MOUNTAIN HYDROLOGY

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Ph.D. in Earth Science (University of Grenoble, France)

Teaching Watershed Management

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Main research interests

Modeling :

- effects of climate change on water cycle

(coordinating a national project with climatologists, statistics and groundwater experts)

Monitoring :

- soil moisture
- water fluxes out and into the soil
- snow density and wetness

(trying to patent and build some new tools)

Traditionally one thinks about HYDROLOGY as:

- Water balance
- Computation of water fluxes
- Computation of stream discharges

… and HYDRAULICS ?

- How the discharge moves
- What velocity values
- What water height values

DISCHARGE is volume per unit time

- 1 cubic meter per second or 1000 liter per second
- 10 cubic meters per second

STATIC HYDROLOGY

World Freshwater Quantities (2.5 % of total water)

68.6 %
polar ice

30.1 %
groundwater

1.0 %
other ice and snow 340,000 km^3

0.26% 91,000 km^3
lakes

0.05 %
soil moisture

0.04 %
atmospheric water

0.03 %
marshes

0.006 %
rivers

0.003 %
biological water

DYNAMIC HYDROLOGY (Eagleson book 1980s)

There are some indications of an accelerating hydrological cycle in several regions of the Earth.

In general, the evaluation of the dynamics of mass and energy exchanges is crucial in understanding climate related issues.

We need to use the millimeter depth as a unit OF VOLUME

20 mm/hour rainfall

800 mm/year

5 mm/day evapotranspiration

Mass conservation

500-hectare reservoir

Compute the average outflow during a 30-day period

What do I need?

- 0.5 meter drop or 500 mm
- 200,000 cubic meters per day average inflow
- 20 mm seepage loss
- 85 mm evaporation
- 105 mm rainfall

- As an average annual value, the residence time of water in soil can be evaluated as the ratio between the average soil water content range and the annual precipitation.

- The planetary approximations for the two terms are, respectively, 50 mm and 800 mm, leading to an estimate of the average residence time of 23 days, if we disregard the evaporation of intercepted rain and the overland flow.

- Hydrology was officially born in 1965 in the US as a professionel division

- But at the beginning of the XX century Eredia, living in Catania (Sicily) and others mounted a monitoring system (end of May 2008 few days of intense rain valle d'Aosta 35,000,000 euro in few days of intense rain)

Highest rainfall depths in the year, with a duration of:

- 1 hour
- 3 hours
- 6 hours
- 12 hours
- 24 hours

There is a relation between :

RAINFALL DURATION

And

WATERSHED AREA

Sauze di Cesana

(Susa Valley, Piemonte)

30 May 2008

These pictures can be taken everywhere in the Alps, where management has not been FLEXIBLE

- It was possible to calculate rainfall – runoff transformation by Rational method

- A= 5 km2
- L= 3000 m
- ia = 0.02
- C = 0.5
- T = 20 years
- h= 35 t ^ 0.3
- tc(hours)=0.000325 (L/ia^0.5)^0.77
- hc(mm) = 35 tc ^ 0.386
- Q =C hc A /3.6 / tc=30.3 m3/s

In 1932 Sherman invented the UNIT HYDROGRAPH

In 1972 USDA created the SCS-CN method by small scale experiments

- h=50 mm in 1 hour
- A=5 km2
- L=2 km
- iv=0.15
- B group soil
- Wood land use
- AMC II (between 13 and 28 mm rain)
- CN=60

- The planetary approximations for the two terms are, respectively, 40 mm and 800+1270 mm, leading to an estimate of the average residence time of atmospheric moisture of 7 days (one of the reasons why weather cannot be forecasted accurately more than a few days ahead).

- S =25.4(1000/CN-10)=169.3 mm
- V = (50-0.2 S)^2/(50+0.8 S) =1.4 mm
- tc = 0.342 L^0.8/15^.5(1000/CN-9)^0.7
  =0.64 hours
- ta =1/2 + tc =1.14 hours
- Q =0.208 V A /ta =1.29 m3/s

tc(hours)=2.4
hc(mm) = 35 tc ^ 0.3=45.5
Q =C hc A /3.6 / tc=1.29 m3/s
C=0.05

C values

	crops	pasture	wood
Very permeable soil	0.20	0.15	0.10
Medium permeability	0.40	0.35	0.30
Low permeability or shallow bedrock	0.50	0.45	0.40

Then hydrology started using the tools of experimental hydraulics, both open air and closed in the soil.

- Bernoulli found how WATER ENERGY transforms itself

$$z + p/\gamma + v^2/2/g$$

We need to use the meter height as a unit OF HEAD

POTENTIAL HEAD

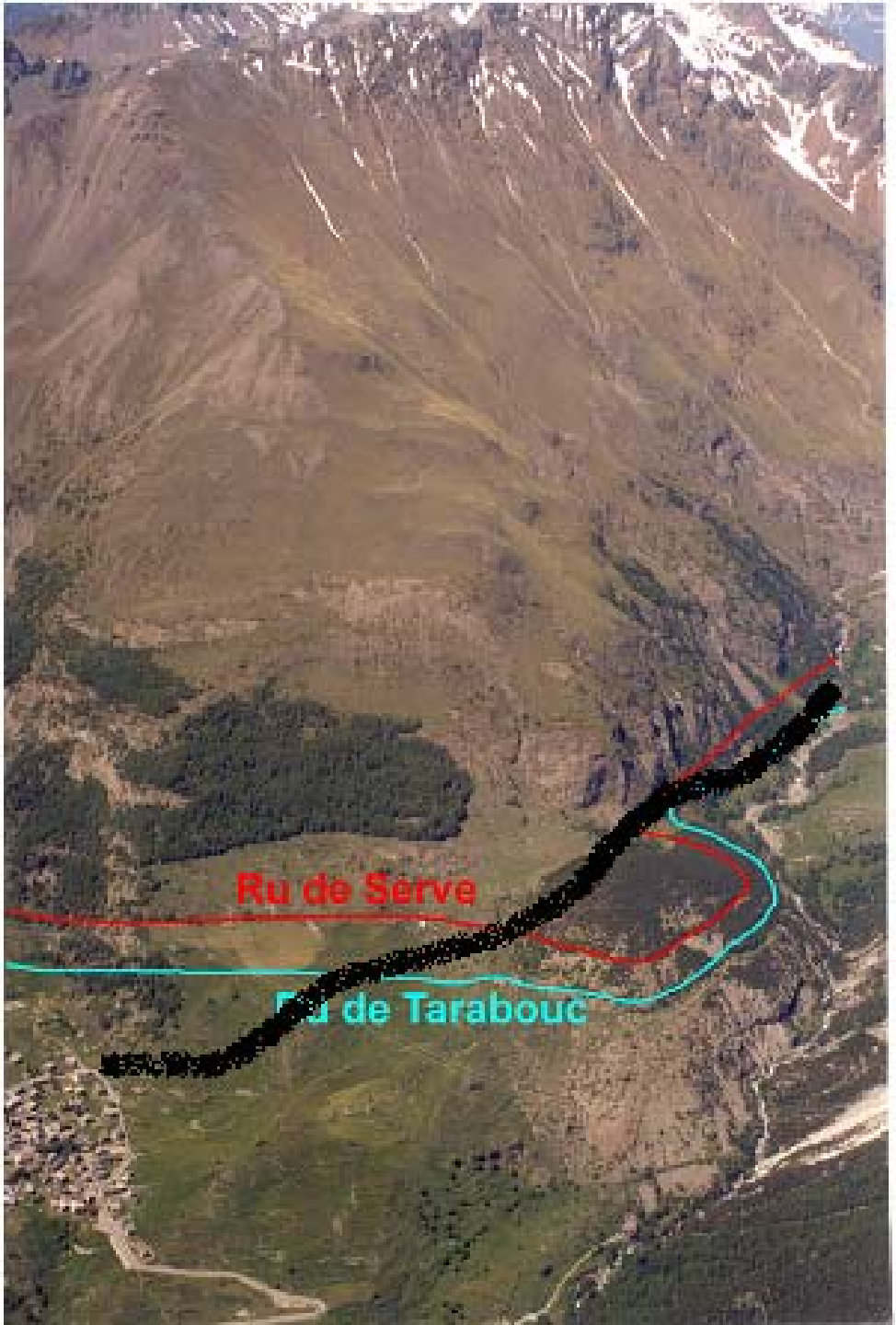
360 meters fall in a mountain hydroelectric plant

0.5 meter to move water in soil

0 meter to make water jump down a step

Hydroelectric plants

- 360 m
- 1.1 m^3/s
- 9810 N/m^3
- 9810*1.1*360*0.8 = 3.1 MW


Ru de Serve
Ru de Tarabouc

In the 18th century Chezy provided the way to easily calculate STREAM DISCHARGE

$Q = 1/n \, R^{2/3} \, i^{0.5} \, A$

- Hydraulic radius
- Manning roughness coefficient

Manning roughness:

Stream

- Winding with weeds and pools 0.050
- Heavy brush and timber 0.100

Hillslope

- Pasture 0.035
- Dense brush 0.070

- I can estimate peak discharge through HYDRAULIC calculations.

…and what about soil and groundwater, the hidden half ?

- Poiseuille (1839) formulated the capillary flow
- Darcy (1856) provided us a phenomenological law

- $Q=k\, dh/dz\, A$

(after 152 years we have not yet found how:

1. Theoretically to demonstrate it
2. To upscale at the practical scale)

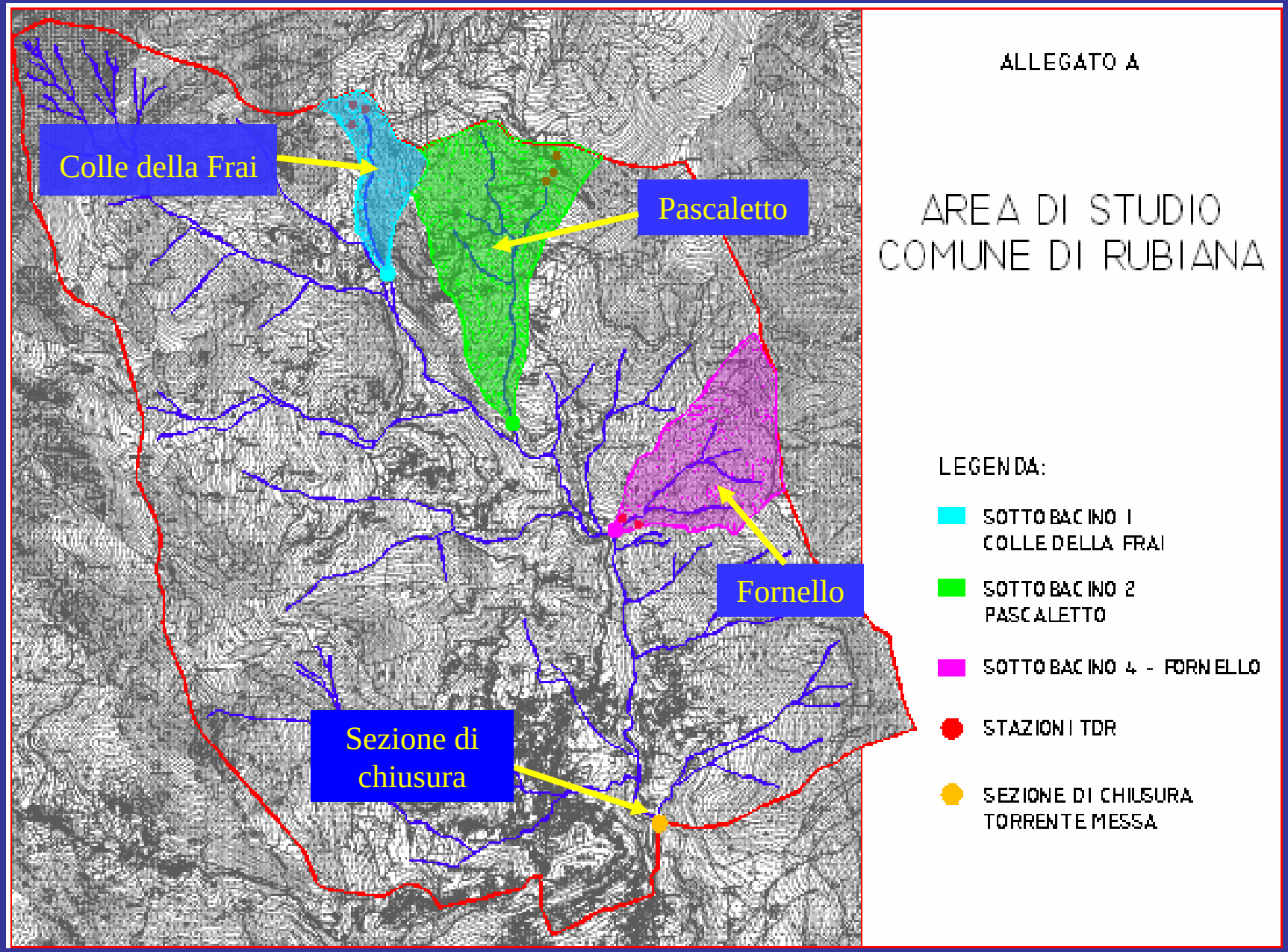
Università degli Studi di Torino
Facoltà di Agraria
Corso di laurea in Difesa del Suolo e Manutenzione Forestale del Territorio
a.a. 2006 / 2007

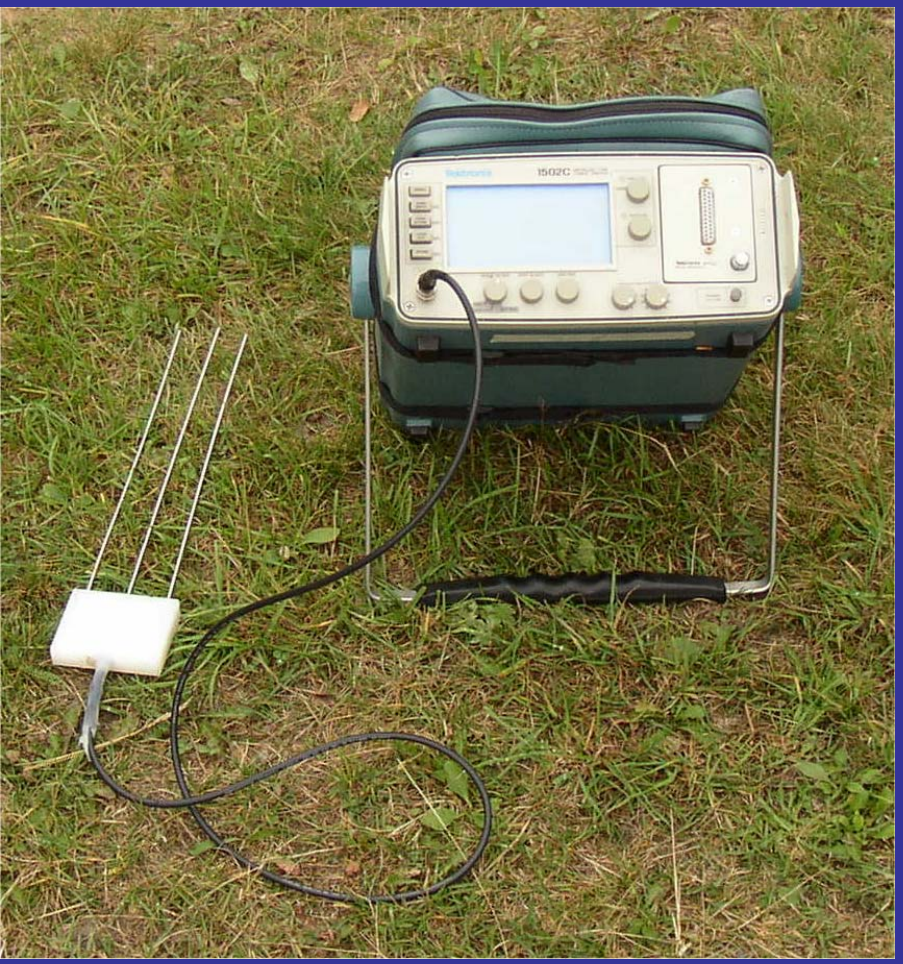
VALUTAZIONE SPERIMENTALE DEL BILANCIO IDRICO DEL TERRITORIO A MONTE DELL'ABITATO DI RUBIANA (TO)

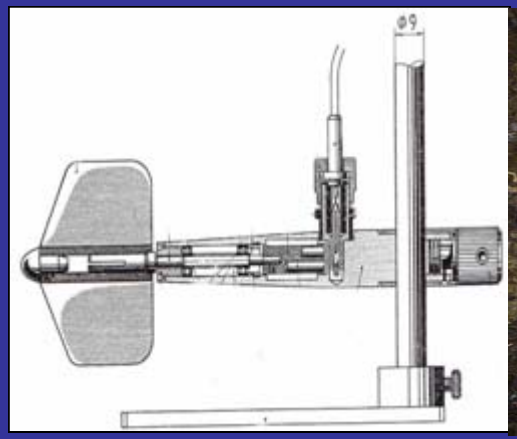
Candidato : Gianluca Stoppa

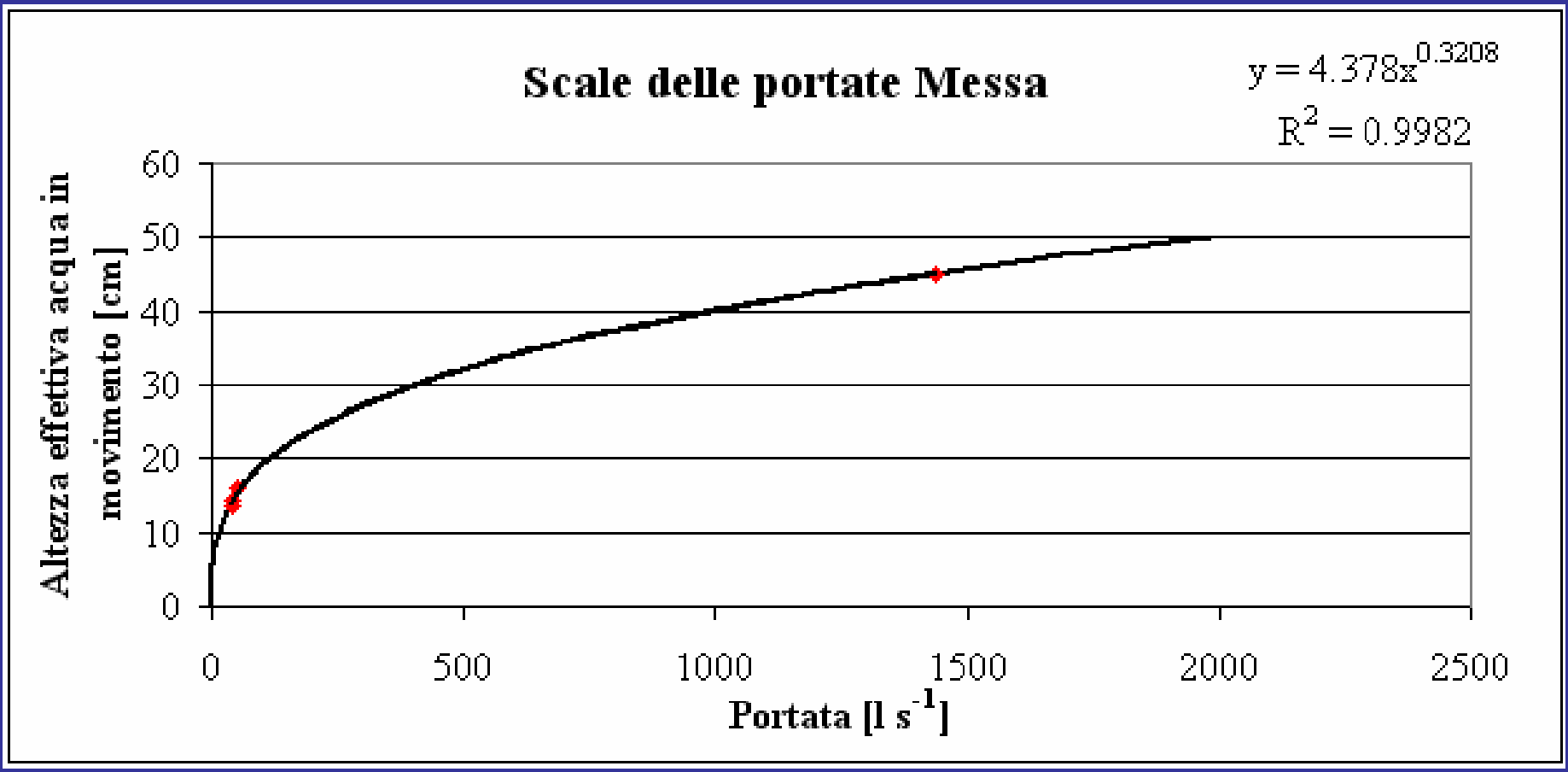
Relatore: Prof. Stefano Ferraris

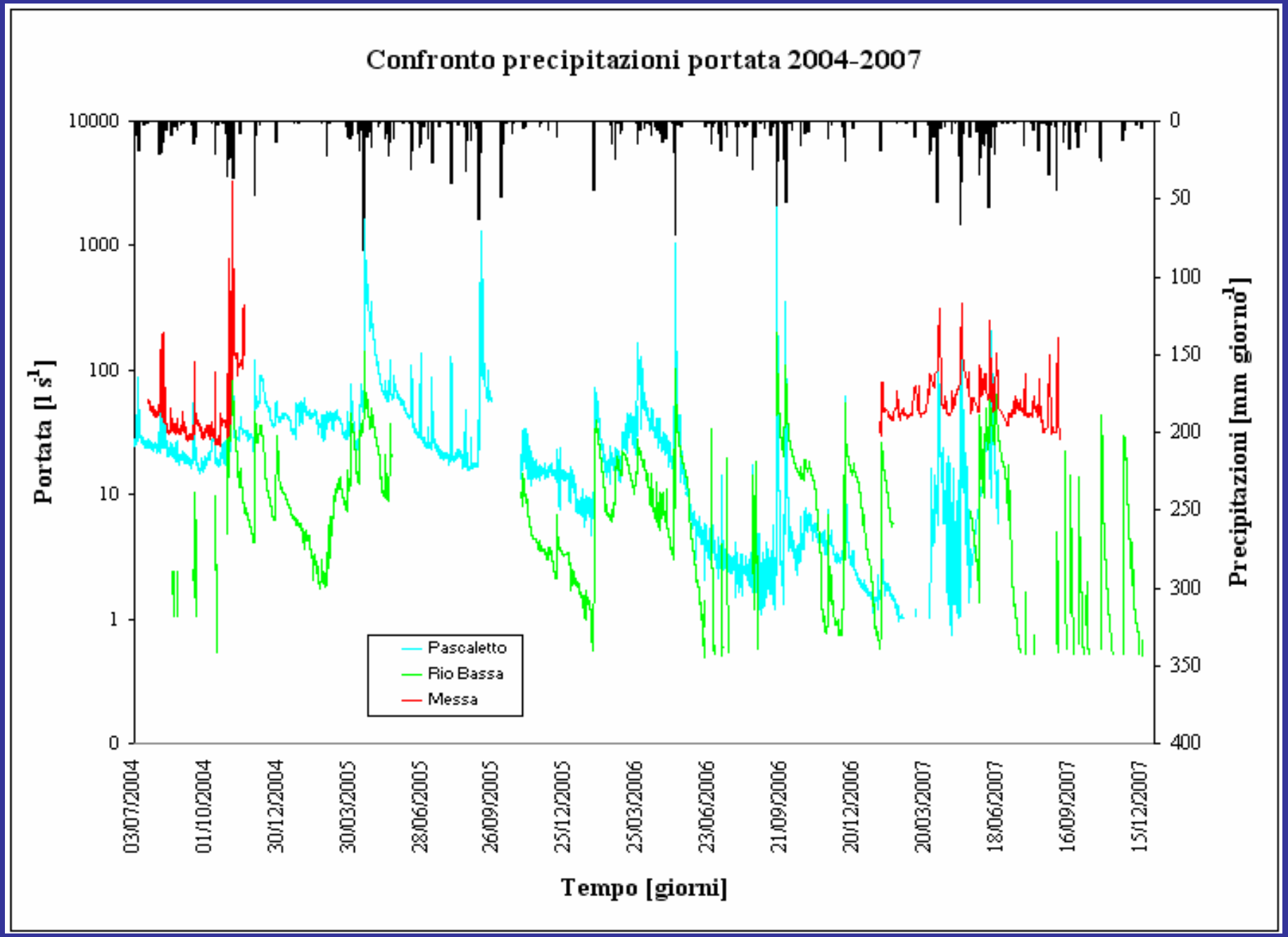
Bacino idrografico oggetto di studio:



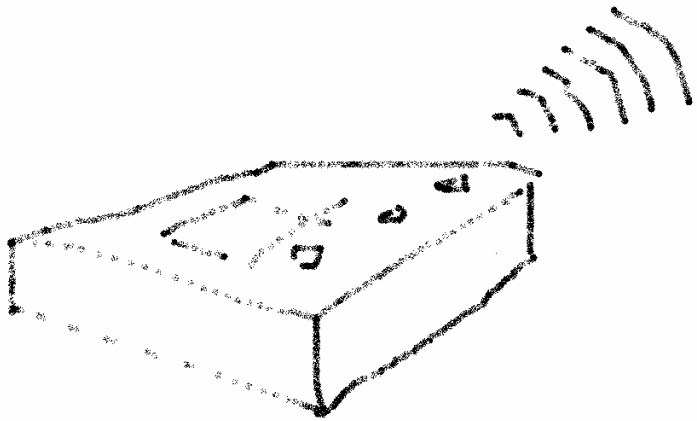

Tektronix
1502C

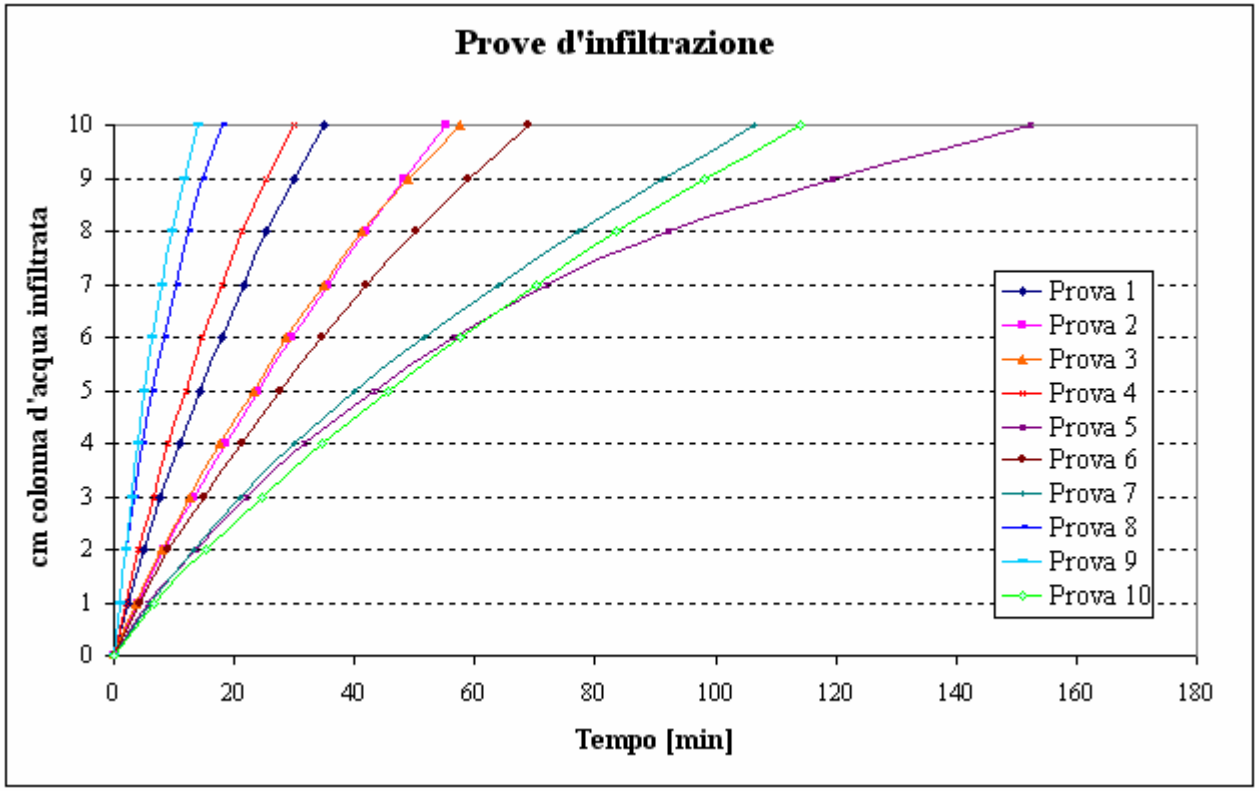


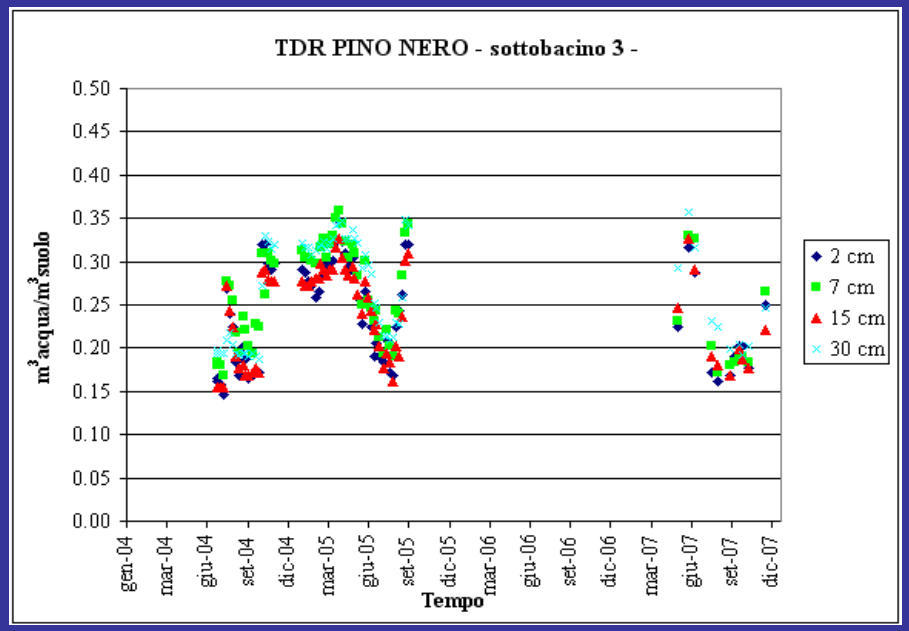


Scale delle portate Messa
y = 4.378x^0.3208
R^2 = 0.9982
Altezza effettiva acqua in movimento [cm]
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
Portata [l s^-1]


Confronto precipitazioni portata 2004-2007
Portata [l s-1]
Precipitazioni [mm giorno-1]
Tempo [giorni]
10000
1000
100
10
1
0
0
50
100
150
200
250
300
350
400
03/07/2004
01/10/2004
30/12/2004
30/03/2005
28/06/2005
26/09/2005
25/12/2005
25/03/2006
23/06/2006
21/09/2006
20/12/2006
20/03/2007
18/06/2007
16/09/2007
15/12/2007
Pascaletto
Rio Bassa
Messa

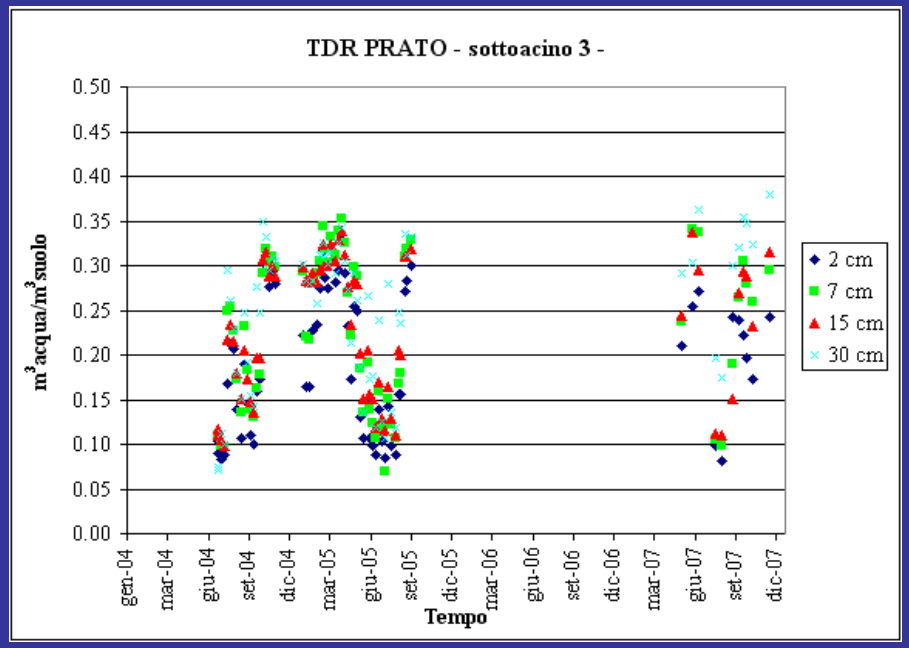
infiltrometer

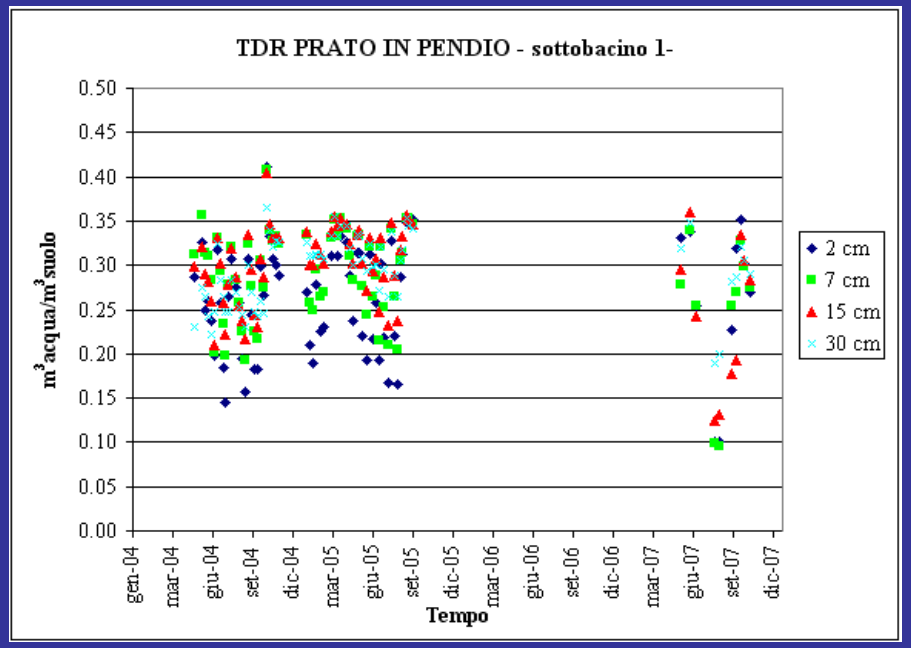






Soil Water Content in different land use cases (and litter is not soil !!)





I add:

We should need the same level of knowledge of:

- The space between the Earth and Mars
- The pillars of motorways
- The blood circulation in our body

In March 2008 a users/stakeholders workshop was held in Canada regarding mountain hydrology.

They stated that more monitoring is required for :

- Stream discharge and temperature
- Solar radiation
- Groundwater level
- Snowpack and snow melting

In New Mexico they ask for more sensors measuring in remote sites:

- Snowfall
- Snowmelt
- Rainfall
- Evapotranspiration
- Soil moisture
- Runoff

- …and decison support models.

Discharge – depth relations of gage sections

Valle Maira,
Cuneo County

(in general few raingages out of the valleys)

Clogging of rain gages

Groundwater data in the mountains are lacking

Cogne,
Aosta Valley

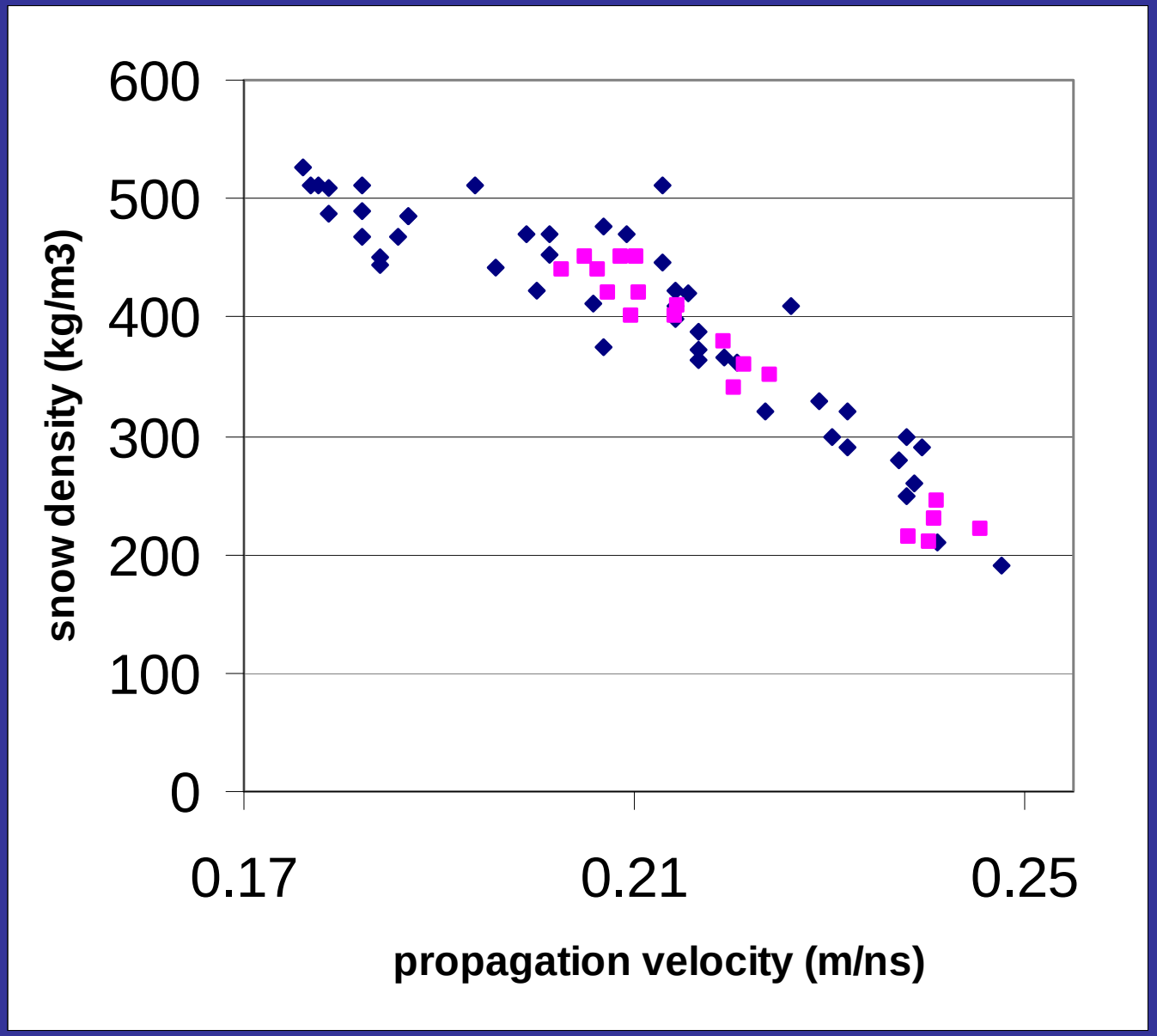
Lake level to monitor springs

Few solar radiation sensors (expecially longwave ones give problems)

Wireless TDR sensors for soil moisture, snow density and snow wetness

TDR (Time Domain Reflectometer)

Reflectometer density measurements

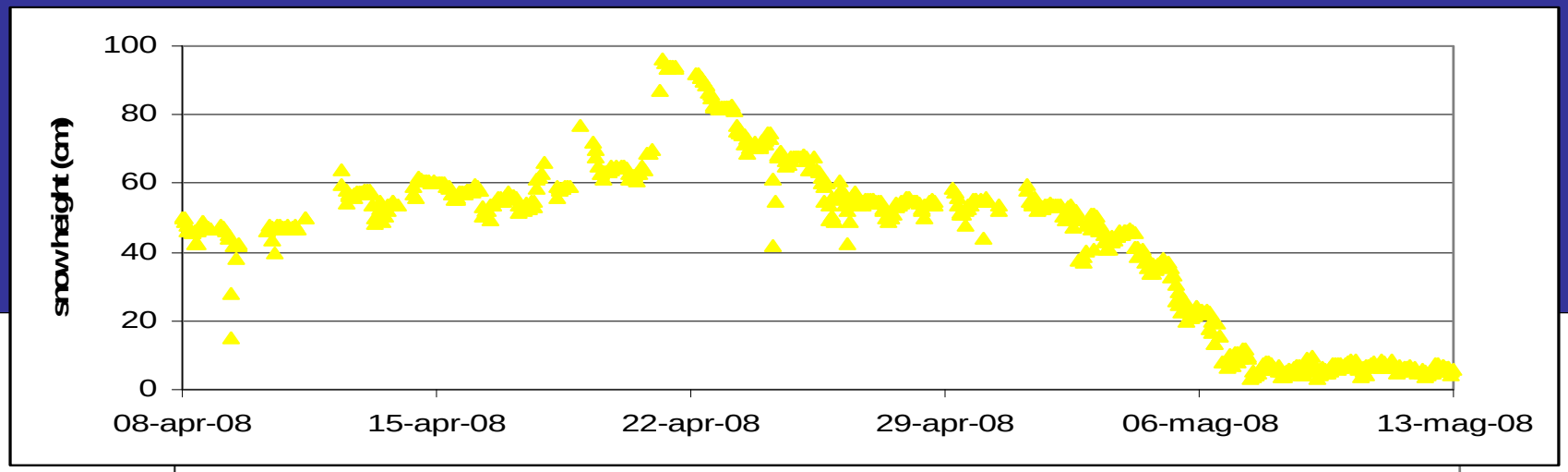


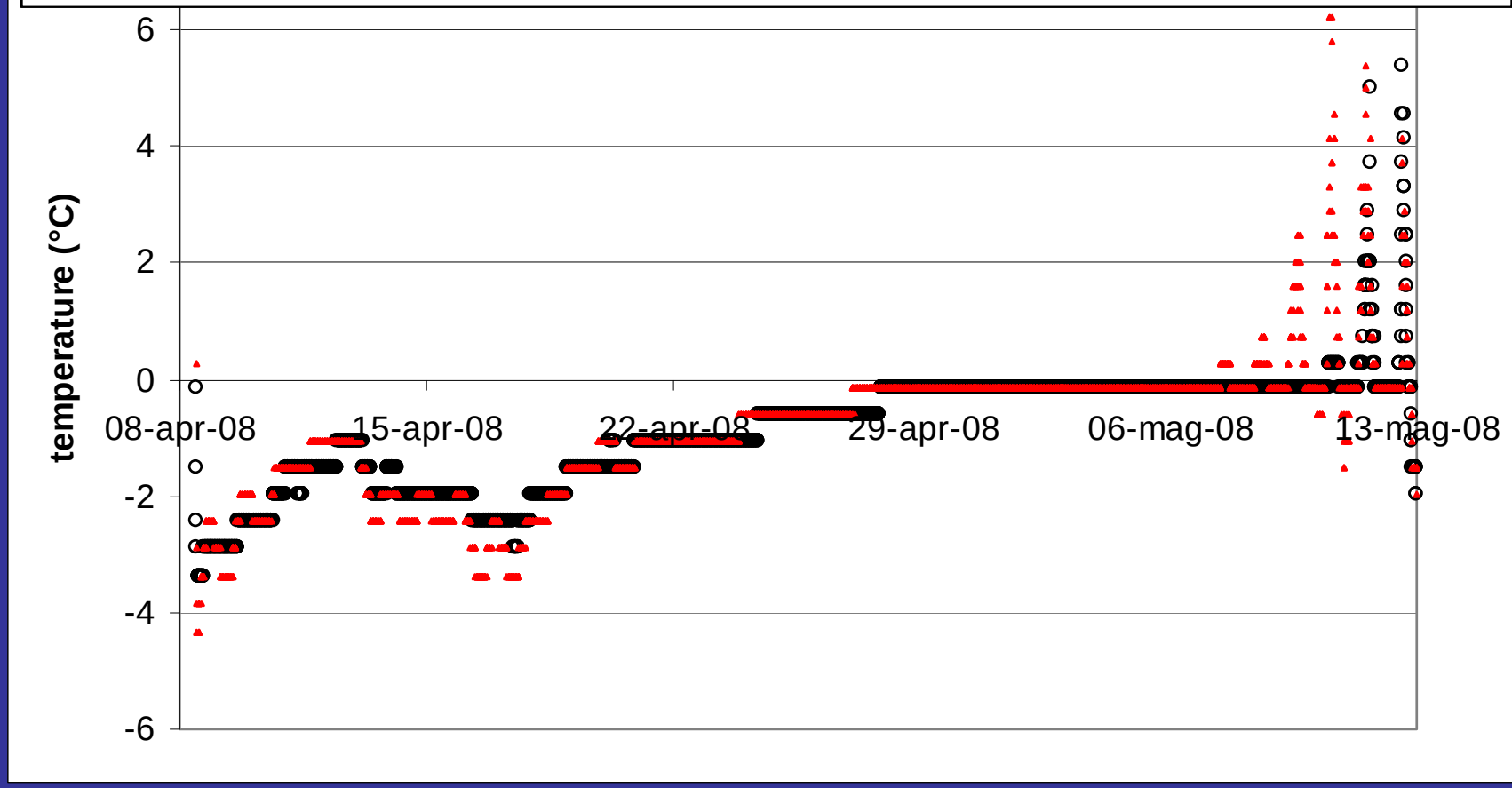
Snowmelt is a complex process

- Winter 2006-2007 had small snow and high temperatures, two resons for low discharges beginning of spring.
- Also winter 2007-2008 small frost, so lower spring discharges.
- Probably in the future in the Alps higher discharges in winter and lower in the beginning of spring

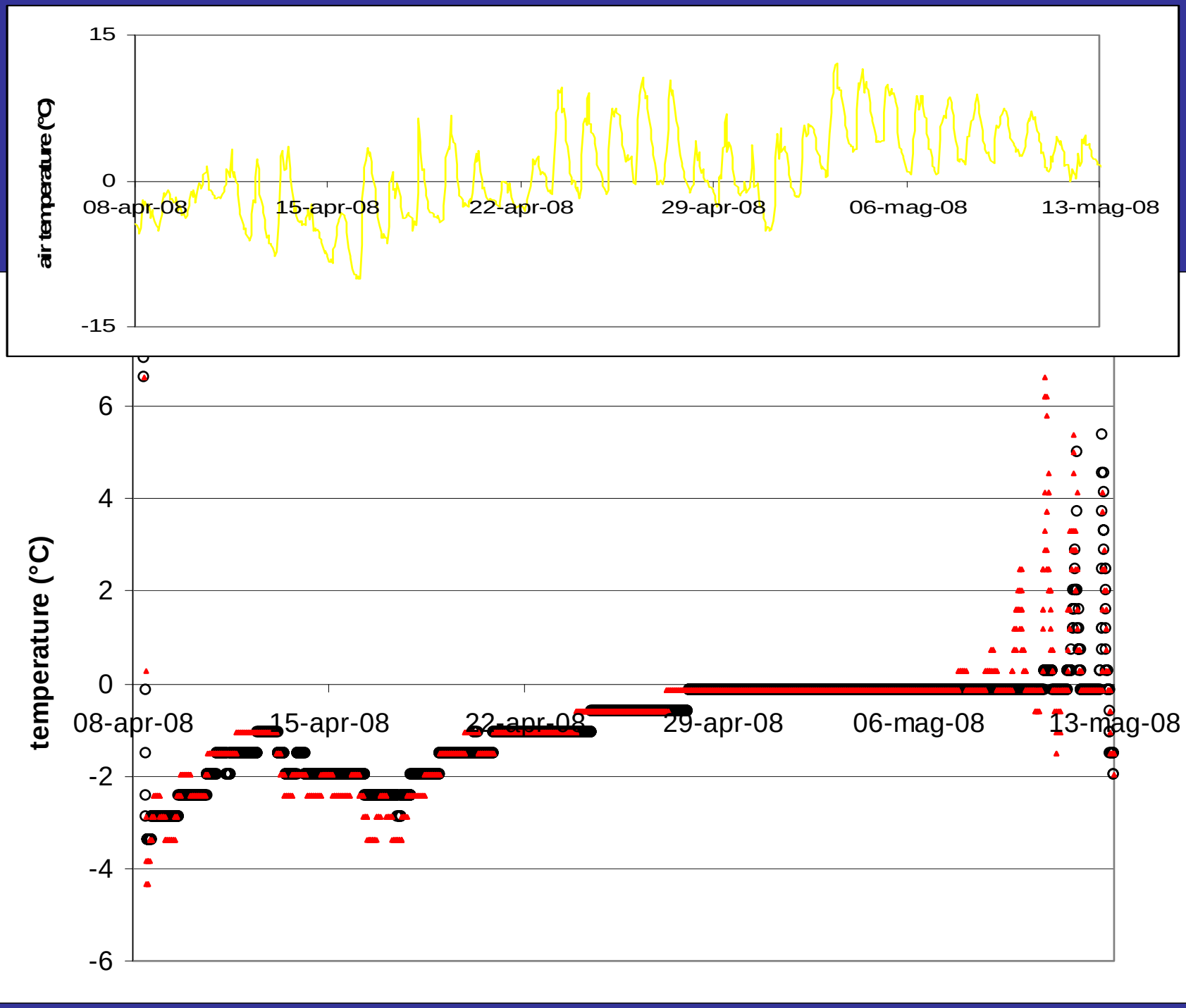
- MODIS overestimate snowcover and albedo because snowcover is generally not continuous at the 500 m scale.

- Ground truth is necessary for snow under trees


snowheight (cm)
100
80
60
40
20
0
08-apr-08
15-apr-08
22-apr-08
29-apr-08
06-mag-08
13-mag-08


temperature (°C)
6
4
2
0
-2
-4
-6
08-apr-08
15-apr-08
22-apr-08
29-apr-08
06-mag-08
13-mag-08

6 May 2008


air temperature (°C)
15
0
-15
08-apr-08
15-apr-08
22-apr-08
29-apr-08
06-mag-08
13-mag-08
temperature (°C)
6
4
2
0
-2
-4
-6
08-apr-08
15-apr-08
22-apr-08
29-apr-08
06-mag-08
13-mag-08

Four soundings at 0 and 12 hours

- The number of days with a snow depth above a certain threshold is the key factor for winter tourism in an Alpine country like Switzerland.
- unprecedented series of low snow winters in the last 20 years.
- This abrupt change resulted in a loss of 20% to 60% of the total snow days.

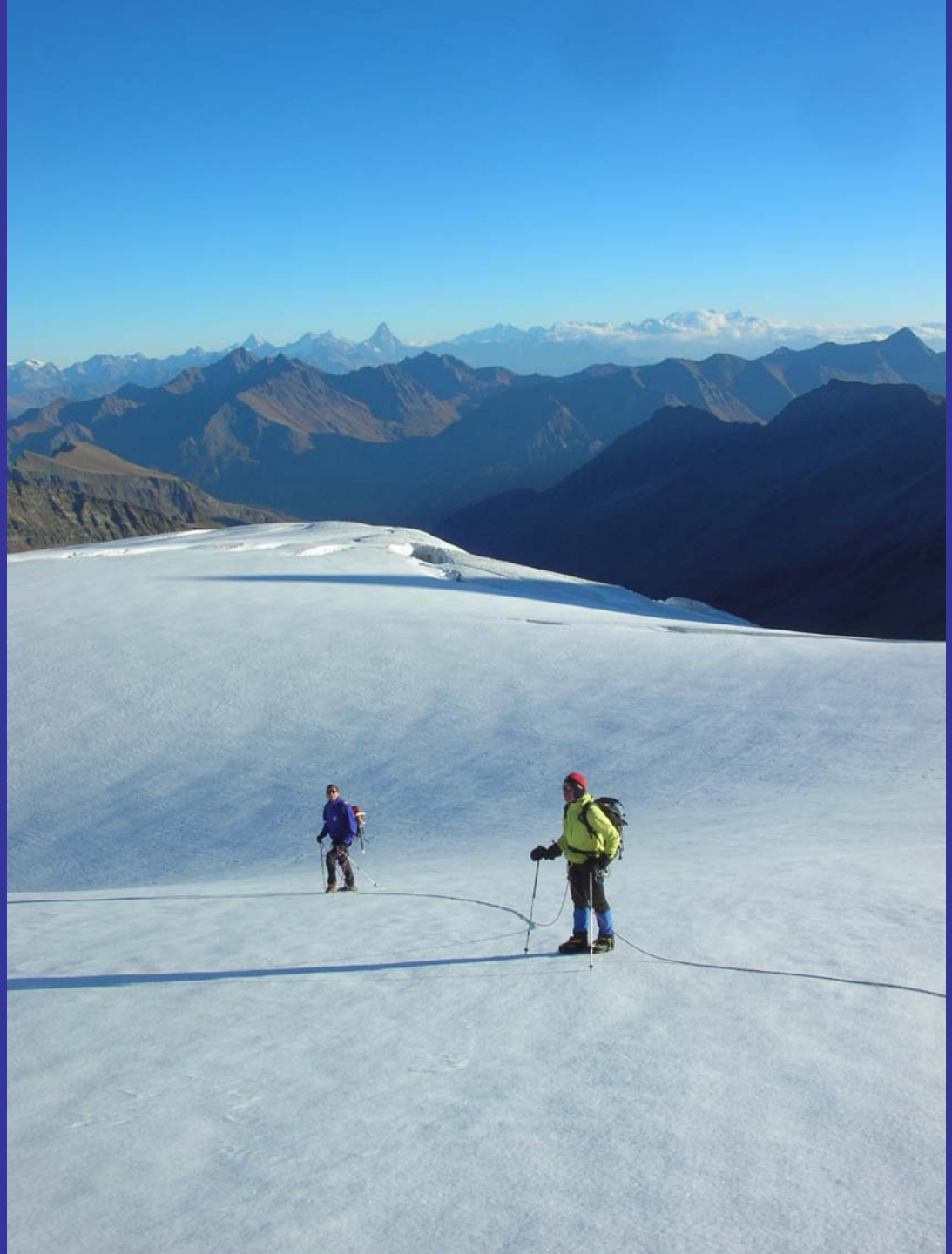
- Analysis of data from Italy, Austria, Germany and France indicates that similar patterns are to be found elsewhere in Europe,

if in the future the precipitations no longer fall as snow there is a higher probability of floods in the winter - and that is what climate models are also forecasting.

- The average number of snow days over the last 20 winters is lower than at any time since records began more than 100 years ago.

- In Switzerland banks are refusing to offer loans to resorts under 1,500 metres as they fear for their future snow cover.

Tribolazione Glacier, Valnontey



Today's end…