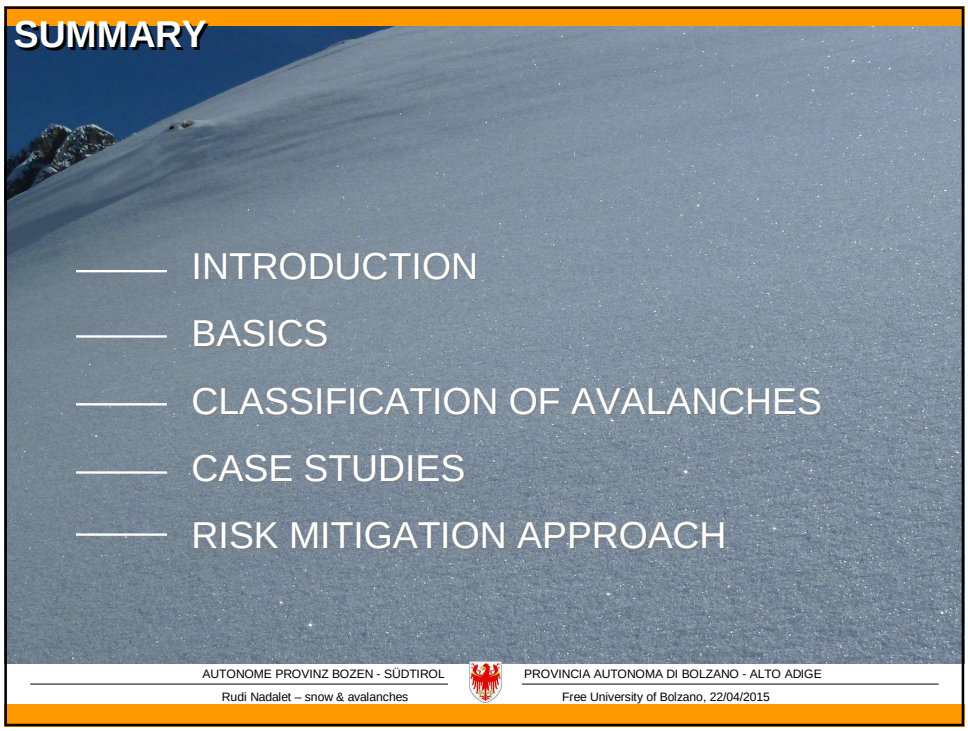

AUTONOME PROVINZ BOZEN - SÜDTIROL
Abteilung 26 – Brand- und Zivilschutz
Hydrographisches Amt
PROVINCIA AUTONOMA DI BOLZANO - ALTO ADIGE
Ripartizione 26 – Protezione antincendi e civile
Ufficio idrografico
SNOW & AVALANCHES
Rudi Nadalet


SUMMARY
INTRODUCTION
BASICS
CLASSIFICATION OF AVALANCHES
CASE STUDIES
RISK MITIGATION APPROACH
AUTONOME PROVINZ BOZEN - SÜDTIROL
Rudi Nadalet – snow & avalanches
PROVINCIA AUTONOMA DI BOLZANO - ALTO ADIGE
Free University of Bolzano, 22/04/2015

INTRODUCTION

INTRODUCTION

Video Pill Lawine

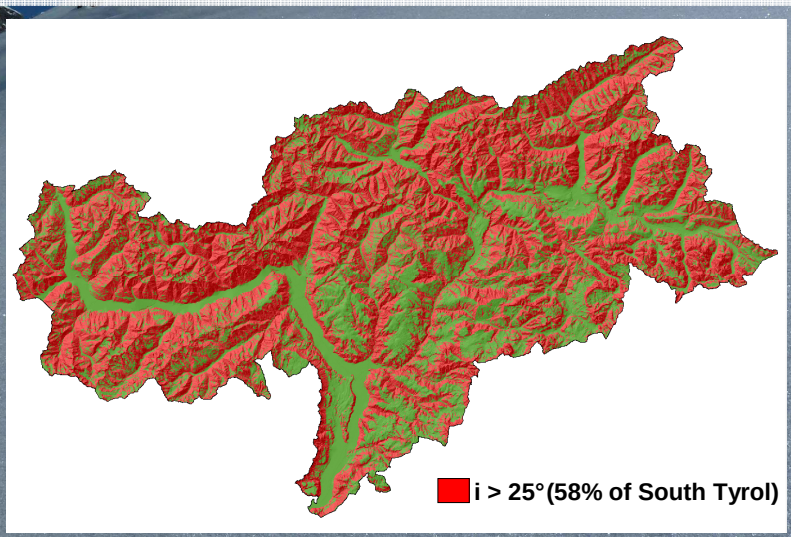
BASICS

Definition:

Avalanche = a rapidly moving snow mass
with volume > 100 m³ and length ≥ 50 m (from EAWS glossary)

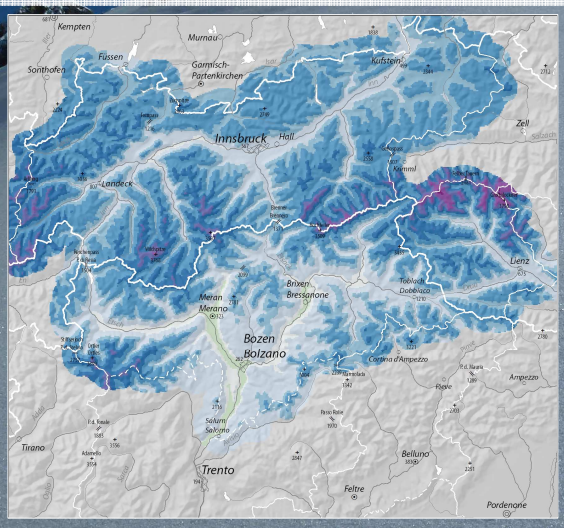
BASICS

Mountain region

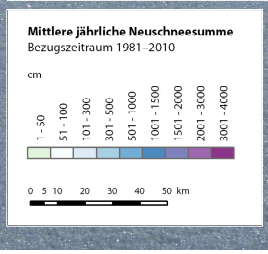


BASICS

Amount of fresh fallen snow (HN) = amount of daily snowfall

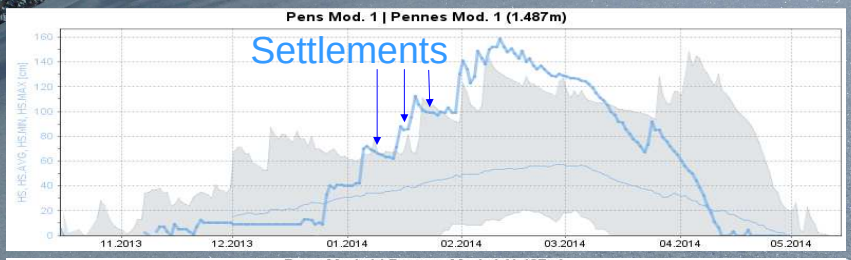


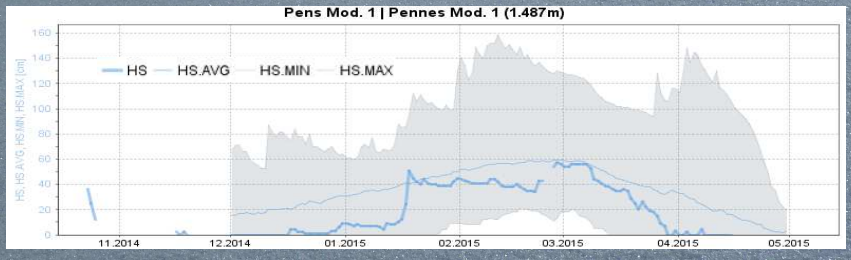
Mean yearly amount for the period 1981-2010



BASICS

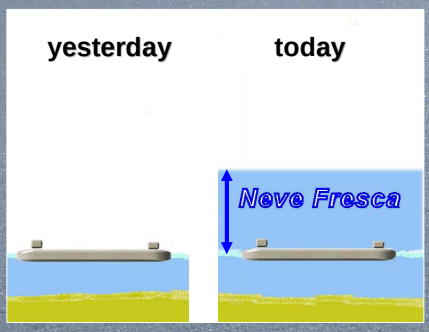
Snow depth (HS) = the measurement from snow surface to ground level





BASICS

Measurement of fresh fallen snow (by observer)



Snow measurement board

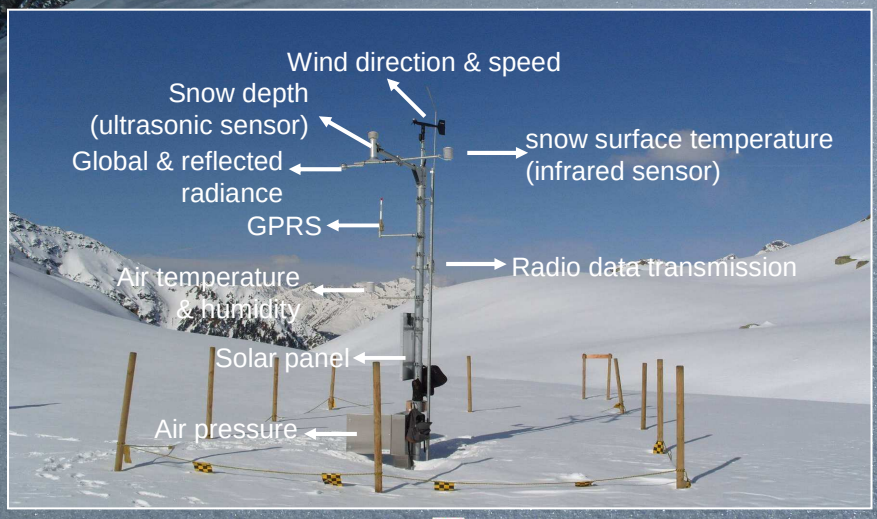
BASICS

Measurement of snow depth (by observer)

Snow measurement stick

BASICS

Measurement of snow depth (by automatic stations)

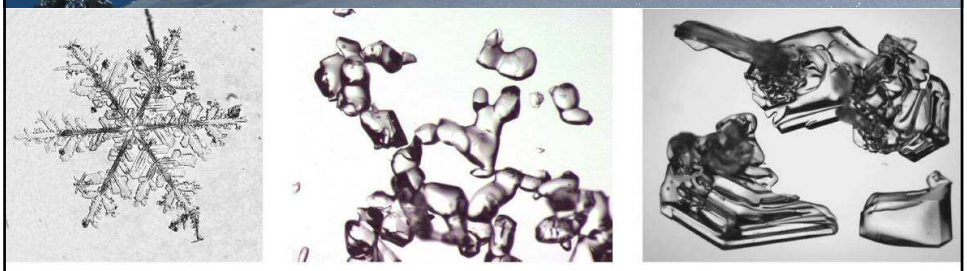


BASICS

Properties of snow

BASICS

Winter snowpack evolution



(a) (b) (c)

Figure 1.1: (a) Typical hexagonal snow flake, 1 mm in diameter. (b) Small rounded grains, 0.25-0.5 mm. (c) Depth hoar, 1-2 mm, (Pictures: archive SLF).

The appearance of snow lying on the ground is completely different from the well known hexagonal shape of a snow flake.

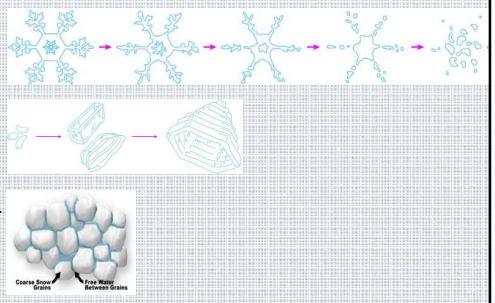
BASICS

Winter snowpack evolution

Metamorphism changes the shape and the size of the grains.

Metamorphism processes:

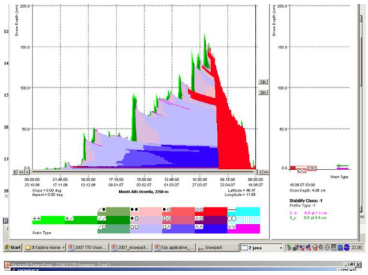
- Destructive metamorphism →
- Constructive metamorphism →
- Melt metamorphism →



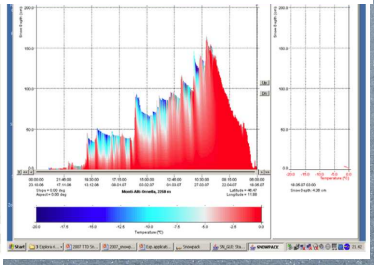
BASICS

Winter snowpack evolution

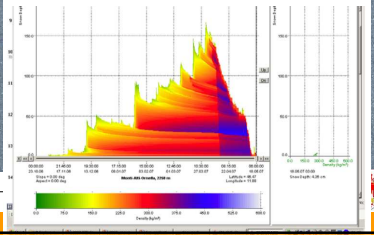
Snow profile



Temperature



Density



BASICS

Mechanical properties of snow

Table 1.1: Snow compared to other porous materials. Data from Gibson and Ashby (1997).

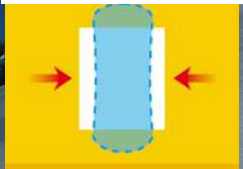
Material	Density ρ (kg/m^3)	Relative density ρ/ρ_{solid}	Porosity	Tensile strength σ_c (kPa)
Snow	50–550	0.05–0.60	40%–95%	0.5–200
Wood	200–750	0.13–0.50	50%–87%	70'000–100'000

Firn	600-830
Pure ice	917

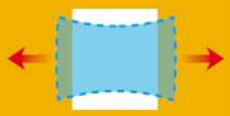
BASICS

Mechanical properties of snow

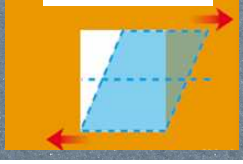
Compressive forces



Tensile forces



Shear forces



- Compressive strenght

- Tensile strenght = ca. 1/10 of comp.st.

- Shear strenght *f*(layer properties)

BASICS

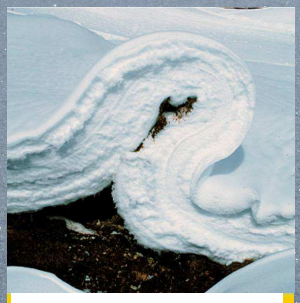
Behaviour of snow under loading

For <u>slow loading</u>

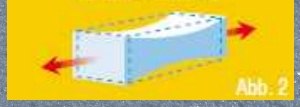
snow behaves ductile

e.g.

- successive snowfalls of low intensity
- slight rainfall
- slow warming



Viscoelastic material



BASICS

Behaviour of snow under loading

For <u>fast loading</u>

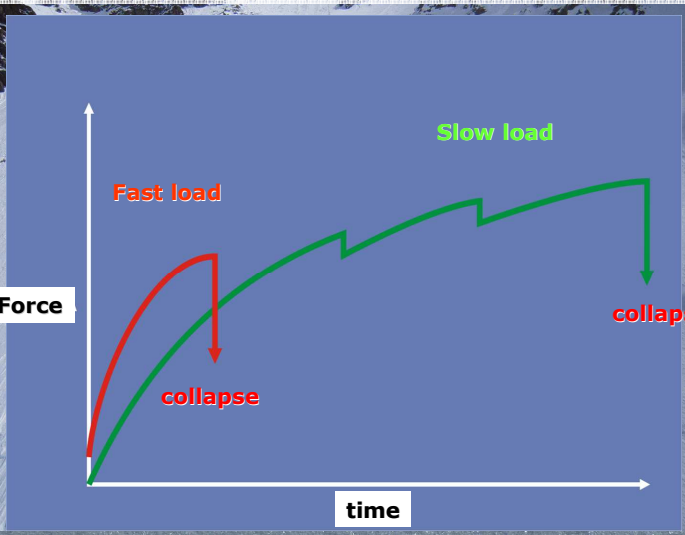
snow behaves brittle

e.g.

- skier as an additional load
- explosives

BASICS

Behaviour of snow under loading

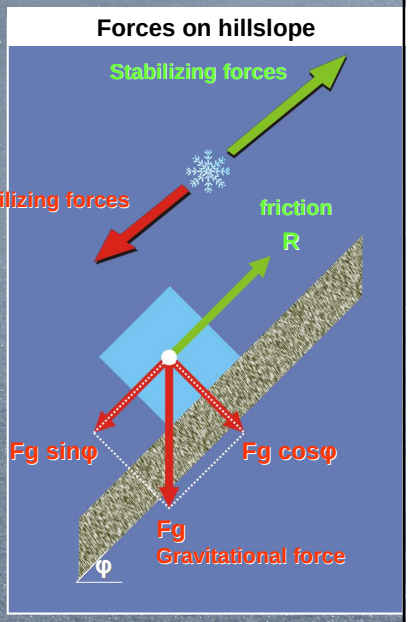


BASICS

Triggering mechanisms

What can happen?

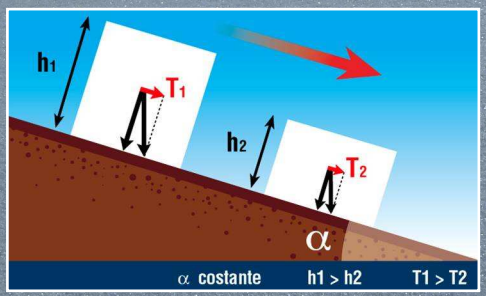
1. Destabilizing forces increase
2. Stabilizing forces decrease
3. Combination of both effects



BASICS

Triggering mechanisms

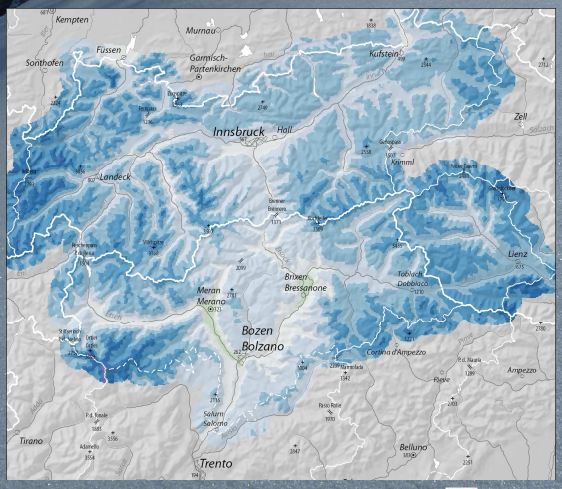
1. Destabilizing forces increase
   e.g. increase of snow weight



BASICS

Triggering mechanisms

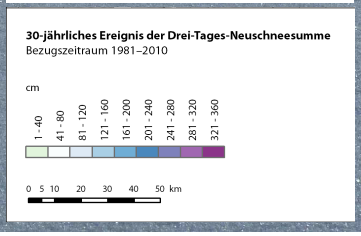
e.g. increase of snow weight



Amount of fresh fallen snow (HN_{3days})

= amount of daily snowfall deposited over 3 days

T_R = 30 Years



BASICS

Triggering mechanisms

1. Destabilizing forces increase
   e.g. using artificial avalanche release techniques

BASICS

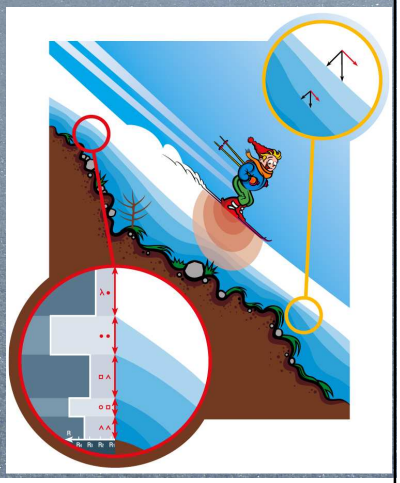
Triggering mechanisms

Video Sella Nevea

BASICS

Triggering mechanisms

1. Destabilizing forces increase
   e.g. additional load through skier



BASICS

Triggering mechanisms

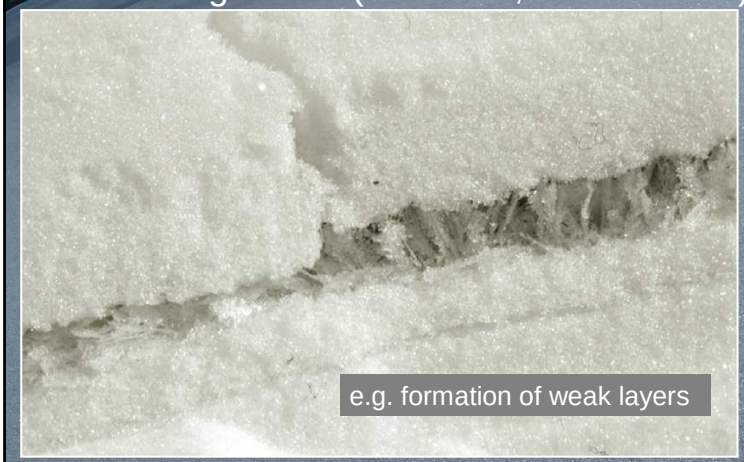
2. Stabilizing forces (cohesion, friction force) decrease

e.g. effect of solar radiation on fresh snow

BASICS

Triggering mechanisms

2. Stabilizing forces (cohesion, friction force) decrease



e.g. formation of weak layers

BASICS

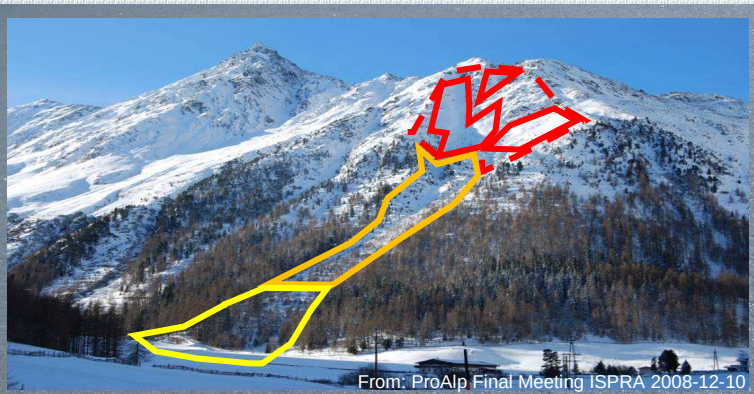
Triggering mechanisms

Video rusty

CLASSIFICATION

Parts of an avalanche:

- Starting zone with potential release areas - initiation
- Transit zone or track - motion
- Run out and deposition zone - deposition

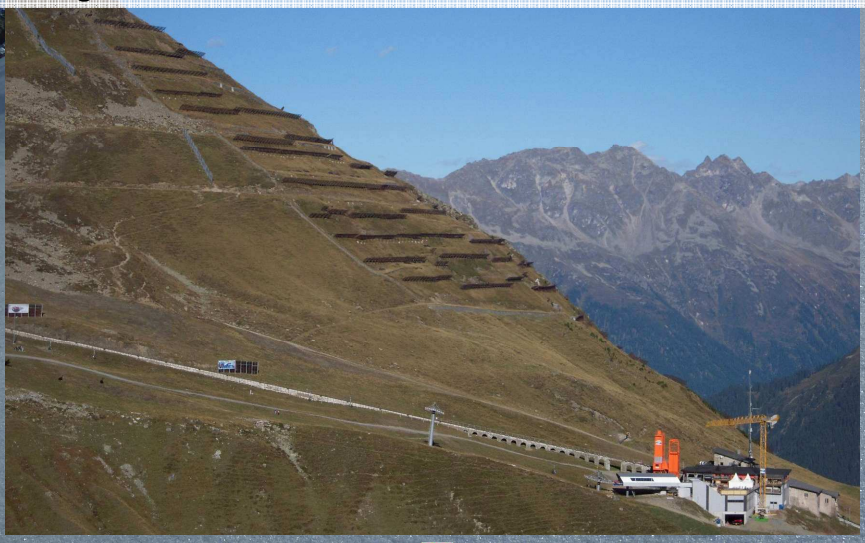


CLASSIFICATION

Starting zone

CLASSIFICATION

Starting zone



AUTONOME PROVINZ BOZEN - SÜDTIROL
PROVINCIA AUTONOMA DI BOLZANO - ALTO ADIGE
Rudi Nadalet – snow & avalanches
Free University of Bolzano, 22/04/2015

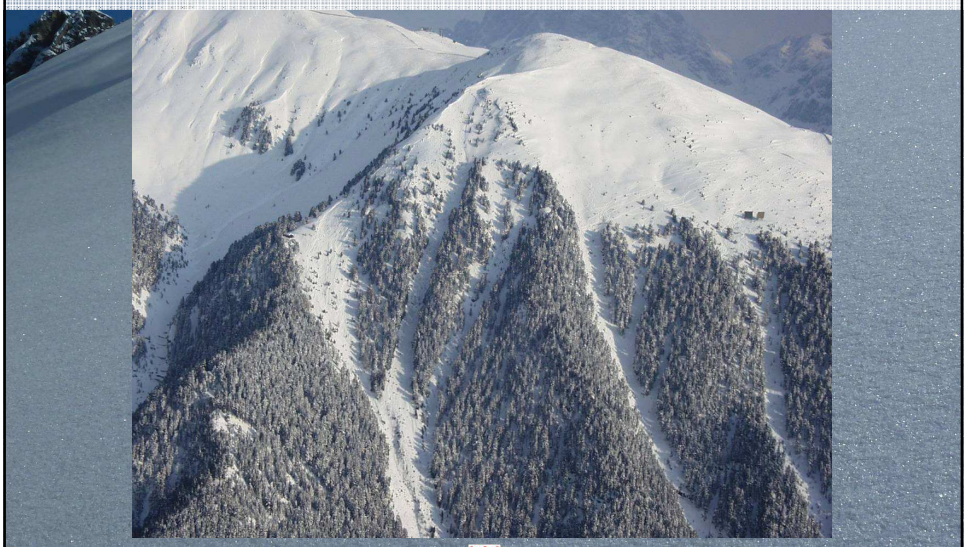
CLASSIFICATION

Starting zone

09/02/2009, Tauf Lahn Karthaus

CLASSIFICATION

Transit zone

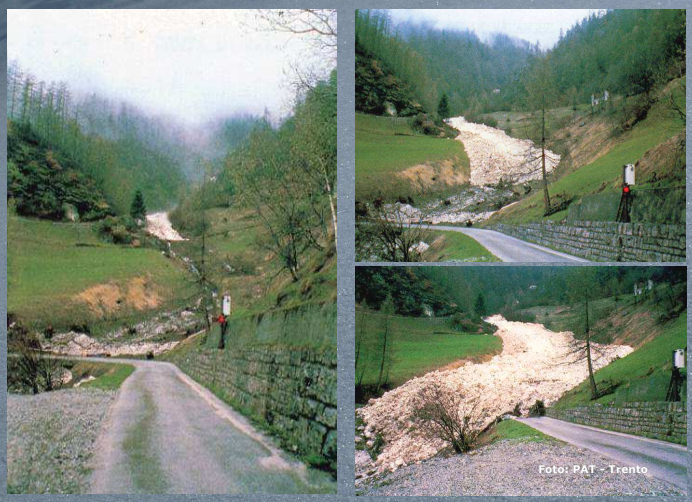


CLASSIFICATION

Transit zone

CLASSIFICATION

Transit zone



CLASSIFICATION

Transit zone

CLASSIFICATION

Transit zone

AUTONOME PROVINZ BOZEN - SÜDTIROL
PROVINCIA AUTONOMA DI BOLZANO - ALTO ADIGE
Rudi Nadalet – snow & avalanches
Free University of Bolzano, 22/04/2015

CLASSIFICATION

Transit zone

CLASSIFICATION

Deposition zone

CLASSIFICATION

Deposition zone

CLASSIFICATION

Deposition zone

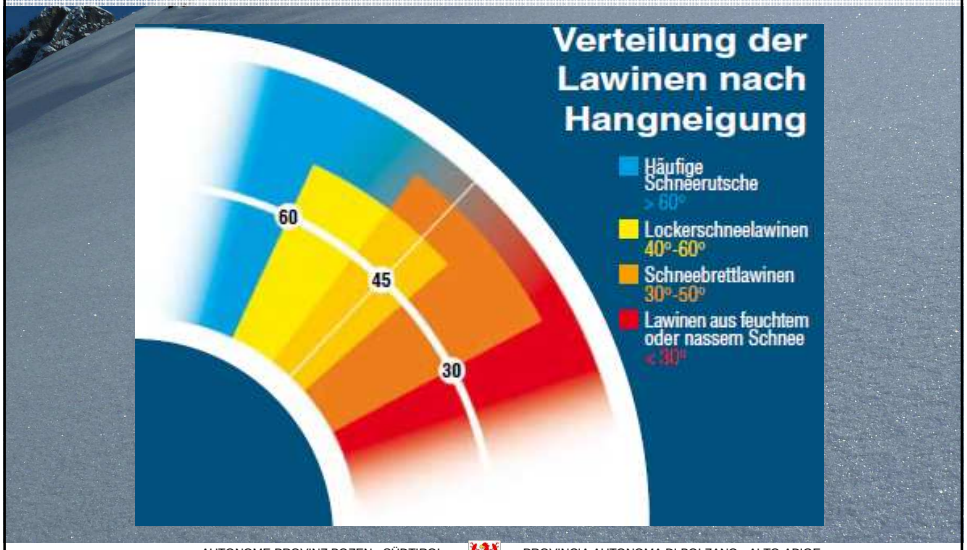
Schnals, 25.01.09

CLASSIFICATION

Deposition zone

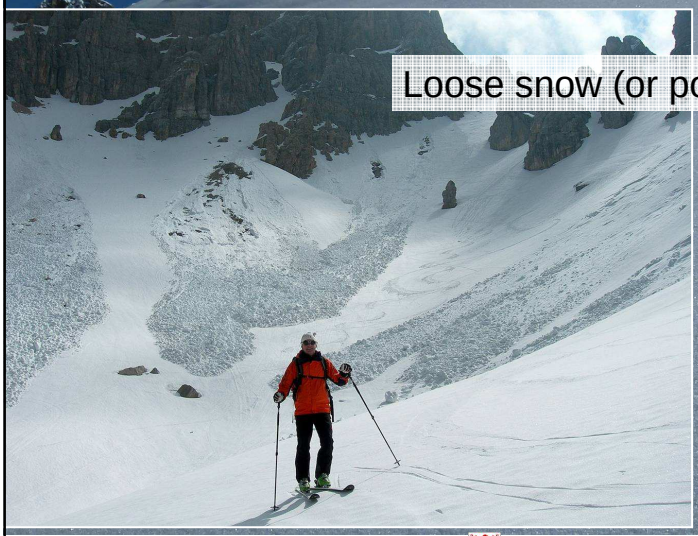
CLASSIFICATION

Basic avalanche types

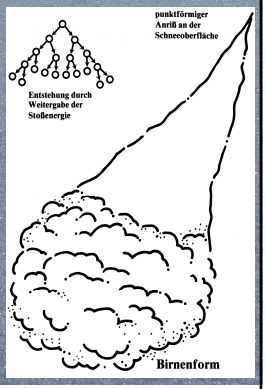


CLASSIFICATION

Basic avalanche types



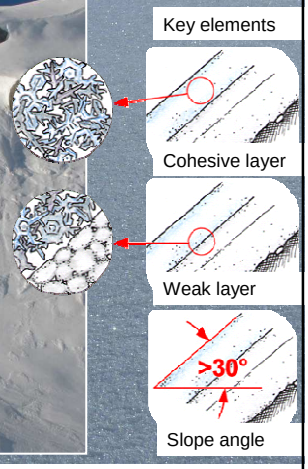
Loose snow (or point) avalanche



CLASSIFICATION

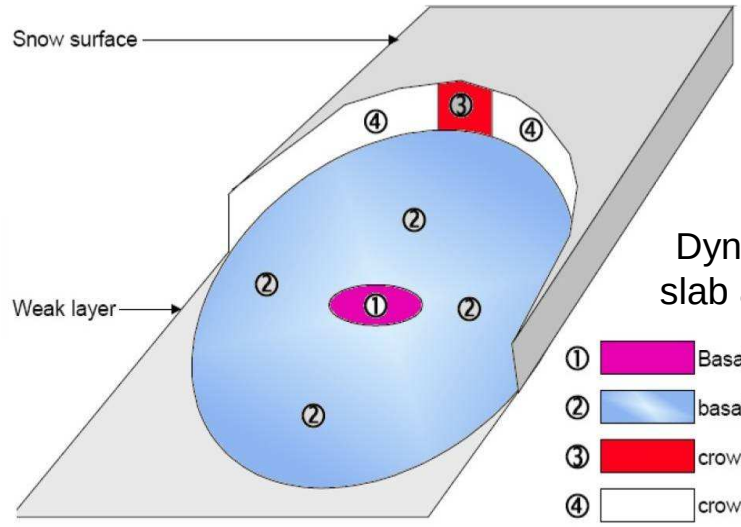
Basic avalanche types

Slab avalanche



CLASSIFICATION

Basic avalanche types



Dynamic of a slab avalanche

① Basal crack nucleation
② basal crack propagation
③ crown crack nucleation
④ crown crack propagation

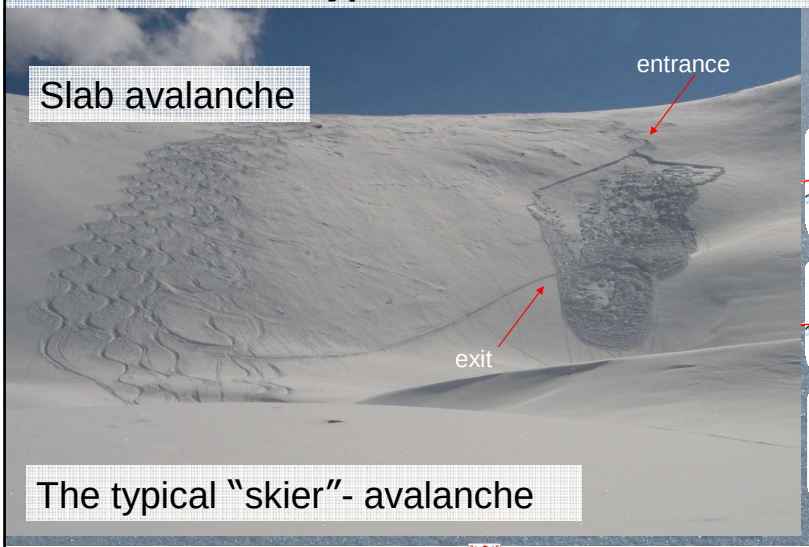
BASICS

Basic avalanche types

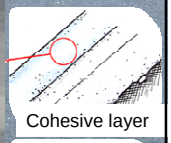
Video placa

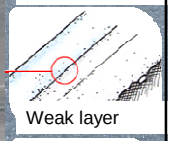
CLASSIFICATION

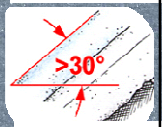
Basic avalanche types



Key elements







CLASSIFICATION

Basic avalanche types

AUTONOME PROVINZ BOZEN - SÜDTIROL
PROVINCIA AUTONOMA DI BOLZANO - ALTO ADIGE
Rudi Nadalet – snow & avalanches
Free University of Bolzano, 22/04/2015

CLASSIFICATION

Basic avalanche types

CLASSIFICATION

Basic avalanche types

CLASSIFICATION

Basic avalanche types

Wet snow avalanche

CLASSIFICATION

Basic avalanche types

Wet snow avalanche

Video Vals

CLASSIFICATION

Basic avalanche types

CLASSIFICATION

Basic avalanche types

AUTONOME PROVINZ BOZEN - SÜDTIROL
PROVINCIA AUTONOMA DI BOLZANO - ALTO ADIGE
Rudi Nadalet – snow & avalanches
Free University of Bolzano, 22/04/2015

CLASSIFICATION

Basic avalanche types

CLASSIFICATION

Avalanche size

Size 1: sluff
minimal danger of burying (danger of falling)
snow relocation typically stops before the end of a slope

Size 2: small avalanche
could bury, injure or kill a person
snow avalanche stops typically at the end of a slope

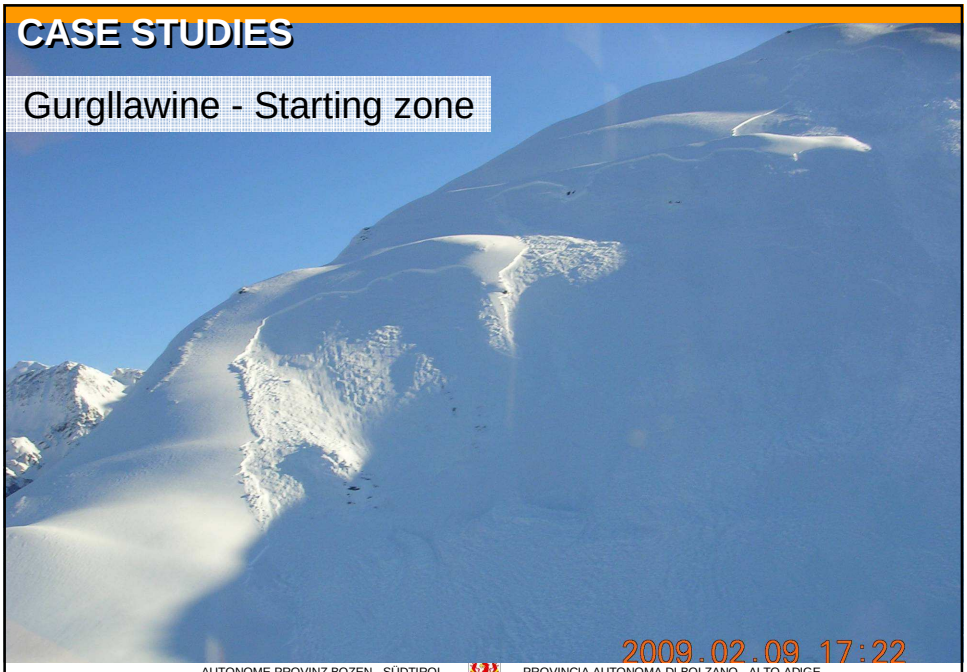
Size 3: medium avalanche
could bury & destroy a car, damage a truck; destroy a small building or break a few trees
avalanche could traverse flat terrain (considerably below 30°) over distances < 50 m

Size 4: large avalanche
could bury and destroy a railway car, large truck, several buildings or a piece of forest
snow avalanche traverses flat terrain (considerably below 30°) over distances > 50 m and can reach valley ground

Size 5: very large avalanche
could gouge the landscape; disastrous damage potential
snow avalanche reaches valley ground; largest runout distance known

CASE STUDIES

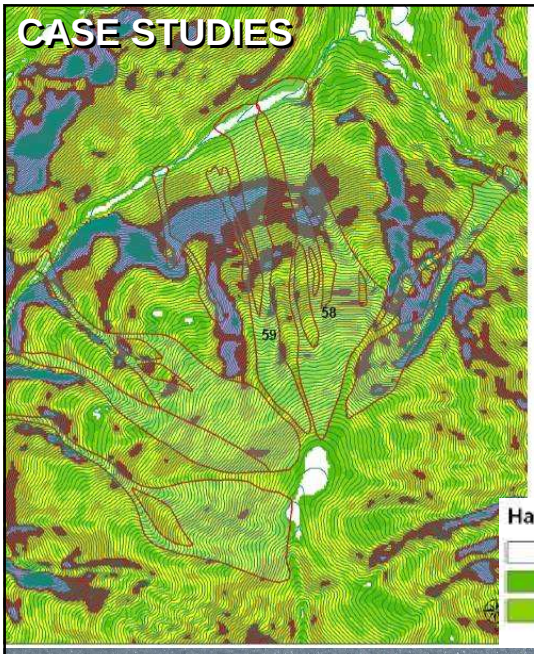
Gurgllawine - Starting zone



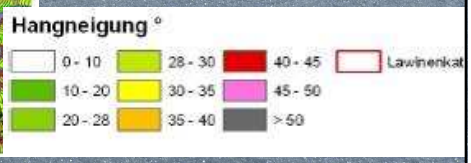
CASE STUDIES

Gurgllawine – Track(s)

CASE STUDIES



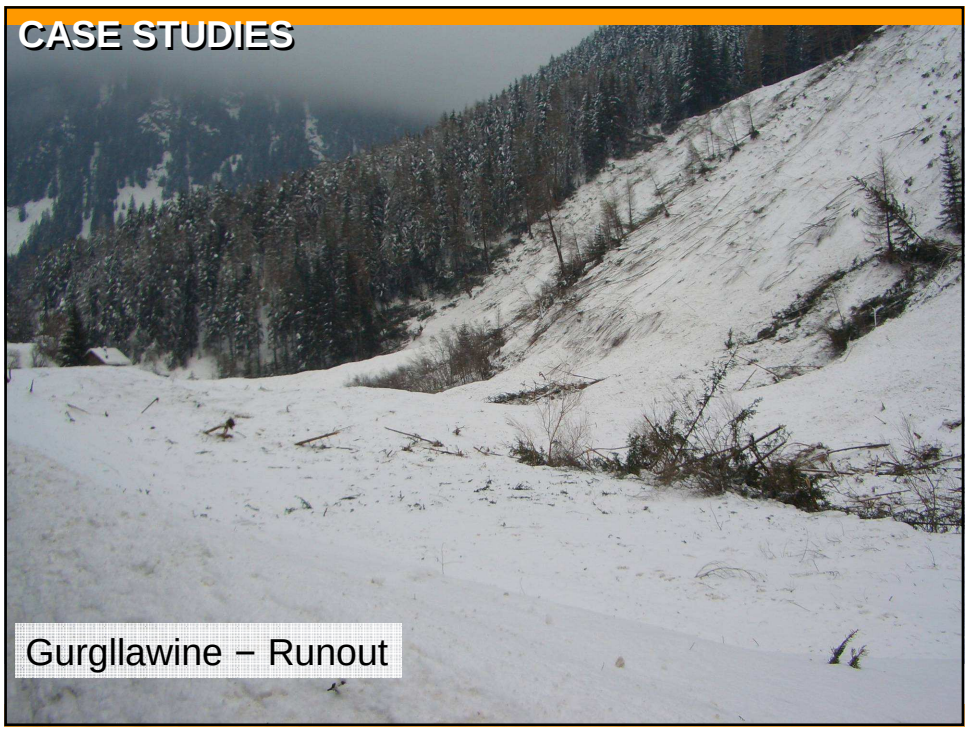
Starting zone ~ 9 ha
Track Δh > 800 m
v ~ 100 km/h
p ~ 4-5 kPa



CASE STUDIES

Gurgllawine - Video

CASE STUDIES



Gurgllawine – Runout

CASE STUDIES

Gurgllawine – Runout

CASE STUDIES

Gurgllawine – Runout

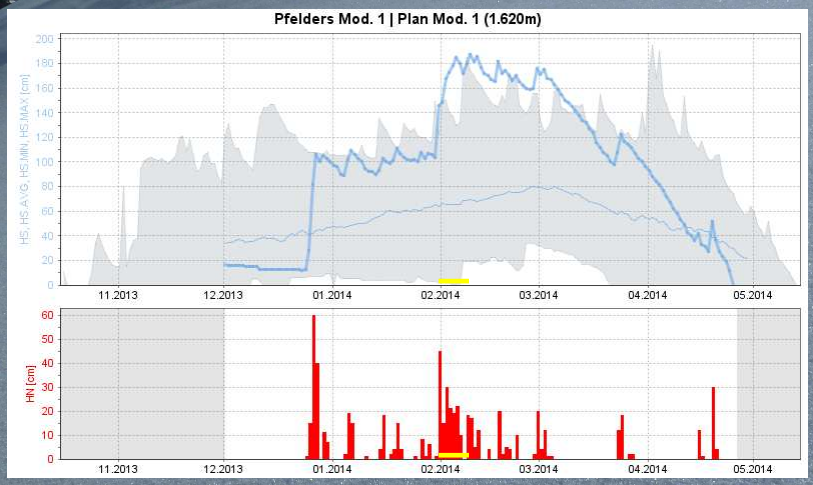
CASE STUDIES

Pill Lawine

Mixed avalanche form

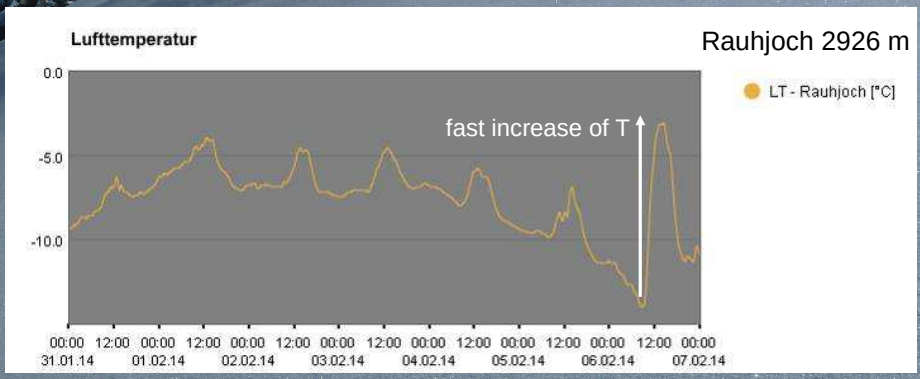
CASE STUDIES

Pill Lawine



CASE STUDIES

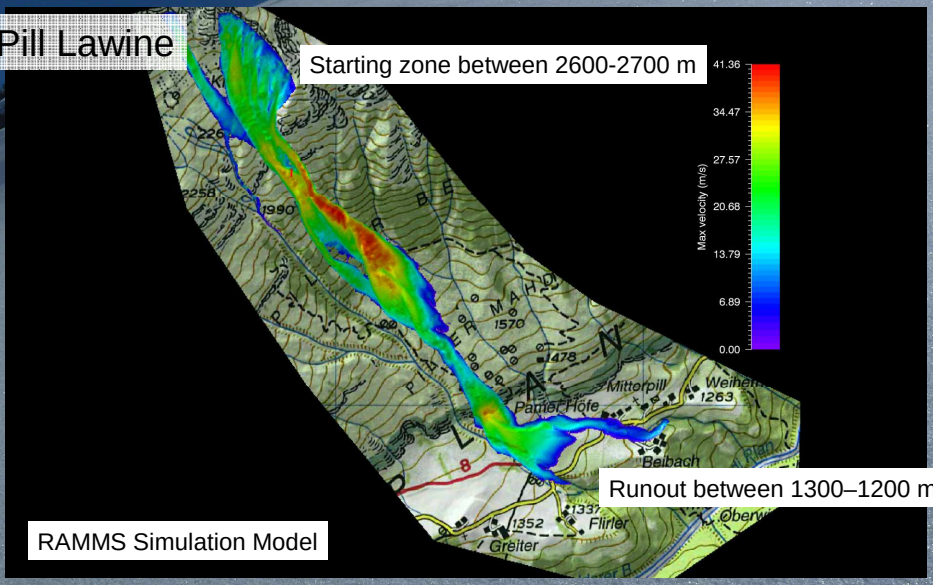
Pill Lawine



CASE STUDIES

Pill Lawine

Starting zone between 2600-2700 m

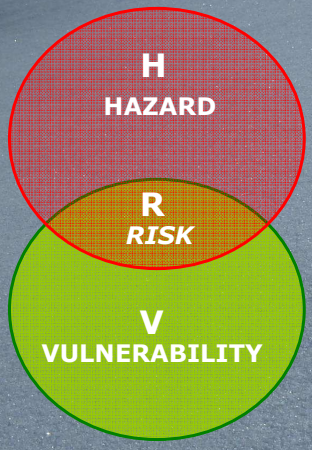


Runout between 1300–1200 m

RAMMS Simulation Model

RISK MITIGATION APPROACH

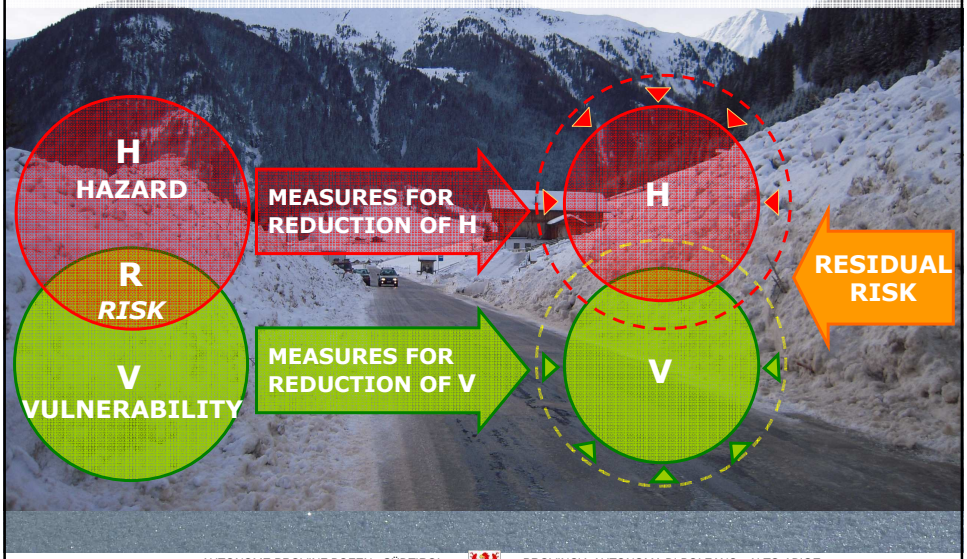
HAZARD, VULNERABILITY & RISK



$R = H \cap V$

RISK MITIGATION APPROACH

RESIDUAL RISK



RISK MITIGATION APPROACH

INTEGRATED RISK MANAGEMENT

	ACTIVE	PASSIVE
TEMPORARY	Local avalanche commissions	Weather forecast Avalanche bulletins
	AVALANCHE CONTROL	
PERMANENT	Defence Works	Hazard zones planning

RISK MITIGATION APPROACH