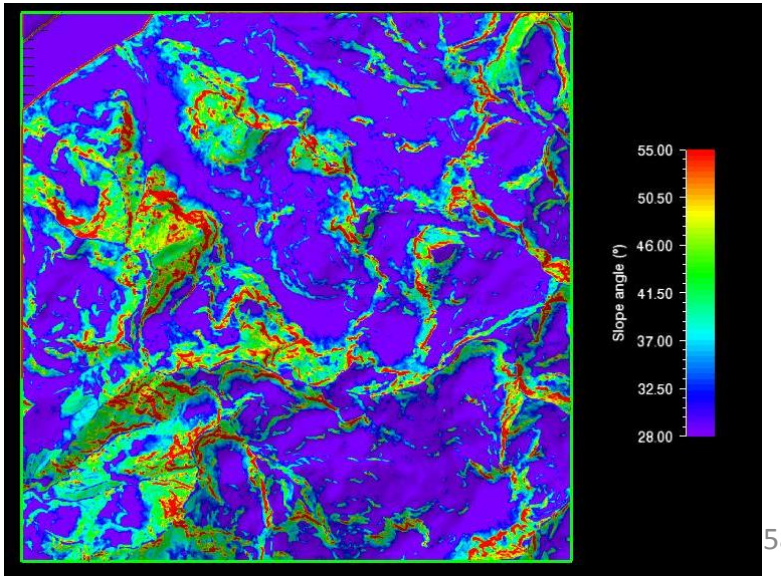
AVALANCHE Module

Voellmy Friction model (1955)

- Elevation
- Slope
- Curvature

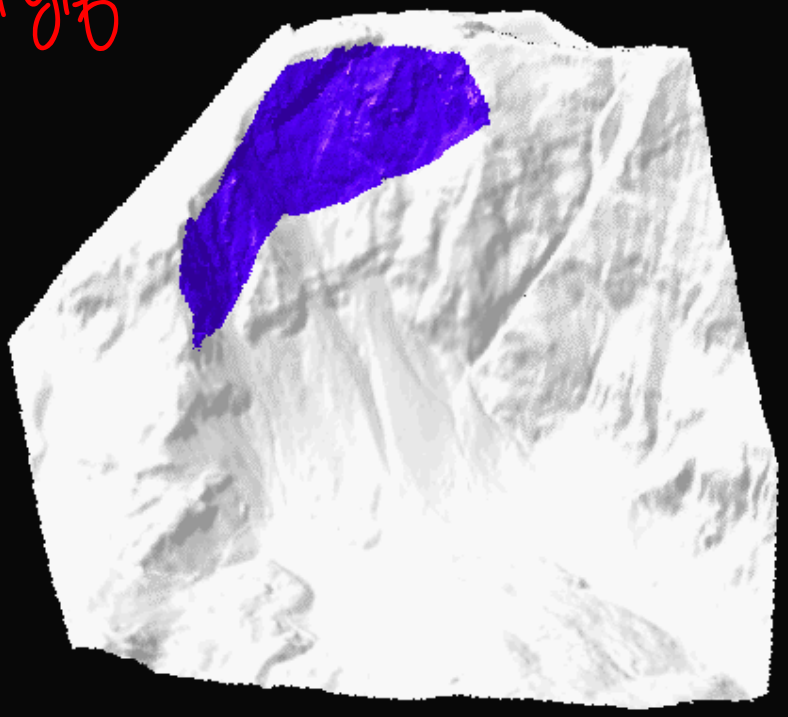






RAMMS Avalanche Simulation

Animated GIF



Two-dimensional dynamics modeling of rapid mass movements in 3D alpine terrain

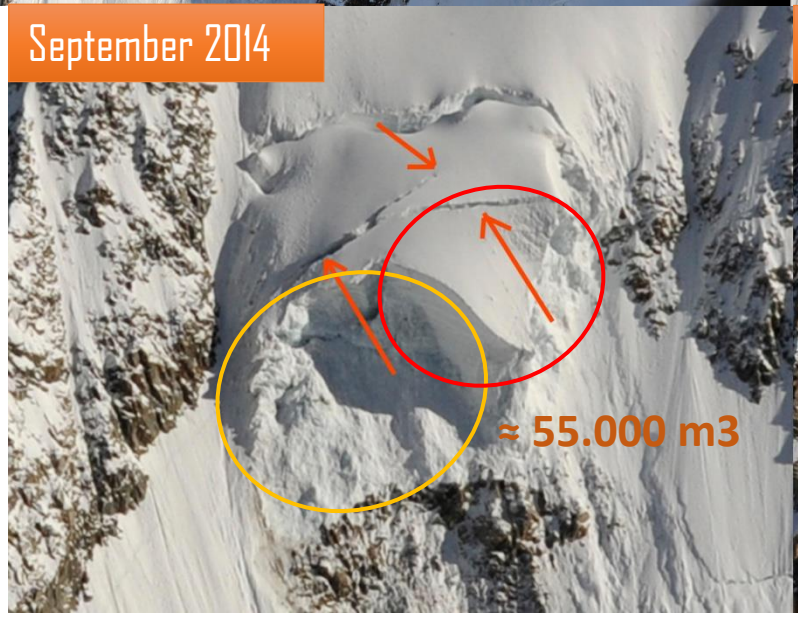
Glacial Study

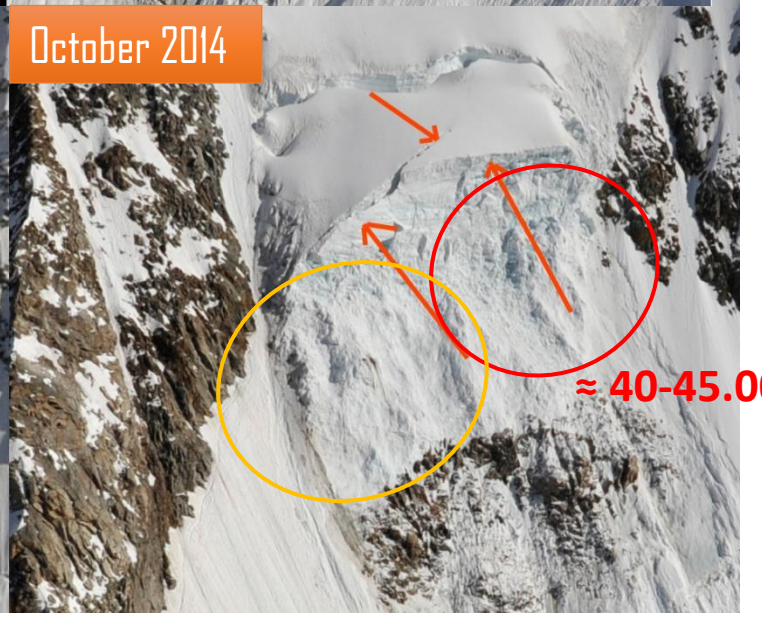
Glacial risk Grandes Jorasses

FONDAZIONE
MONTAGNA SICURA
MONTAGNE SÛRE

Hanging seracs ice-falls

Glacial risk Grandes Jorasses





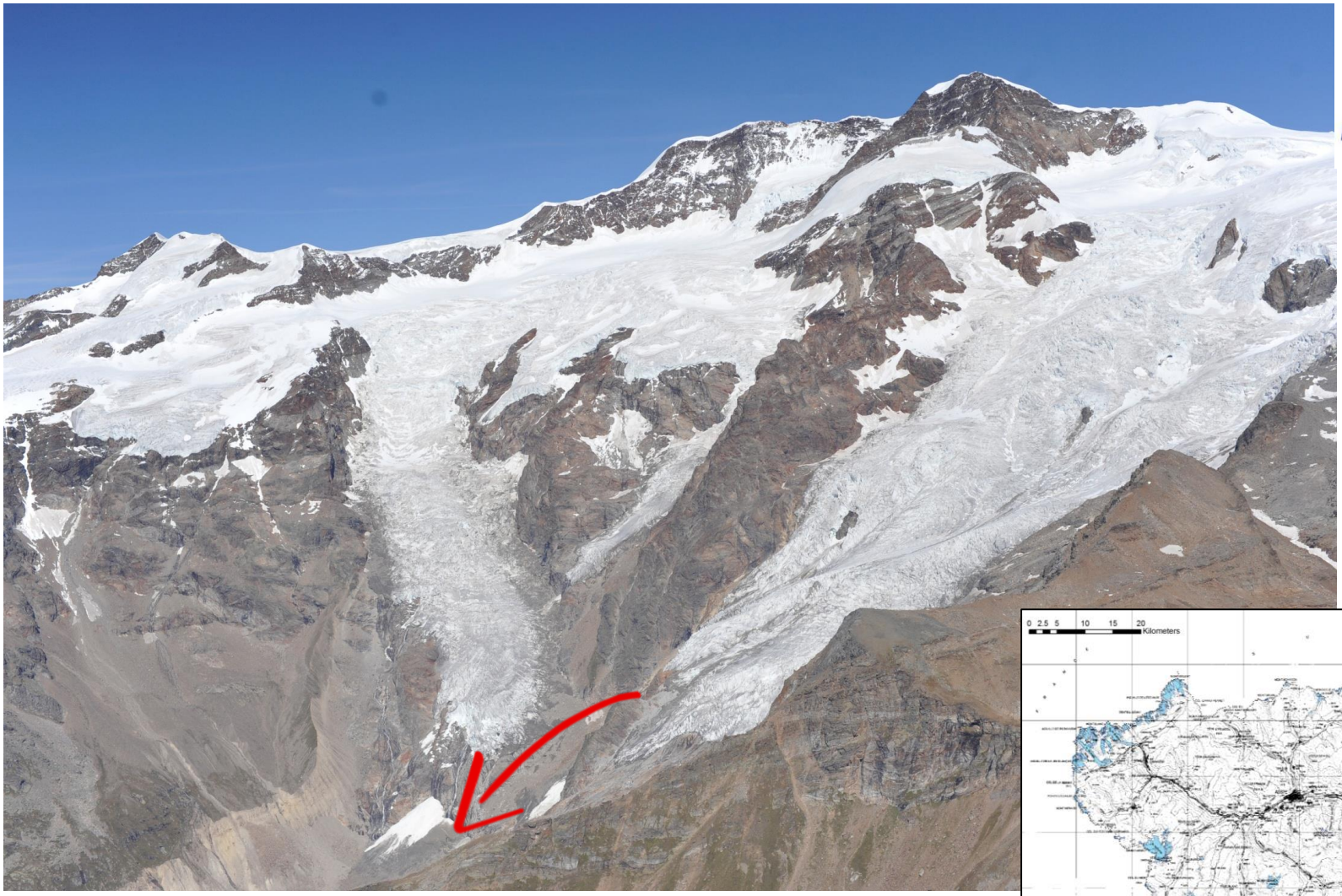
FONDAZIONE MONTAGNA SICURA
MONTAGNE SÛRE

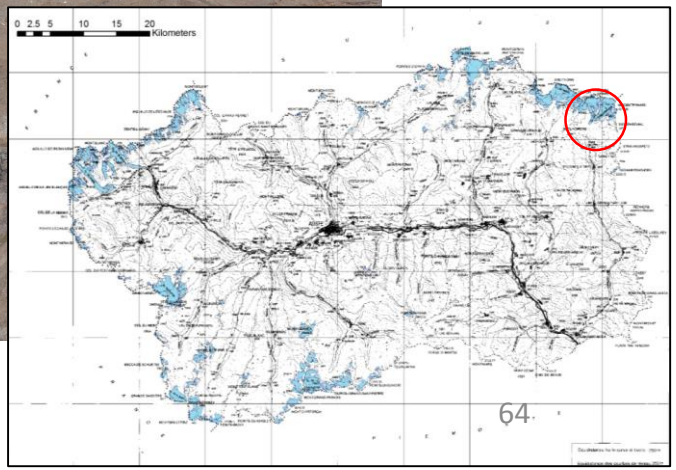
PHOTOGRAMMETRIC PROCESSING

Volumetric analysis

GLACIAL RISK LYS

FONDAZIONE
MONTAGNA SICURA
MONTAGNE SÛRE





GLACIAL RISK LYS

Contact lake growth at the Lys Glacier tongue…

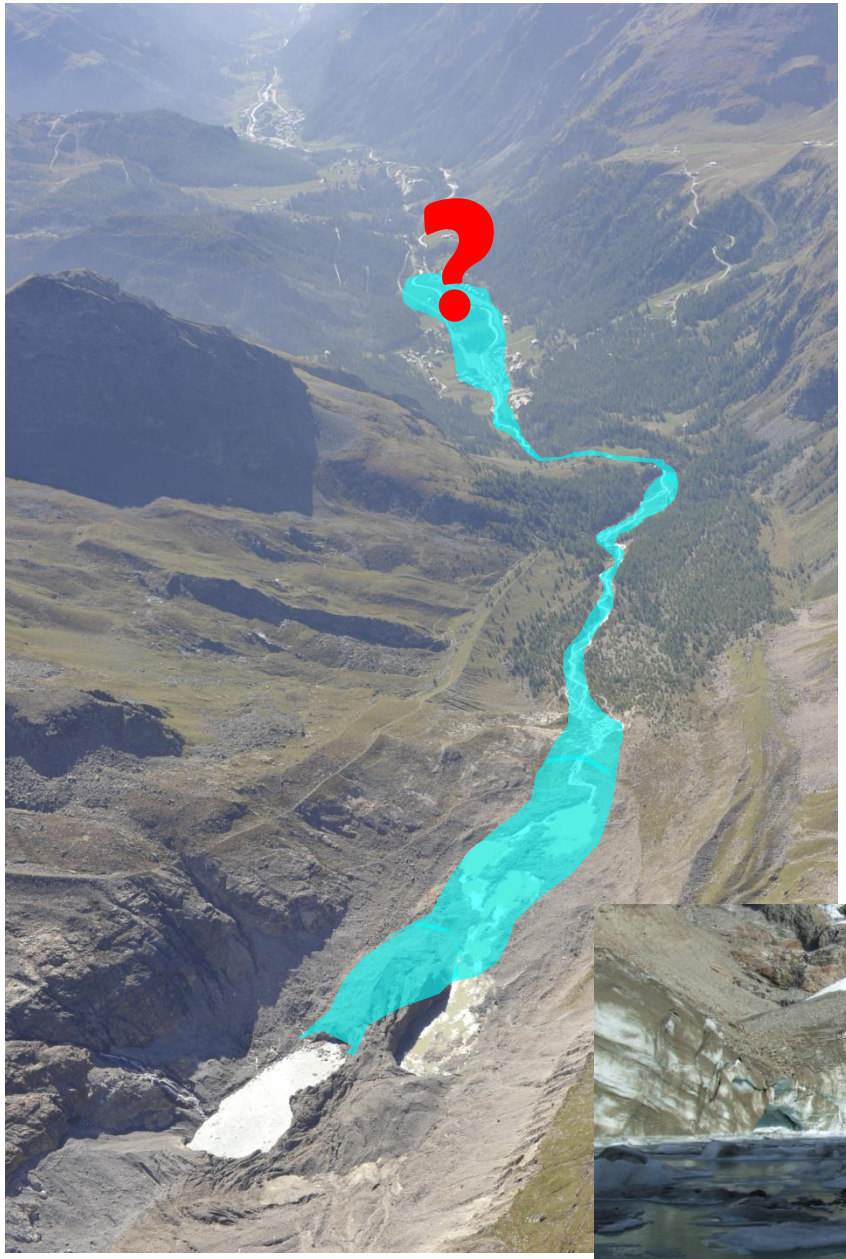
Ice fall

+

flooding risk

Glacial lake outburst flood
GLOF

GLACIAL RISK LYS



Concern : can this lake generate an outburst flood and endanger inhabited areas downstream?

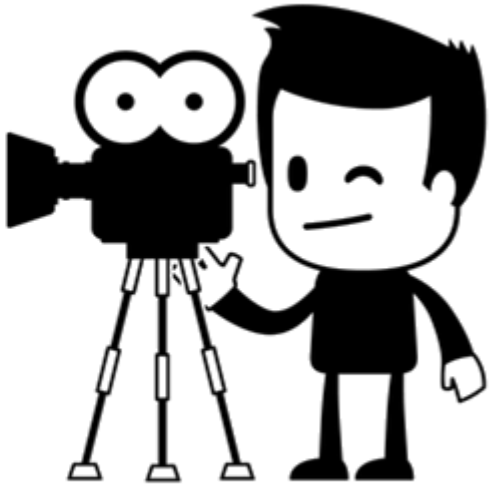
- ❑ What water volume is accumulate?
- ❑ What volume could be released?
- ❑ Is a "dam break" outburst possible?

rapid glaciers evolution due to climate warming

GLACIAL RISK LYS

FONDAZIONE
MONTAGNA SICURA
MONTAGNE SÛRE

Video time...



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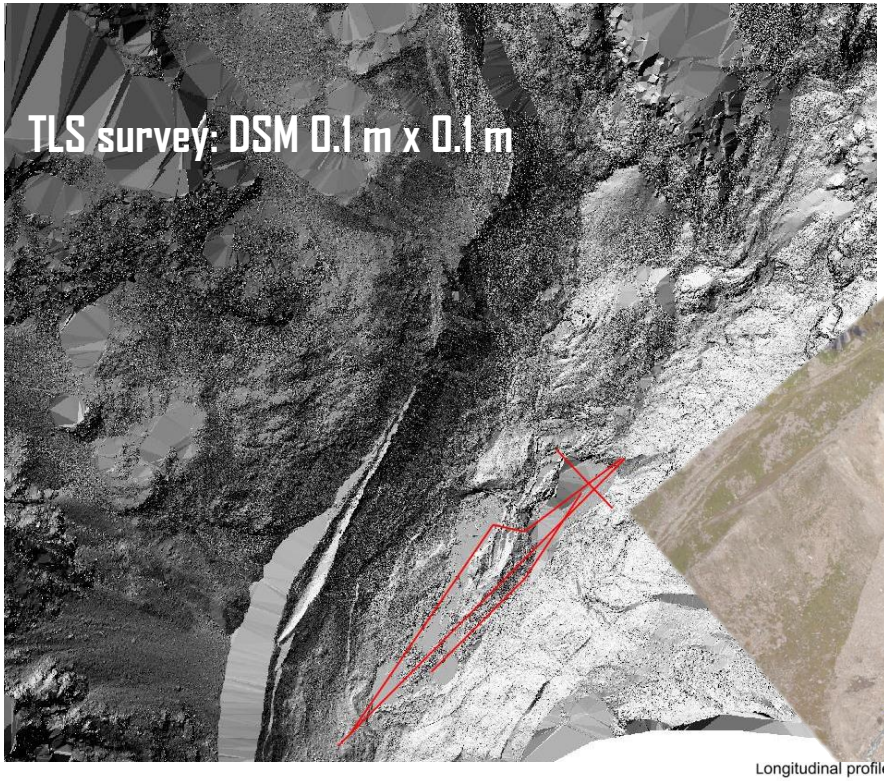
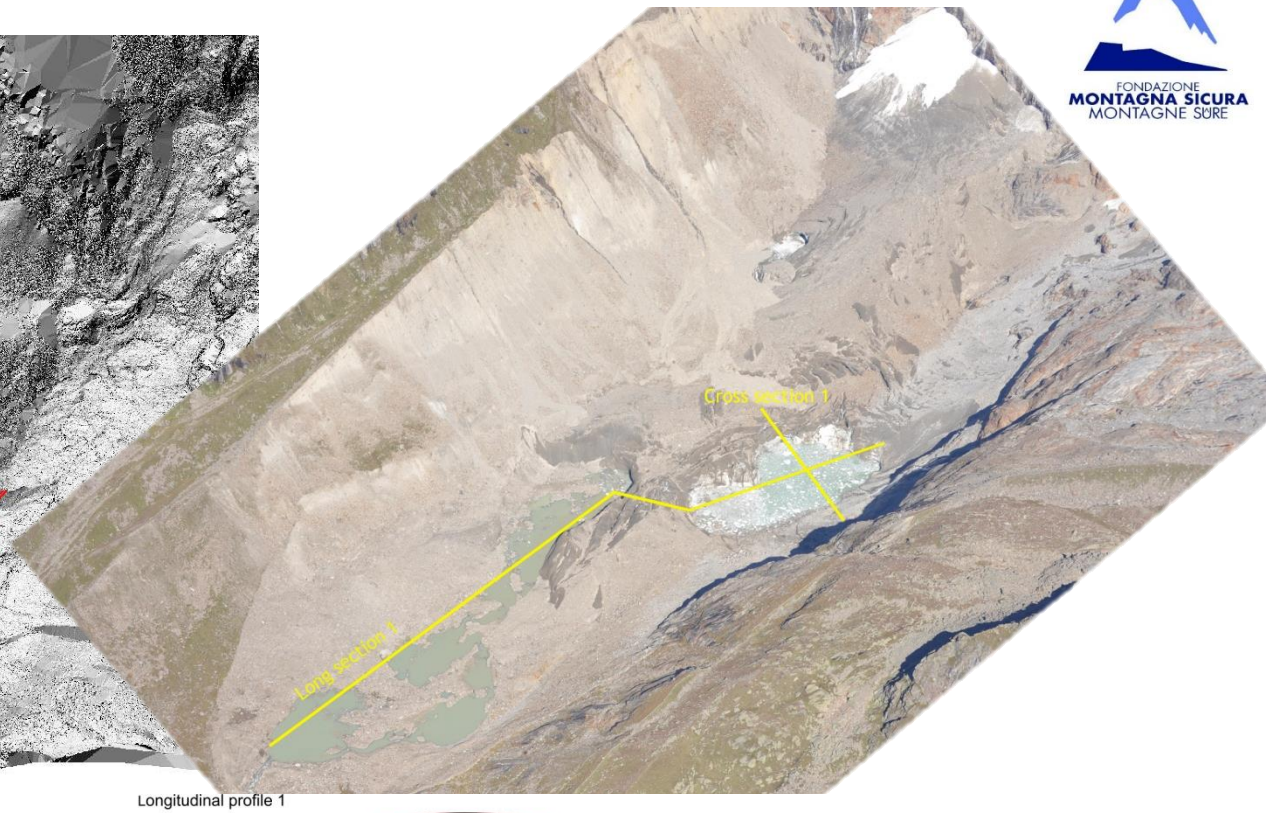
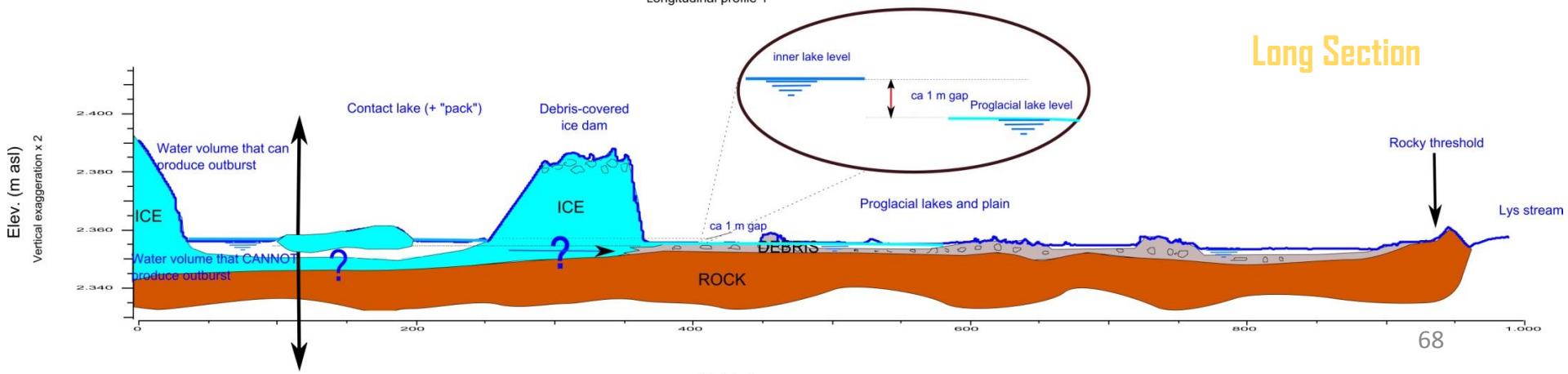
GLACIAL RISK LYS

FONDAZIONE MONTAGNA SICURA
MONTAGNE SÛRE





Longitudinal profile 1



Conclusion

Terrain analysis → environmental phenomena & natural instability

GIS techniques → spatialize data

TLS and Drone → integrated and fast

High resolute models → evaluation of natural dynamic phenomena

Photogrammetric models → volume evaluation and mass balance

POLITECNICO DI TORINO

Acknowledgement

Région Autonome
Vallée d'Aoste
Regione Autonoma
Valle d'Aosta

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DIATI
Department of Environment, Land
and Infrastructure Engineering

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DIATI
Department of Environment, Land and Infrastructure Engineering

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