

# **The Galtuer Avalanche Catastrophe 23.02.1999 from the vantage point of meteorology and avalanche science**

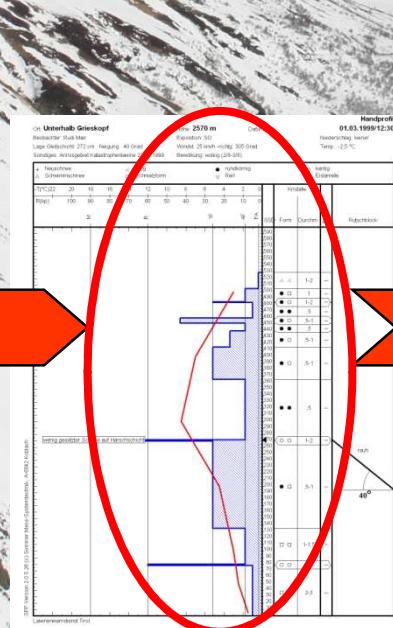
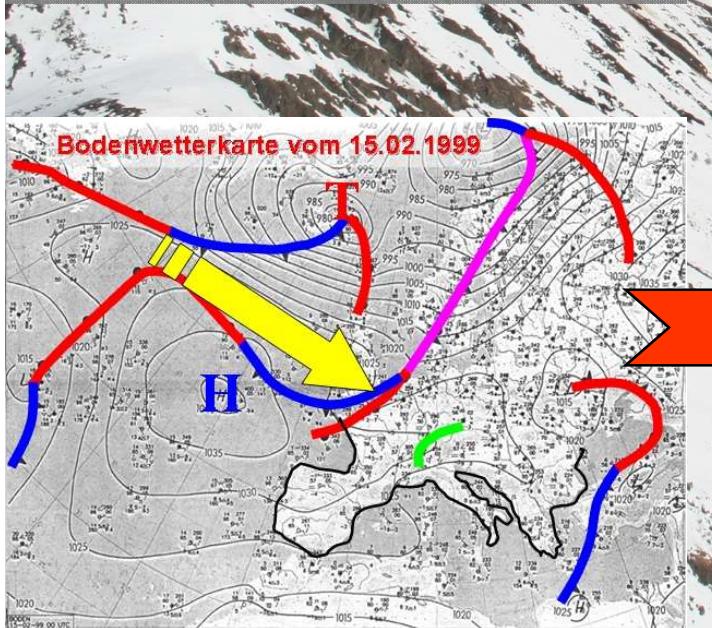


**Dr. Rudi MAIR, Avalanche Warning Service Tyrol**

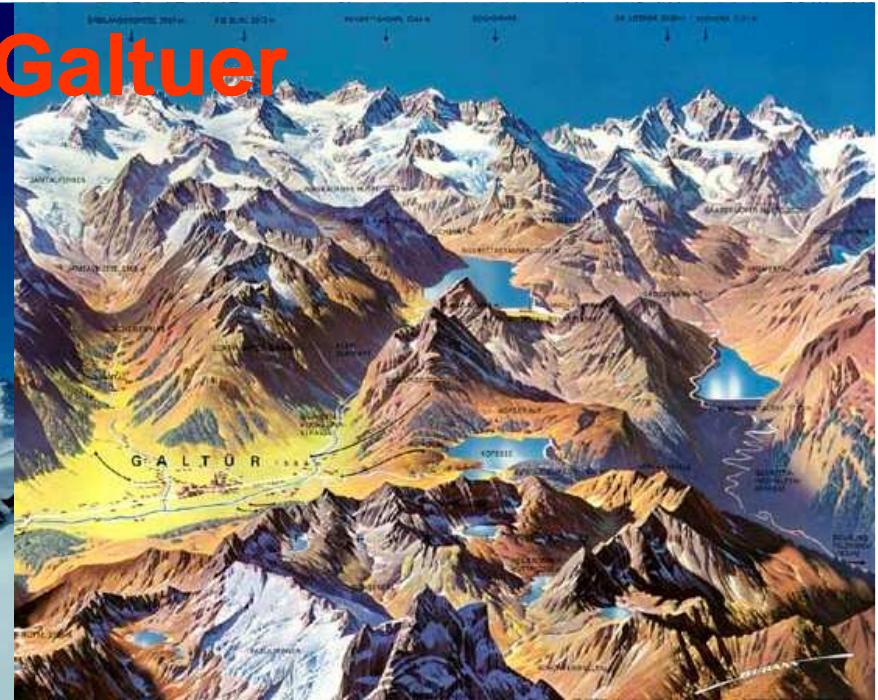
A particular sequence of meteorological conditions consisting of long-continuing precipitation, interrupted only by brief interims of warmth...

**...leads to extremely stable snowpack layering and far above average snow depths...**

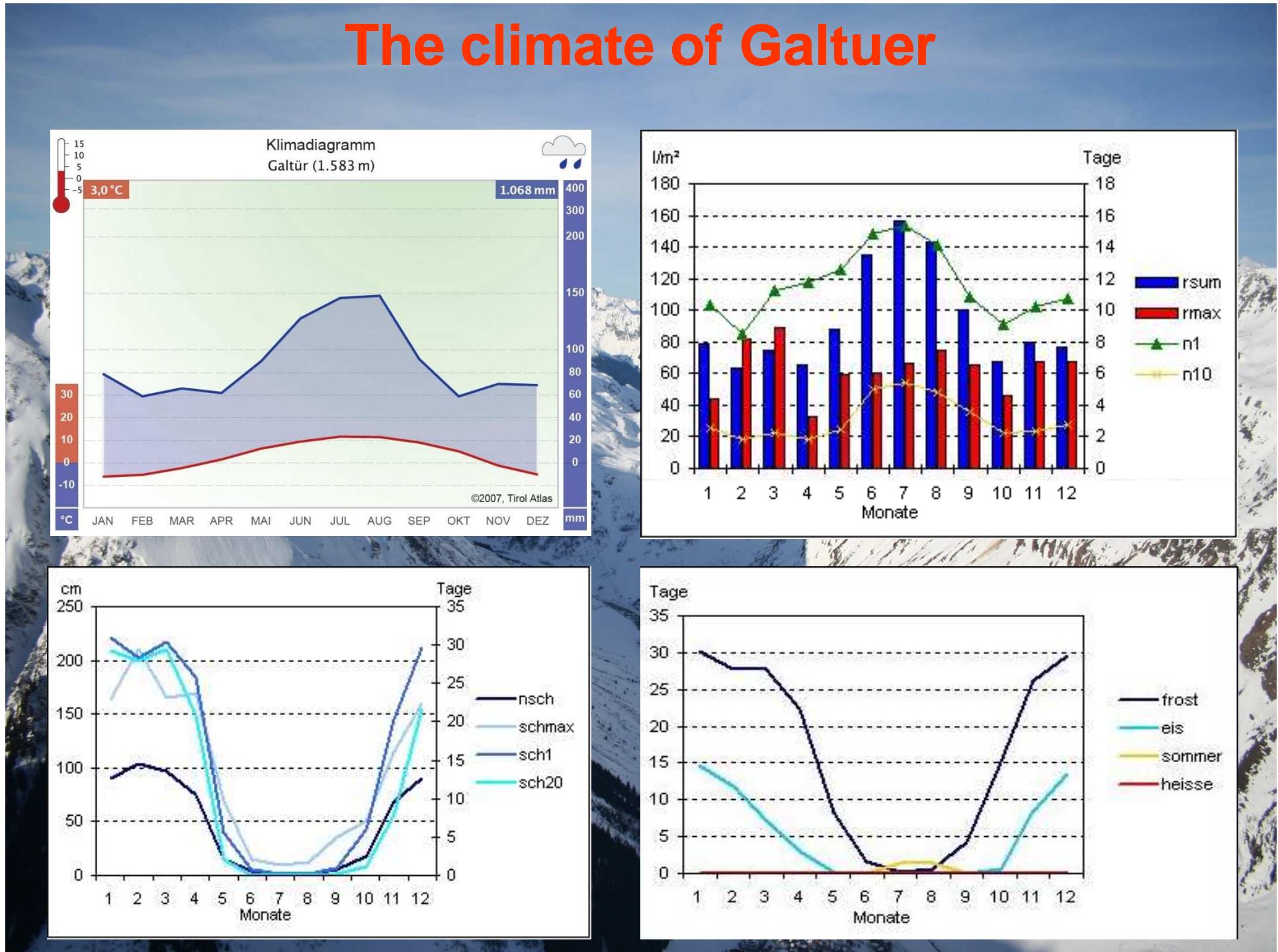
**...which, in turn, enables huge powder snow avalanches to be unleashed in undreamed of dimensions!**



# The site of Galtuer



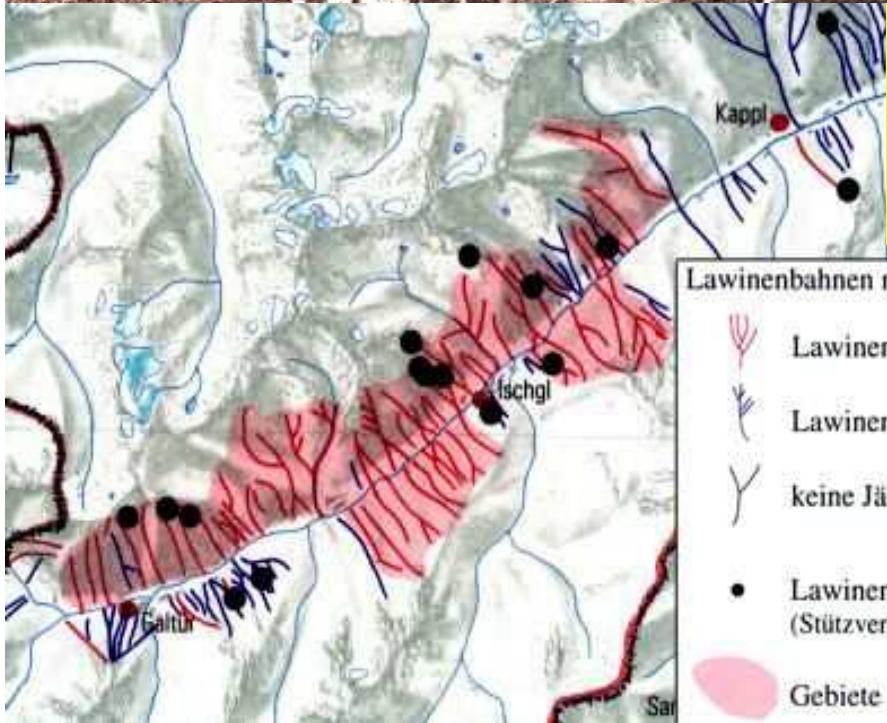
# The climate of Galtuer



# Avalanche chronicles and corridors in Galtuer



Year	Location	Deaths
1383	Vermunt pasture	3
1613	Kinge	4
1616	Wide Valley Avalanche, Birche	1
1682	Wide Valley Avalanche	5
1689	Shadow Valley Avalanche, Tschafein	29
1699	no name	4
1720	Hochegg	4
1723	Larein	1
1817	no name	2
1835	Innertschafein	6
1874	Portrinner Avalanche	1
1919	Inner/Outer Wasserleiter Avalanche	5
1952	Larein Valley Avalanche	9
1984	Adamsberg-Portrinner Avalanche	2
1999	White Riefe-/Outer Wasserleiter Avalanche	31

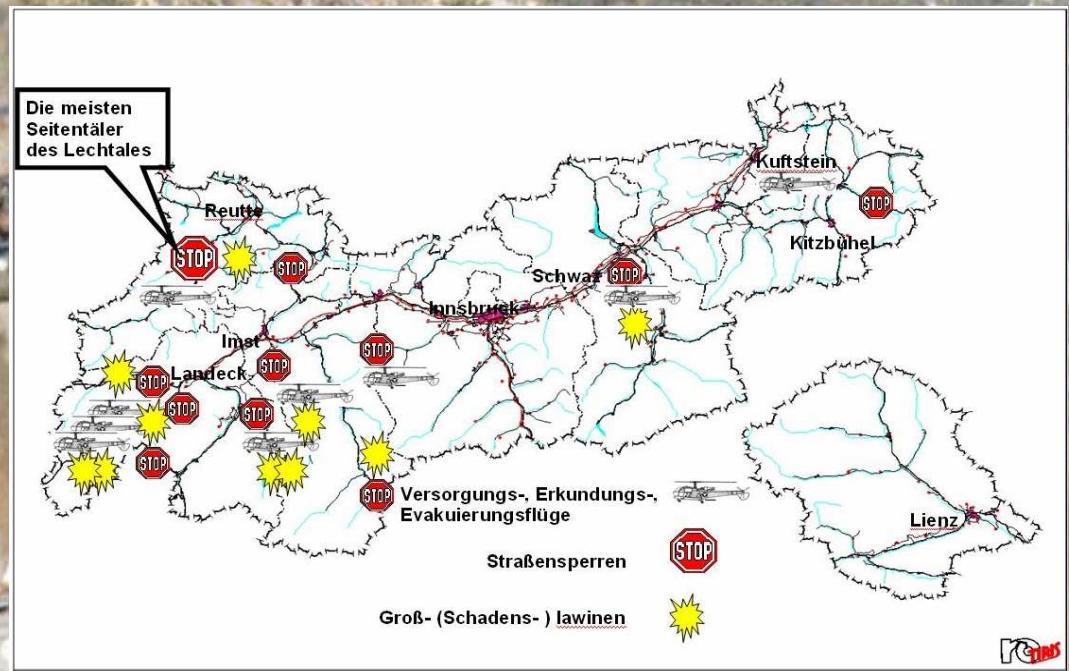


Lawinenbahnen nach Eintrittswahrscheinlichkeit

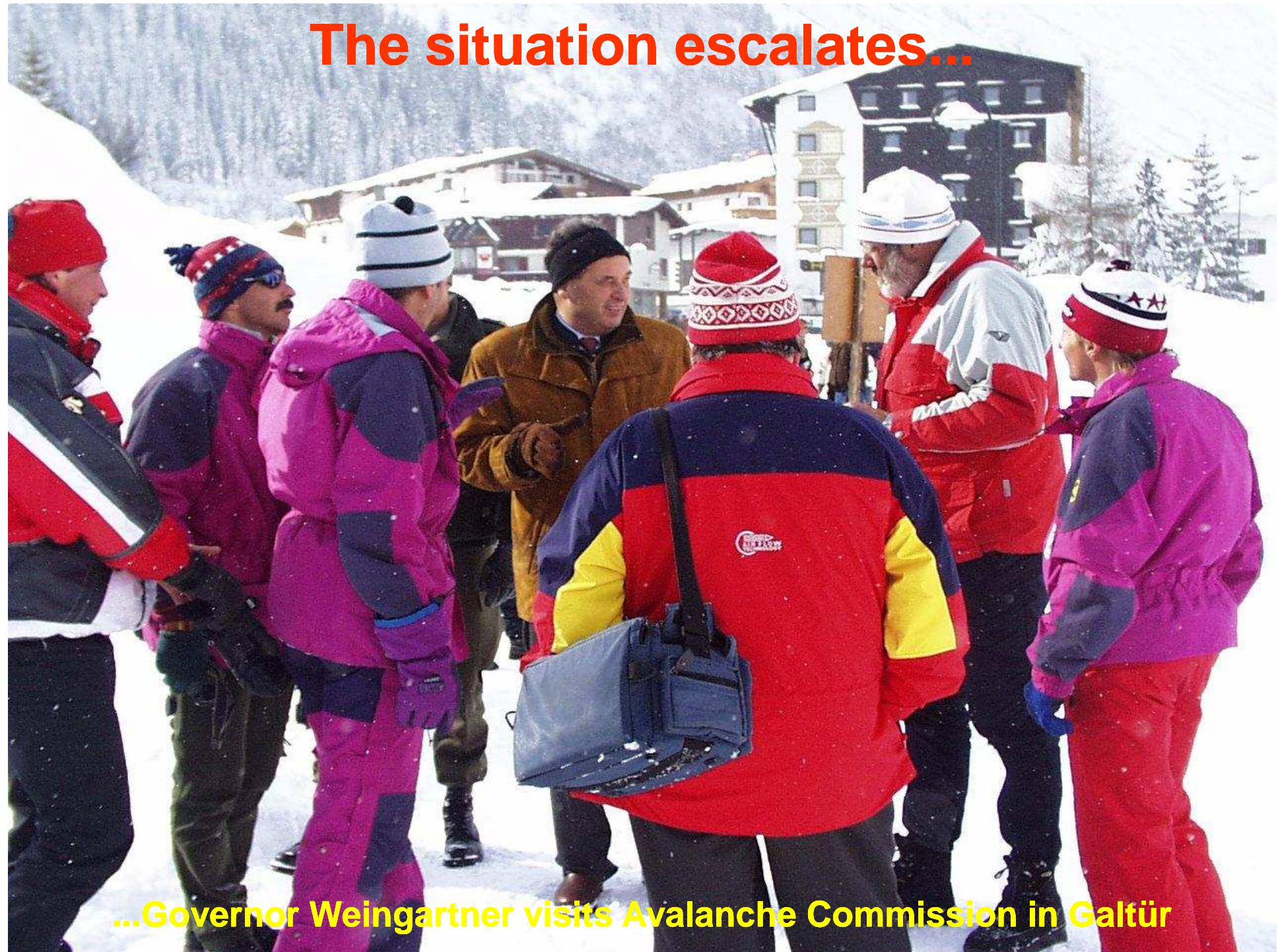
- Lawinen jährlich
- Lawinen seltener
- keine Jährlichkeit ausgewiesen
- Lawinenverbauung  
(Stützverbauungen, Dämme, Verwehungszäune)
- Gebiete mit erhöhtem Lawinenrisiko

- |                  |   |
|------------------|---|
| <u>Innsbruck</u> | Sitz der Sektion der Wildbach- und Lawinenverbauung           |
| <u>Bozen</u>     | Sonderbetrieb für Bodenschutz, Wildbach- und Lawinenverbauung |
| <u>Wörgl</u>     | Sitz der Gebietsbauleitung der Wildbach- und Lawinenverbauung |
| <u>Kempten</u>   | Sitz des Wasserwirtschaftsamtes                               |
| <u>Zernez</u>    | Sitz des Kreisforstamtes                                      |
| •                | Sitz einer Lawinenkommission                                  |
| —                | Grenze der Gebietsbauleitung Wildbach- und Lawinenverbauung   |

# General Avalanche Situation • Tyrol, February '99



The situation escalates...



...Governor Weingartner visits Avalanche Commission in Galtür

**Final supply flights...**

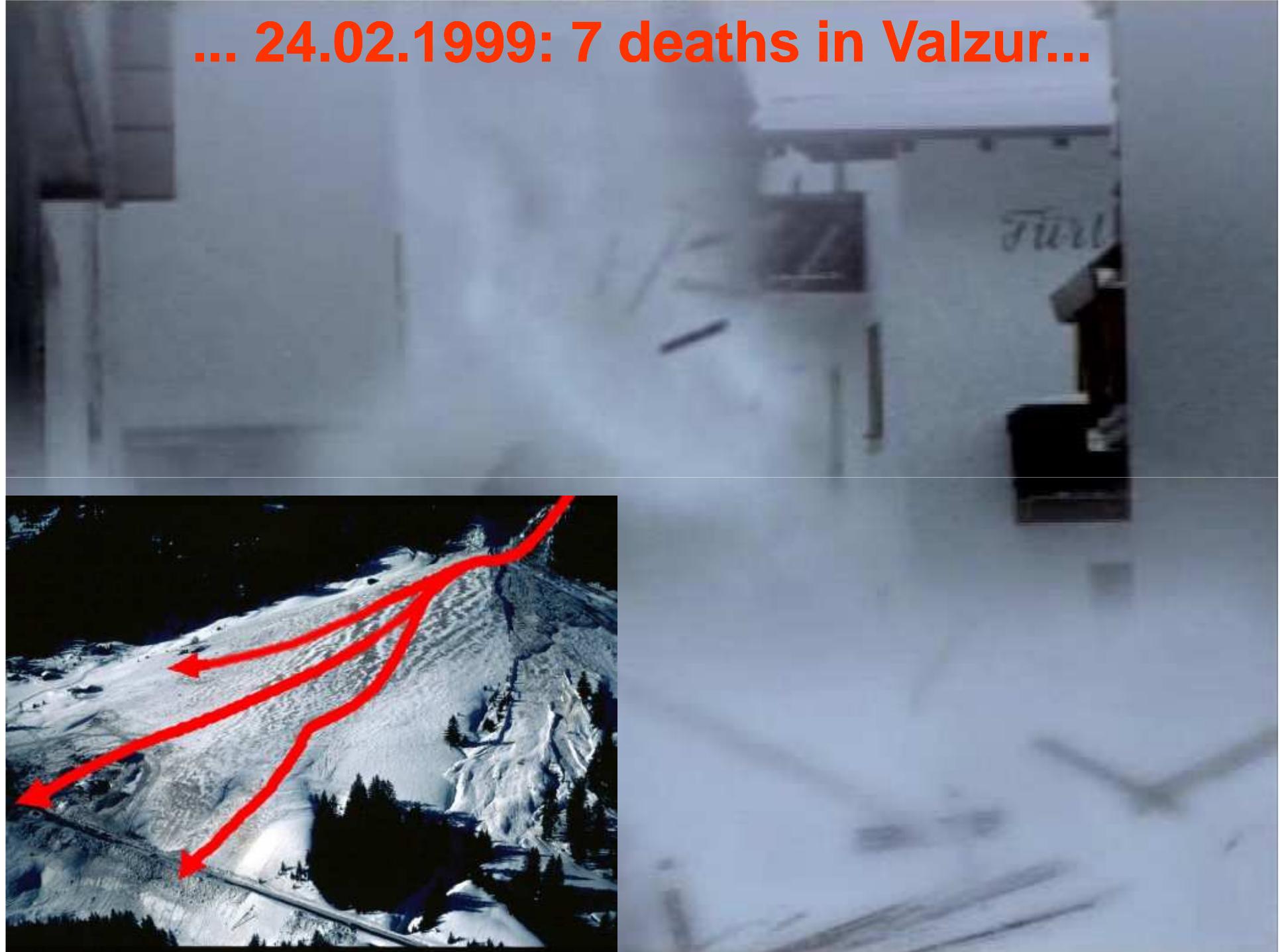
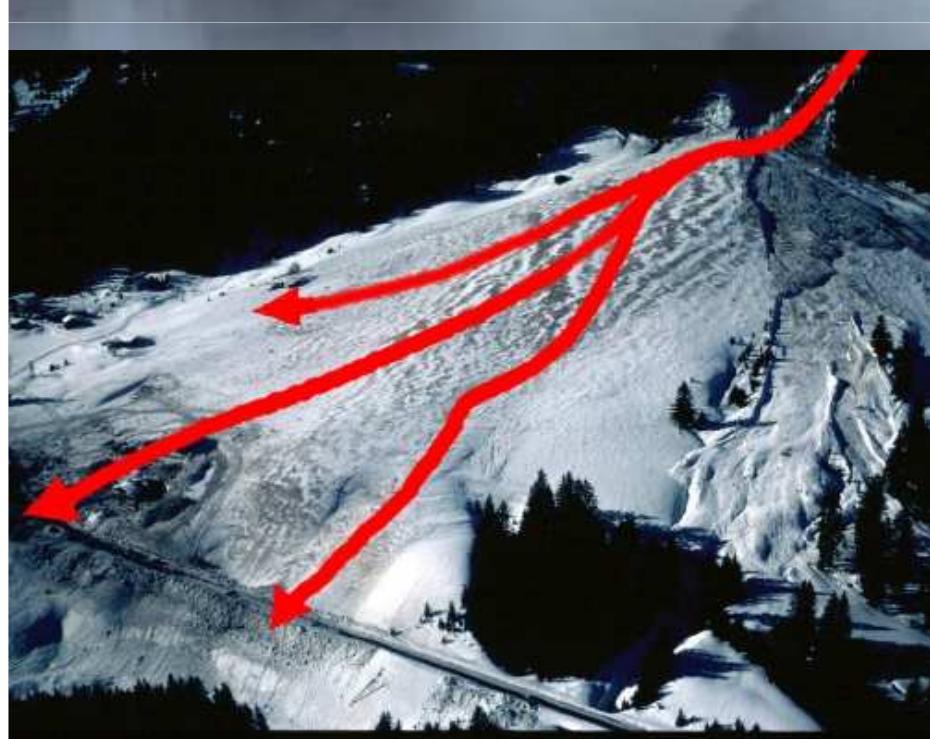


**...and then, disaster strikes:**

**... 23.02.1999: 31 deaths in Galtuer...**



... 24.02.1999: 7 deaths in Valzur...



**...evacuations amid heavy snowfall...**

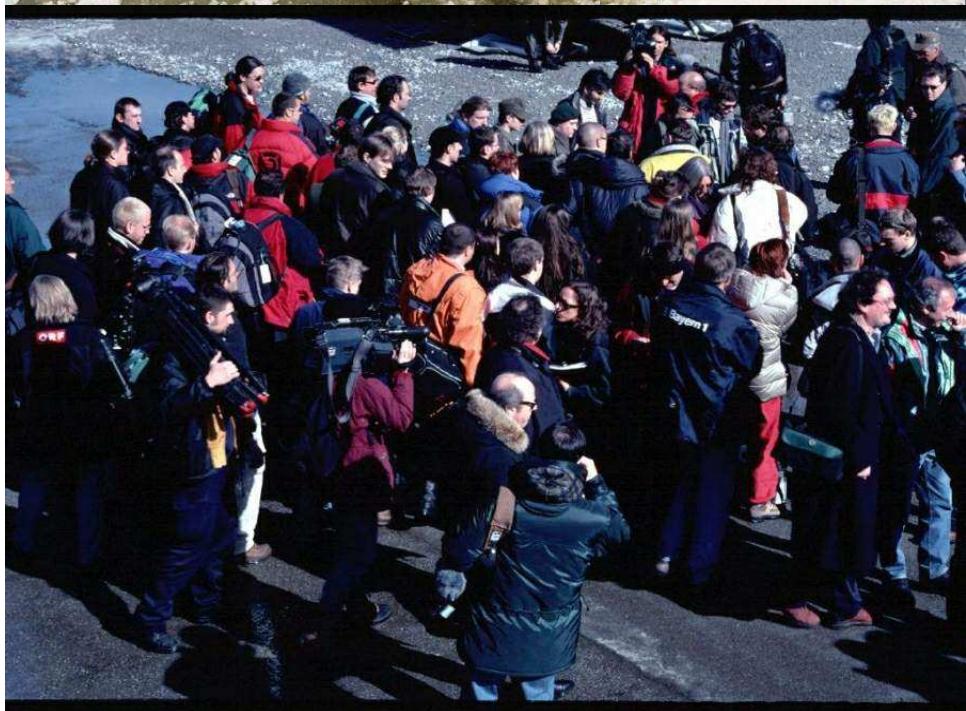


**(they first wanted to get into the valley at any cost, then to get out at any cost)**

# ...Rescue operations in Valzur...



**...ongoing evacuations and the 'media avalanche'...**



# ...Balance sheet...

	Galtuer	Valzur
Deaths	31	7
Serious Injuries	11	1
Light Injuries	20 bis 25	11
Total buried	Ca. 100	19
Destroyed or damaged buildings	Ca. 60	11

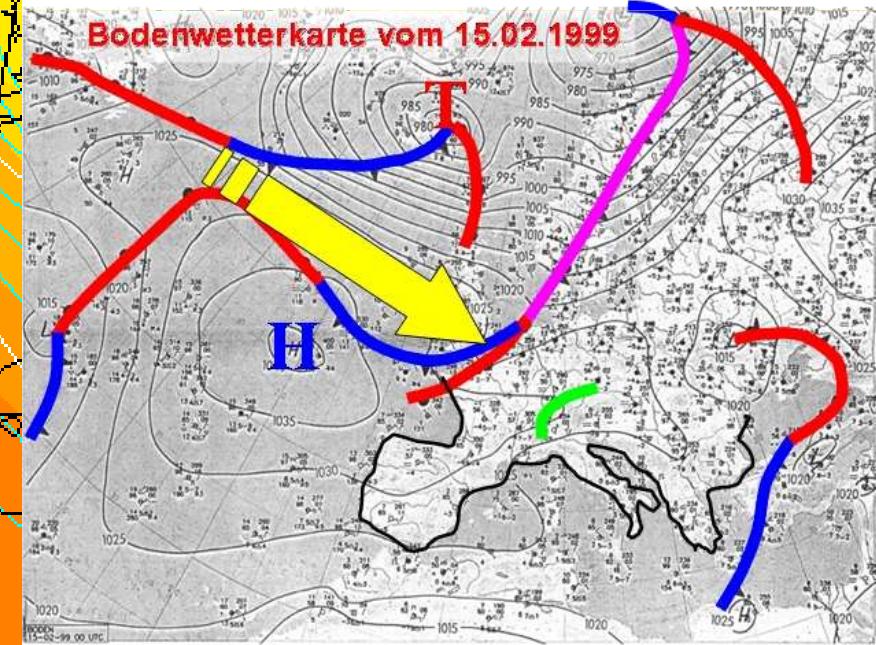
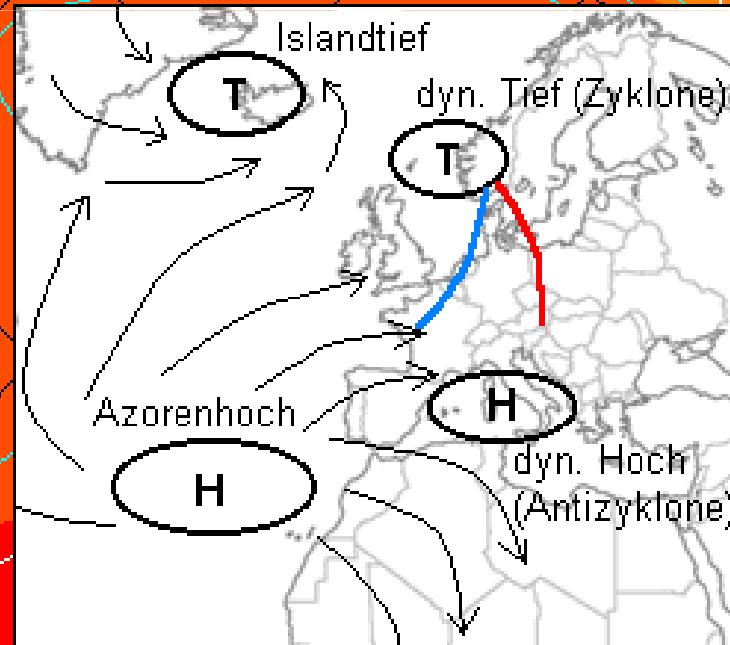


Military Helicopters	
Flight Hours	921 Hrs. 23 Min.
Landings	3.301
No. of persons flown, inc. rescue teams	18.284
Goods flown, in tons	269,91

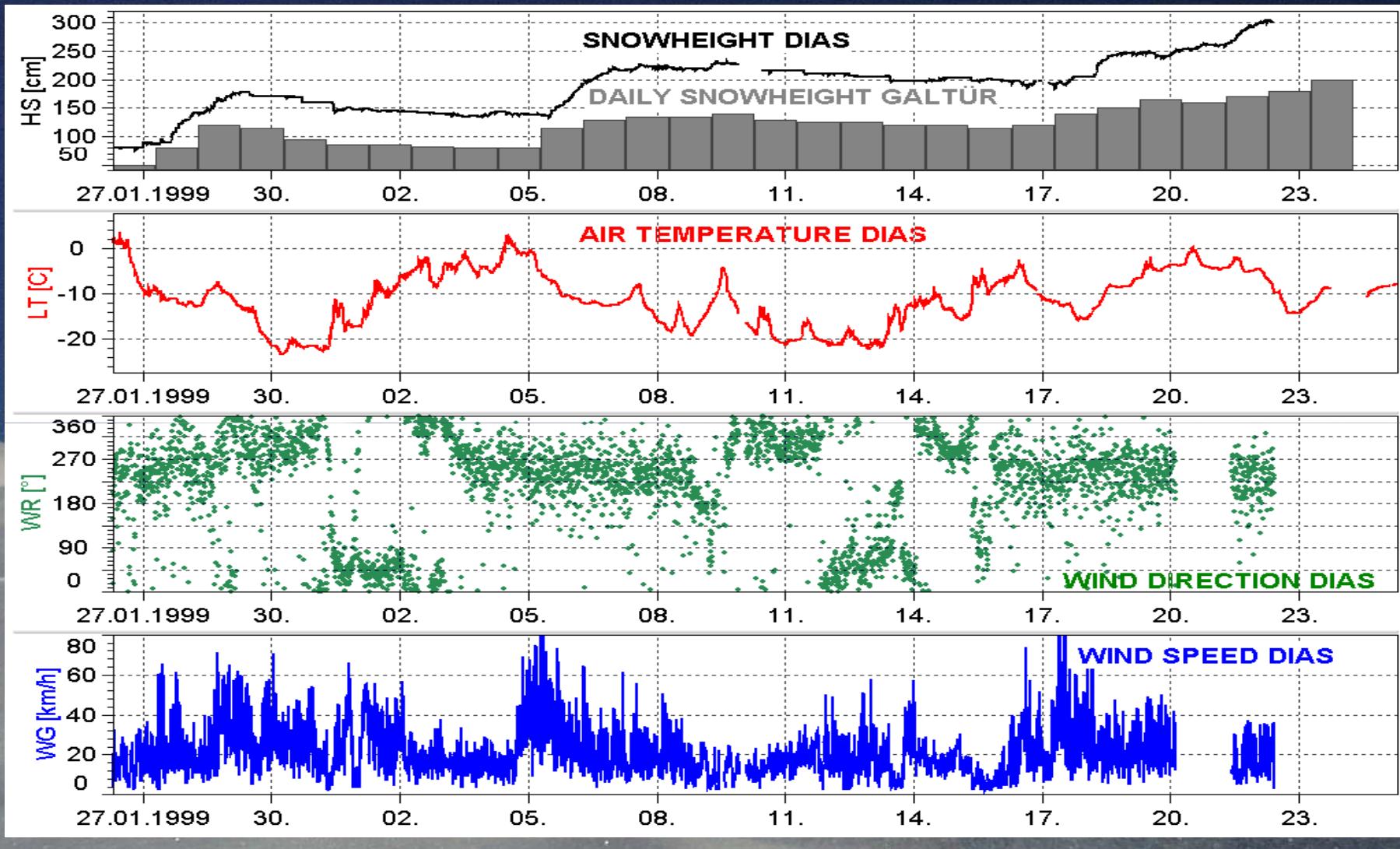
# Overall weather situation in winter 1998/99

Normal airstream pattern in winter over the Atlantic:  
dominated by high from Azores and low from Iceland,  
leads to zoned air currents and westerly winds.

Airstream pattern in winter 1998/99:  
cyclonal NW current with low over British Isles and Atlantic high to the southwest. Leads to strong northwesterly airstream.



# A total of three large periods of precipitation:



27.01. – 04.02.

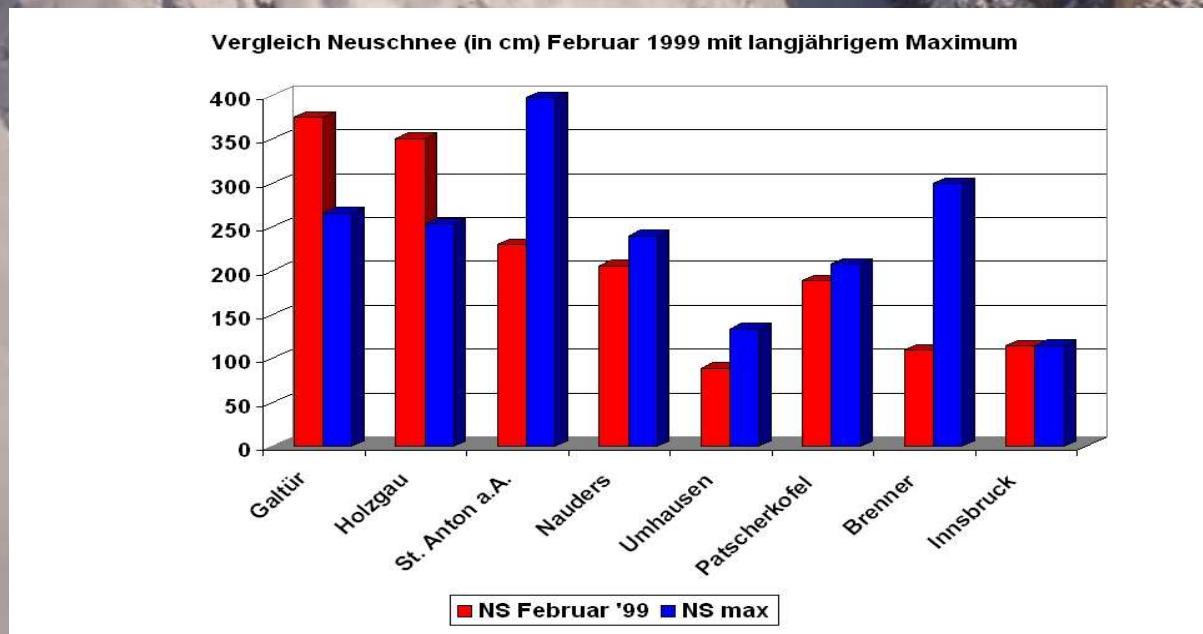
05.02. – 16.02.

17.02. – 25.02.

# Huge snow masses throughout Tyrol:



	NS February '99 (cm)	% Average	NS max (cm)	Year	Rank 99	Period
Holzgau	351	508	254	1984	1	1895-96
St. Anton a.A.	230	324	398	1970	4 ??	1895-96
Galtuer	375	595	266	1970	1	1895-96
Nauders	206	479	240	1970	2	1895-96
Umhausen	89	330	134	1970	2	1953-96
Patscherkofel	189	266	208	1970	2	1945-96
Brenner	110	211	300	1935	5	1895-96
Innsbruck	114	422	115	1970	2	1952-96

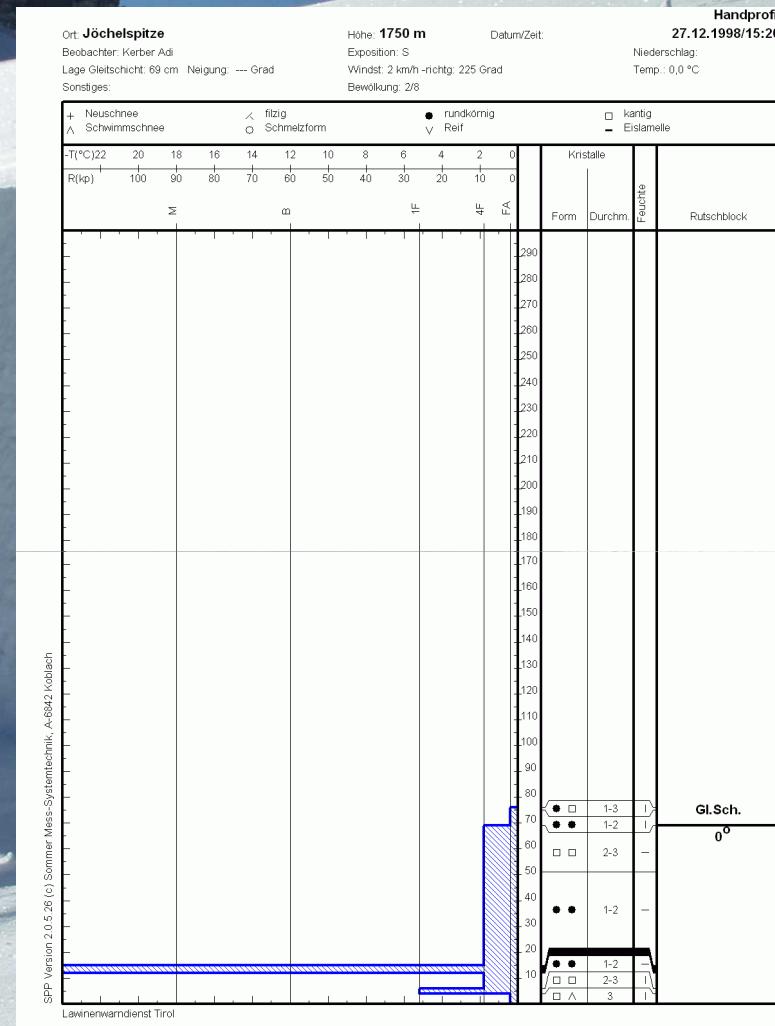
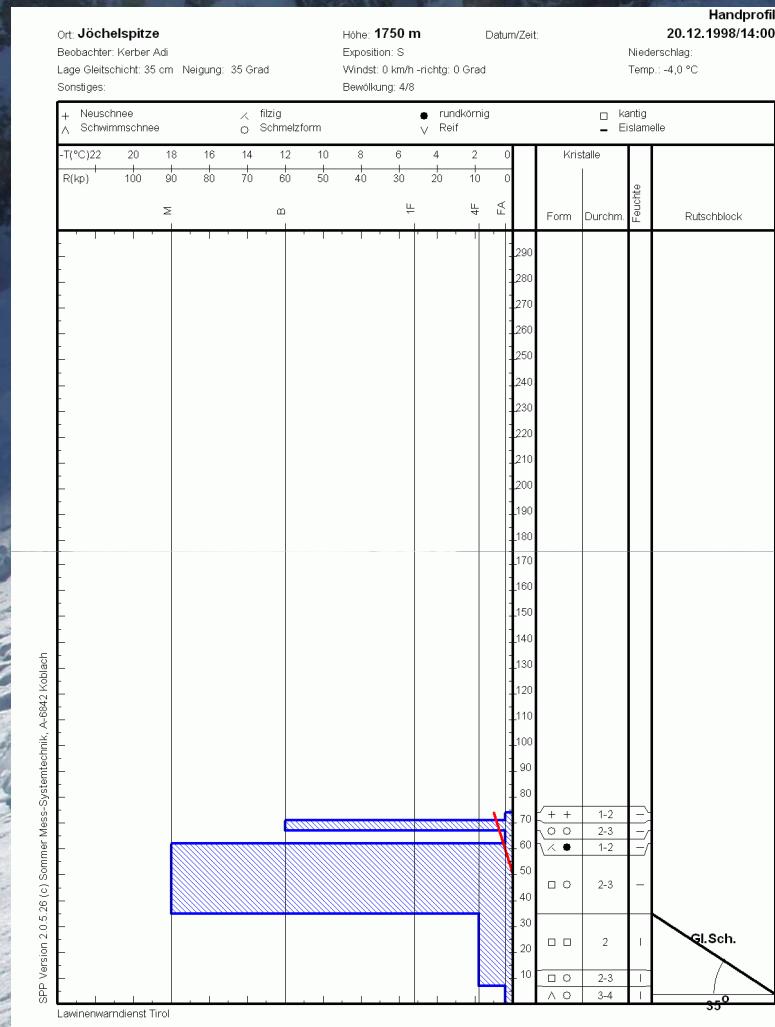


# Snowpack development in winter 1998/99:



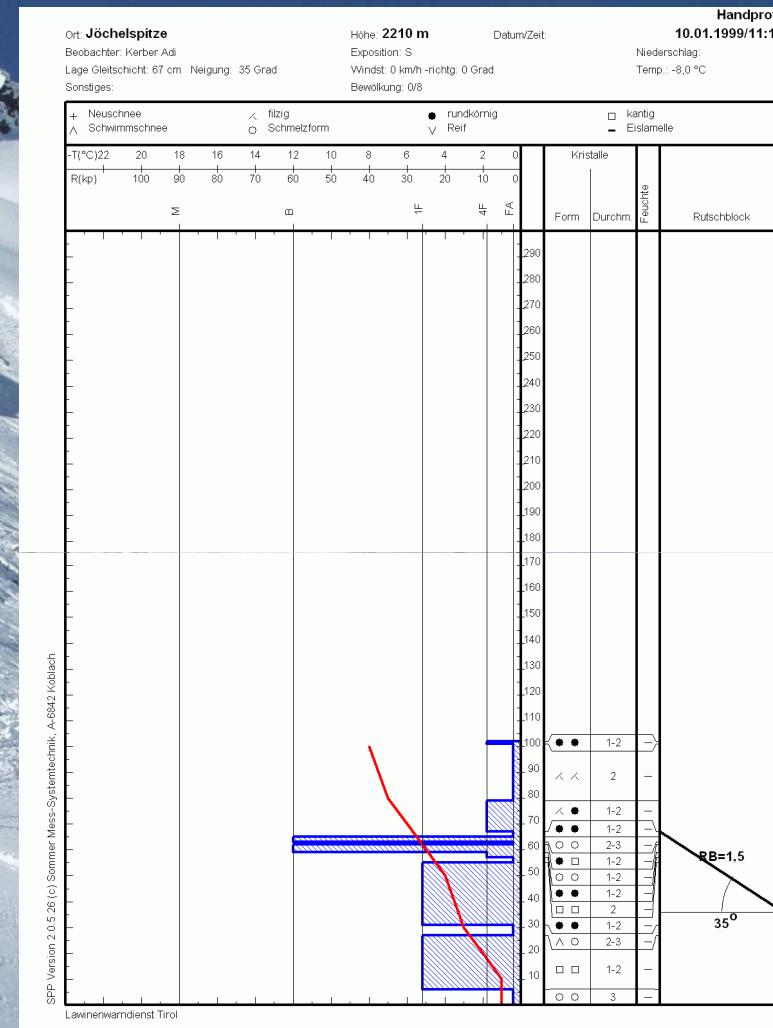
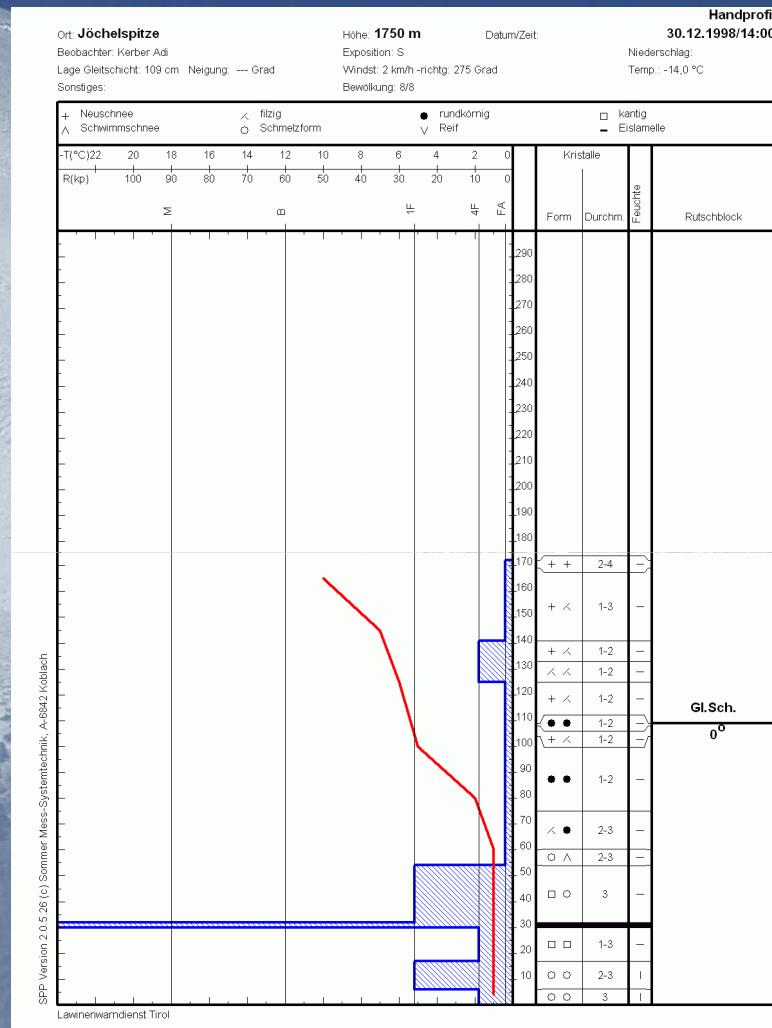
Snow profile at Joechelspitze station (34 km from Galtuer)

# Snowpack development before mid-January:



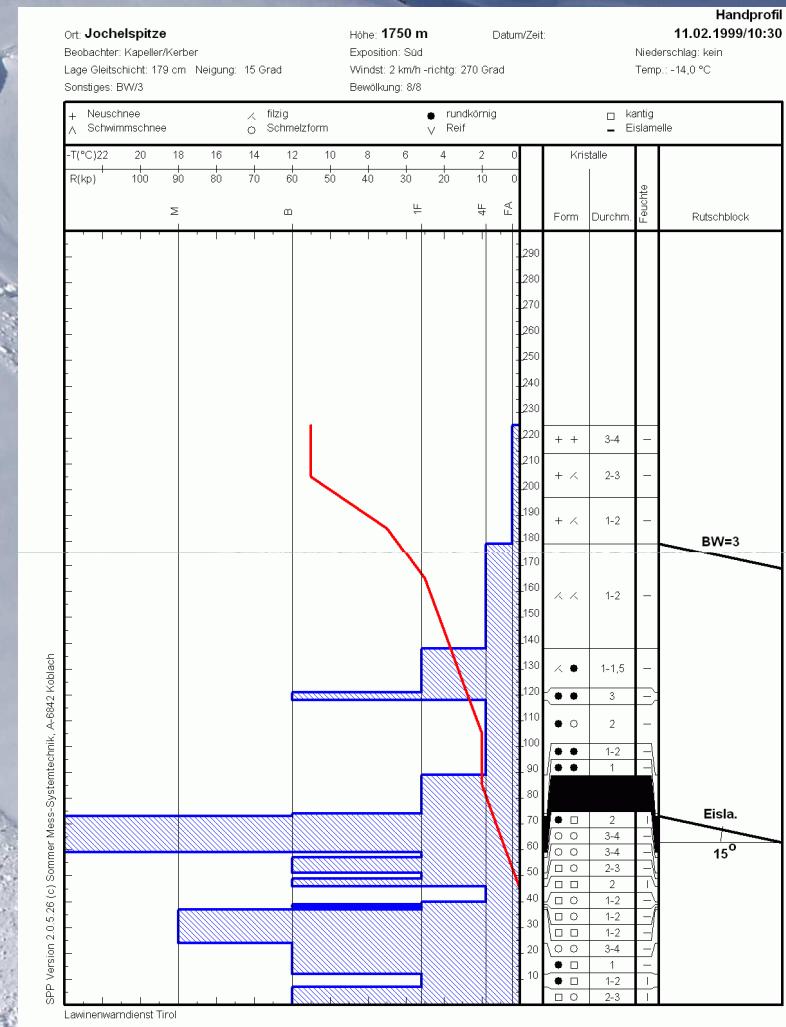
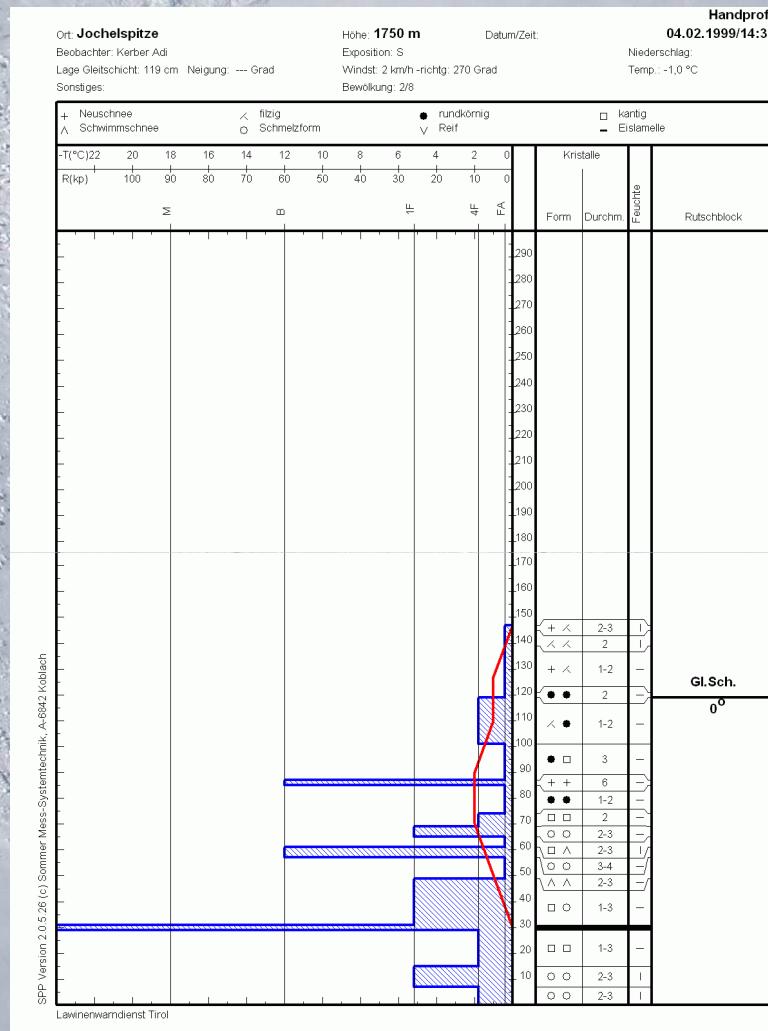
**Weak snow layering: typical early winter fundament of depth hoar, minimum snowfall.  
 Frequent temperature changes gives rise to melt-freeze crusts, breakable crusts observed  
 on the surface widespread.**

# Snowpack development until the beginning of February:



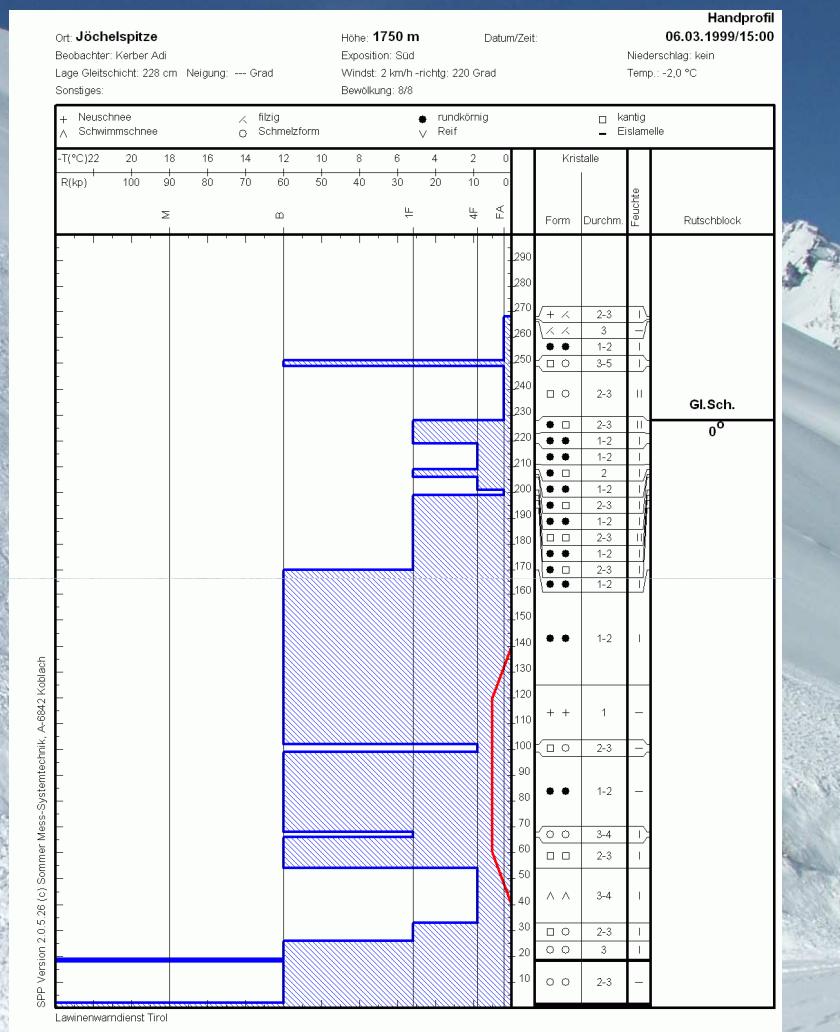
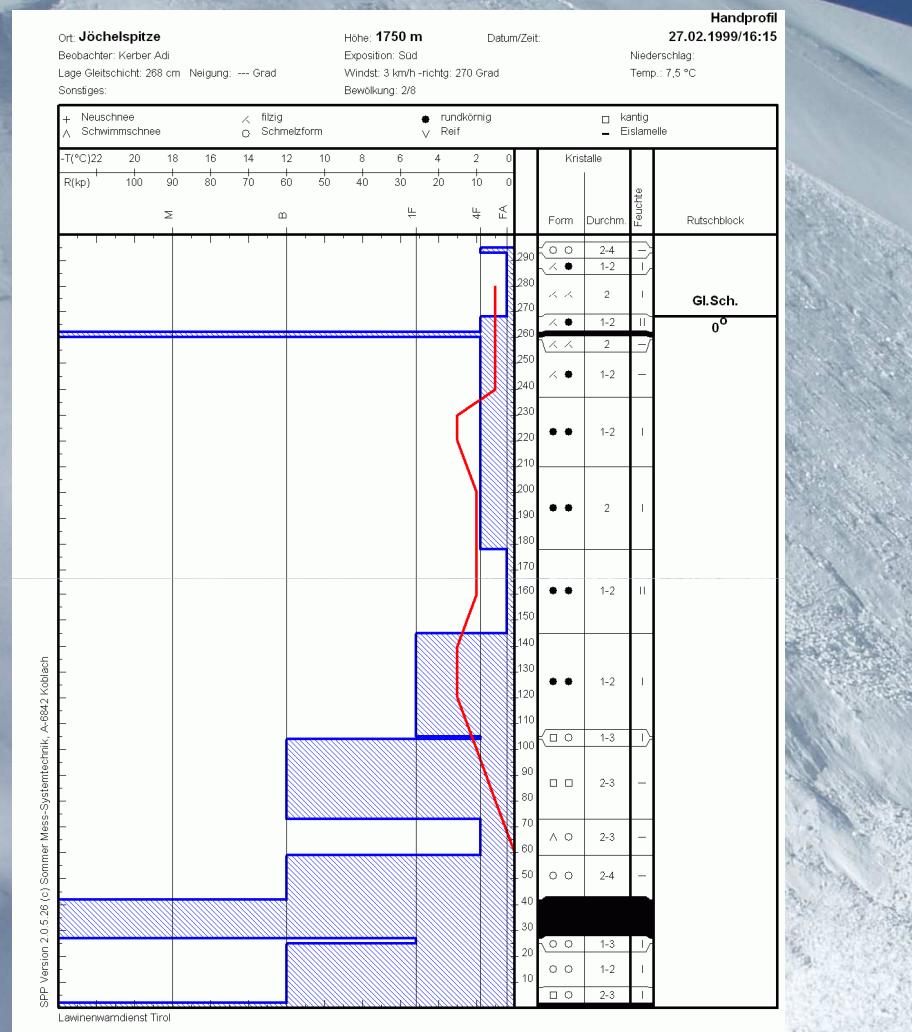
Loosely packed, trigger-sensitive old snowpack. Cold layers of transported new snow poorly bonded with old snowpack. Avalanches usually triggered on old snowpack, since melt-freeze crusts and breakable crusts prevent full fracture.

# Snowpack development until mid-February:



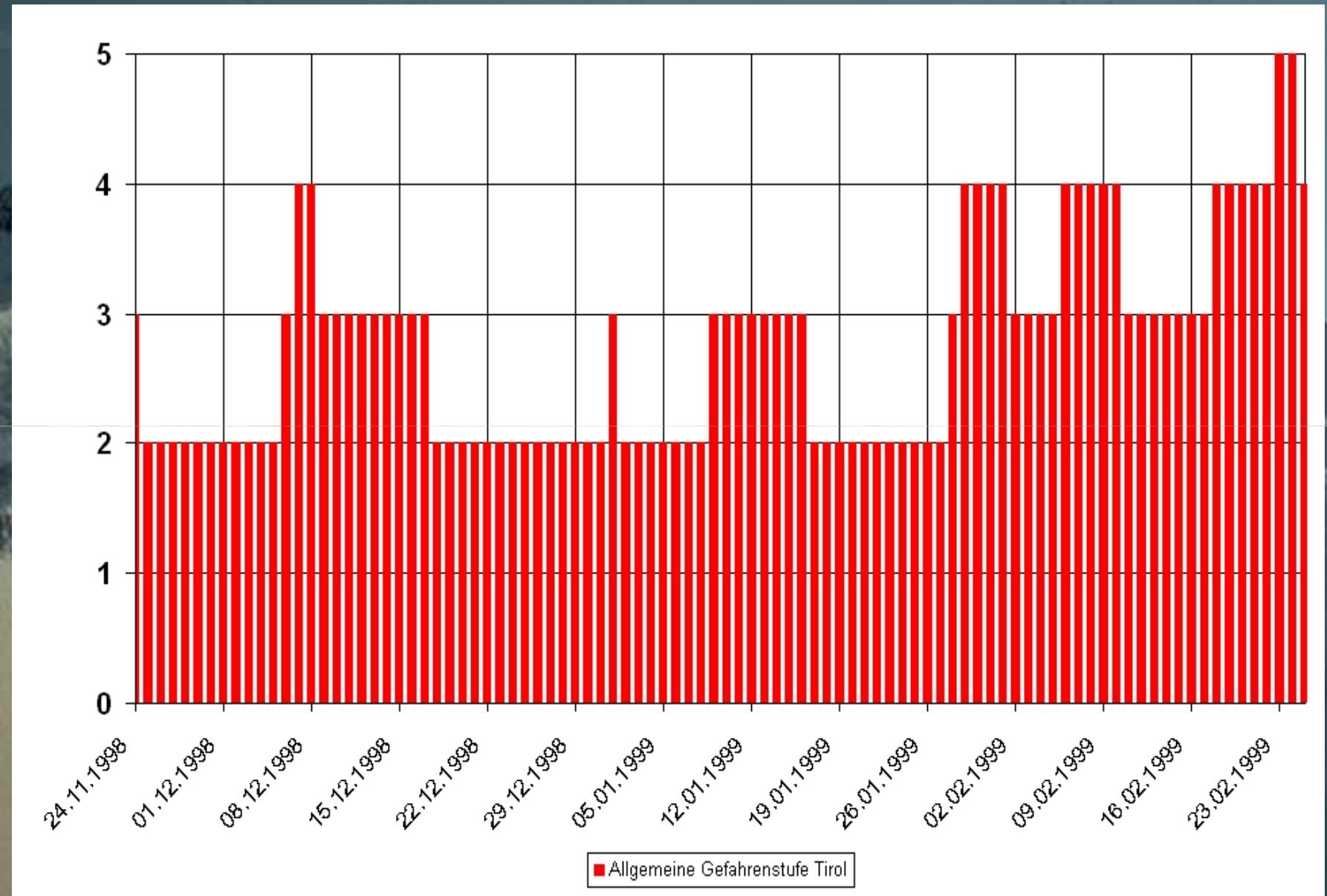
Rising temperatures at end of first period of precipitation causes snowpack to settle and consolidate somewhat; thus, additional loading from second period of snowfall insufficient to trigger avalanches. Unleashed avalanches are small.

# Snowpack development until the end of February:



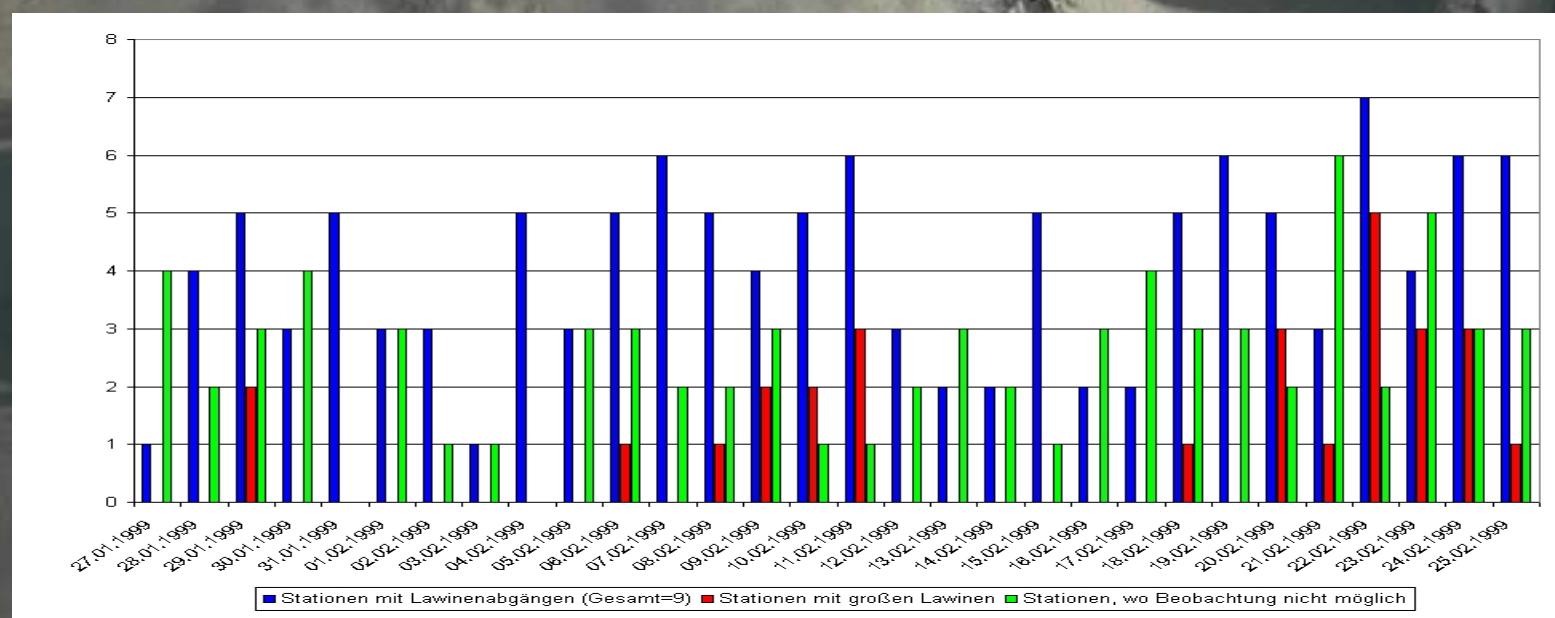
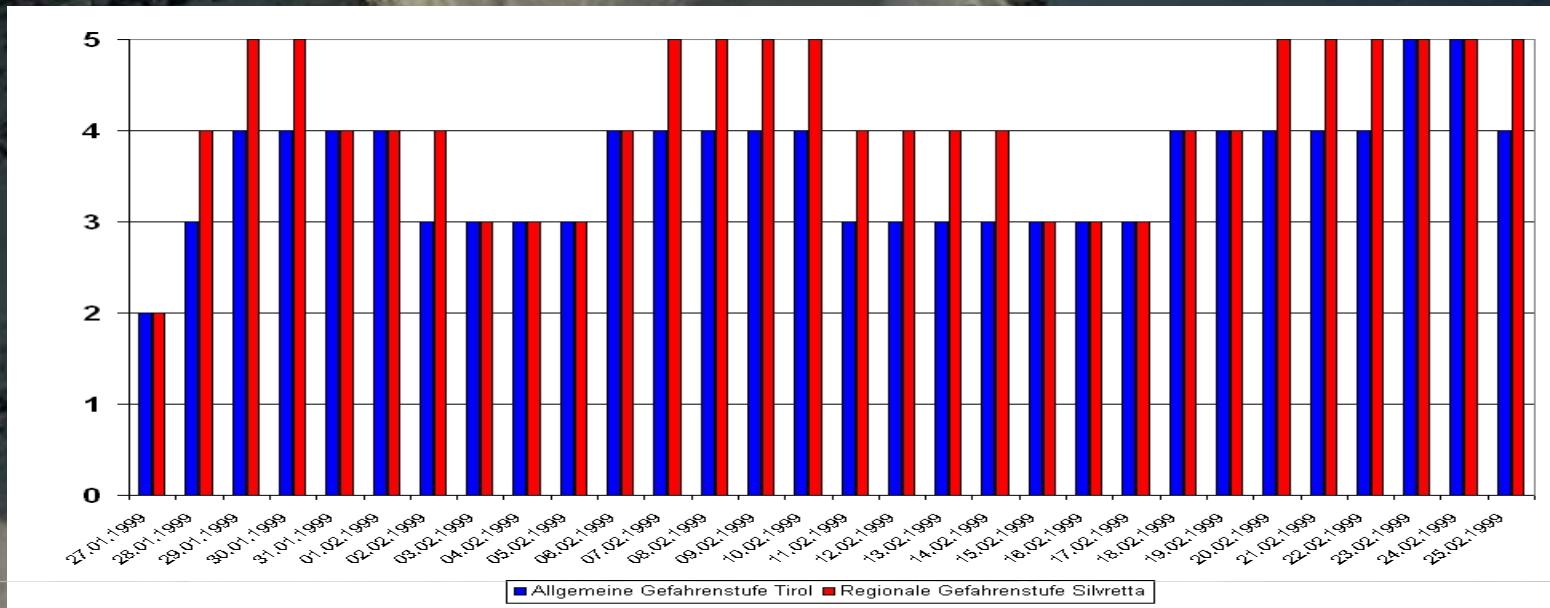
**During third period of precipitation, heavy snowfall again. Overall snow in starting zones many times the average amounts, wind transport increases snow burden, overloaded snowpack ultimately fractures and triggers huge powder snow avalanches.**

# Development of general avalanche danger:



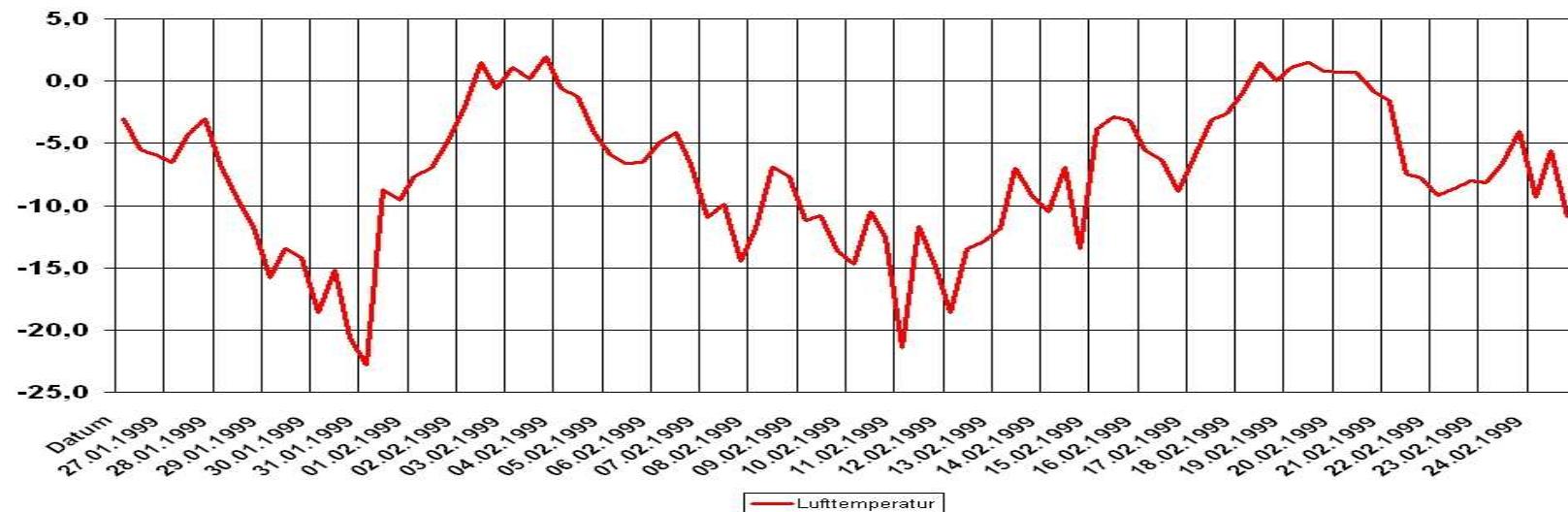
...clearly reflects weather development in winter 1998/99!

# Avalanche danger and discharged avalanches 27.1 - 25.2.99:

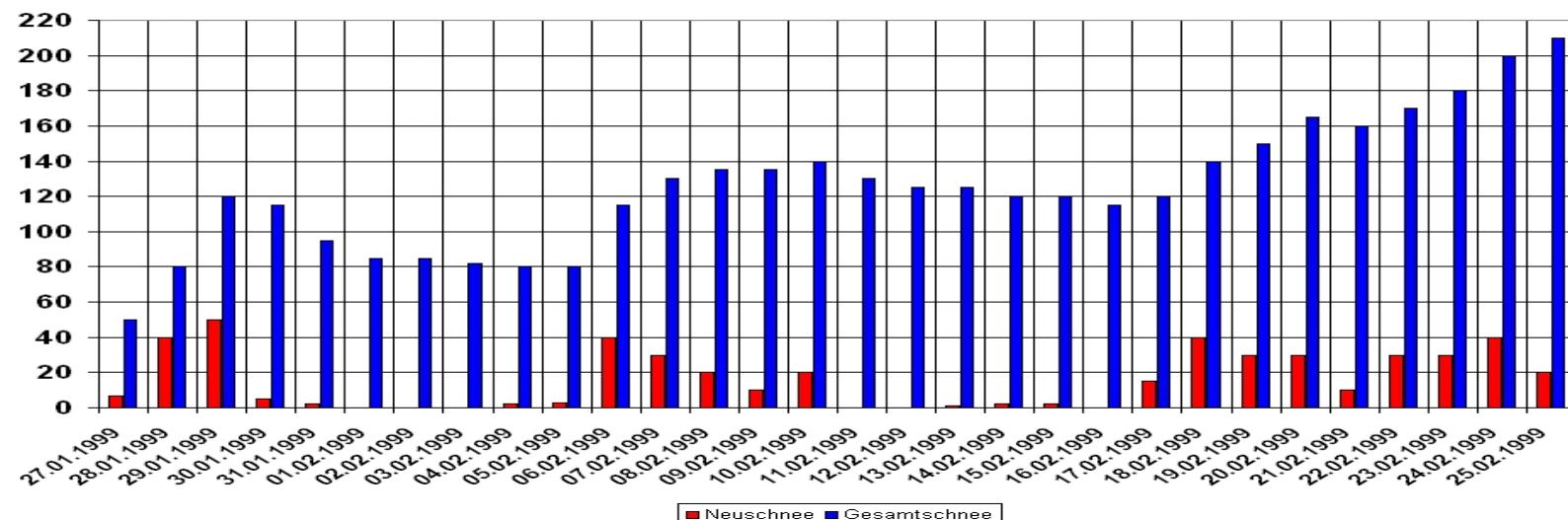


# Weather and snowpack development in Galtuer

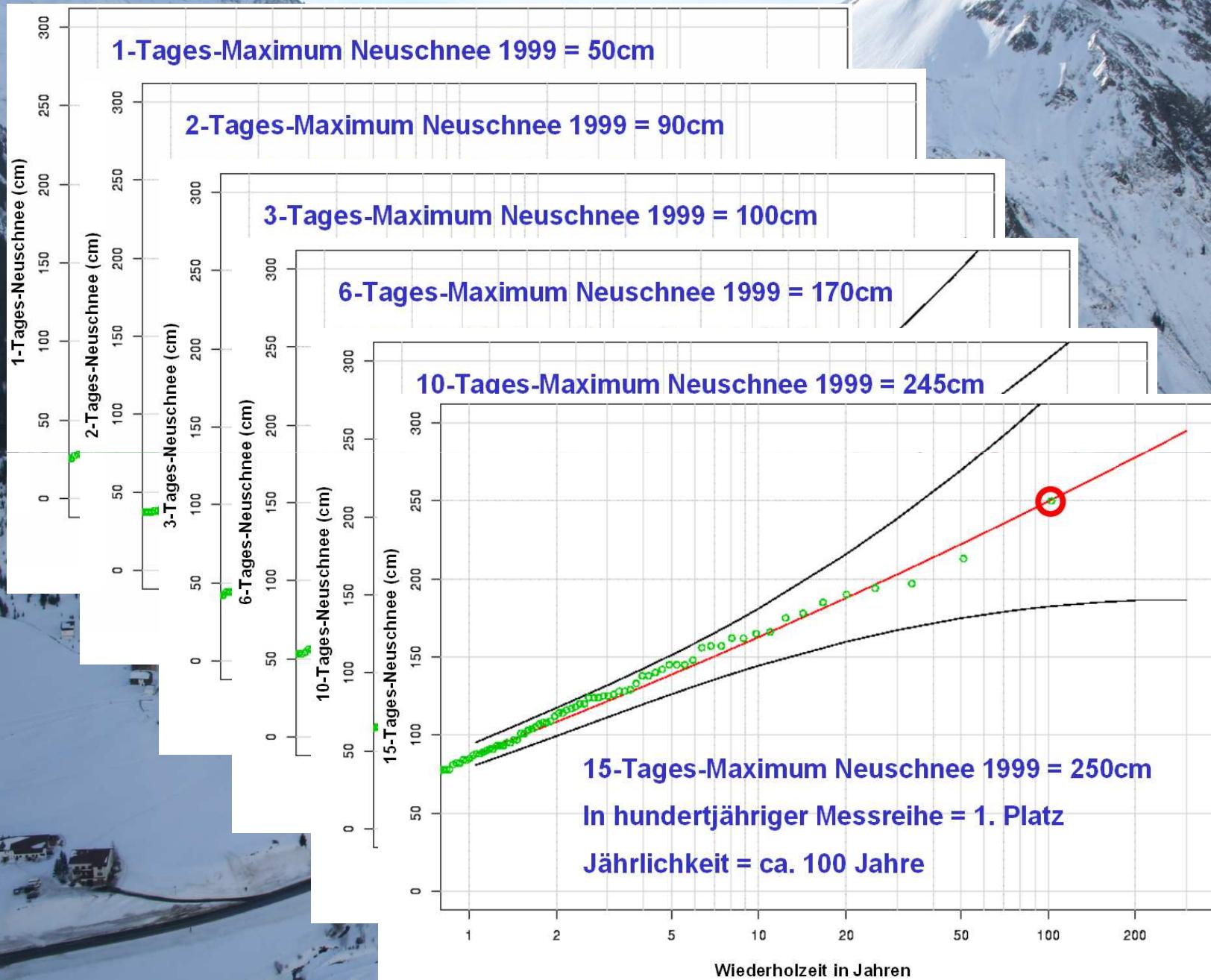
Lufttemperatur (°C) Galtür 27.01.-25.02.1999



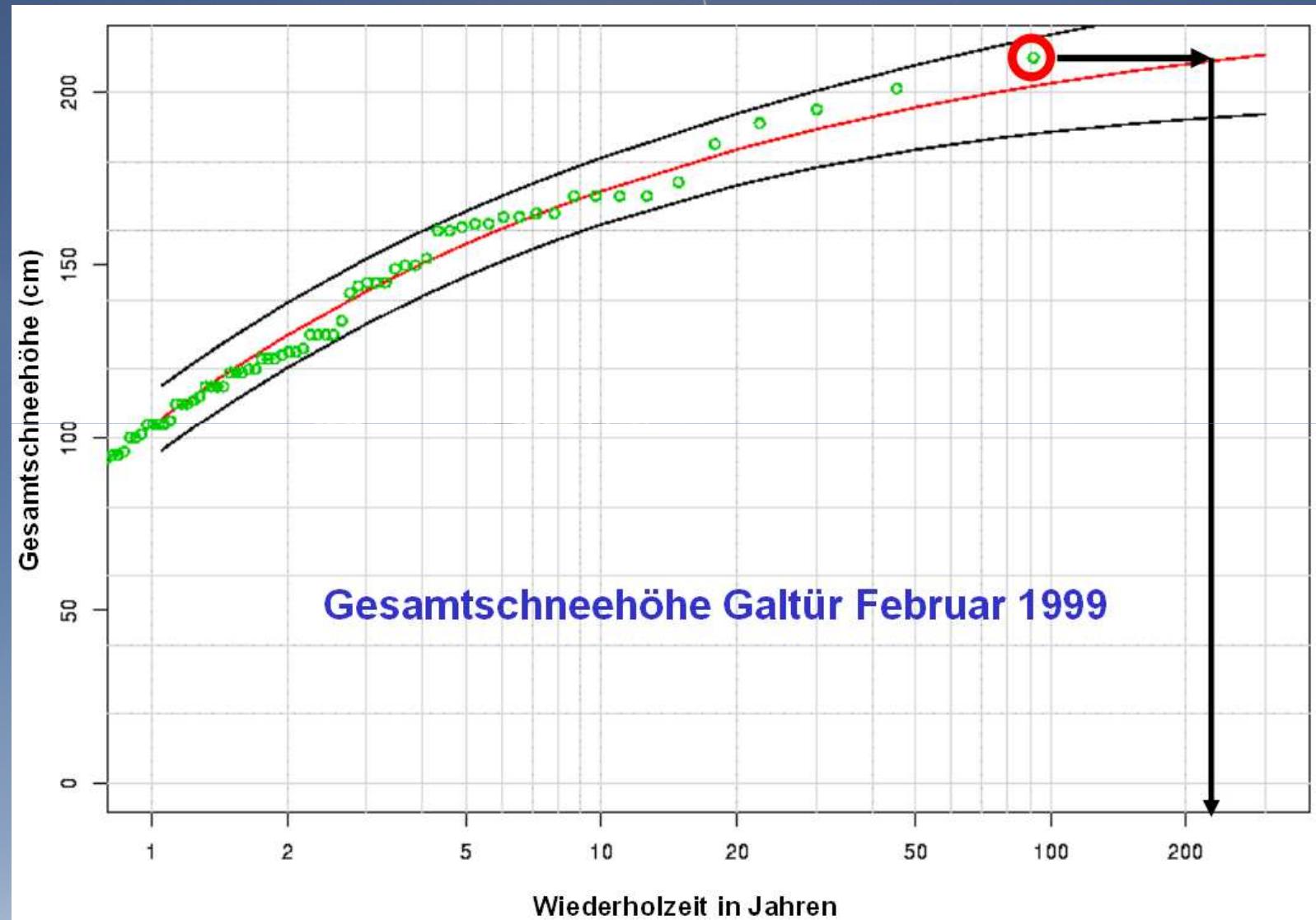
Neuschnee und Gesamtschnee Galtür 27.01.-25.02.1999



# General Extreme Value Distribution GEV



# Overall snow depth Galtuer February 1999



# The avalanche catastrophe



# Fracture area with snow profile

Grieskopf, 2754m



# Innere und Äußere Wasserleiterlawine

Handprofil

www.hanapi.com  
01.03.1999/12:30

Niederschlag: keiner

Temp.: -2,5 °C

Ort: Unterhalb Grieskopf

Höhe: 2570 m

Datum/Ze

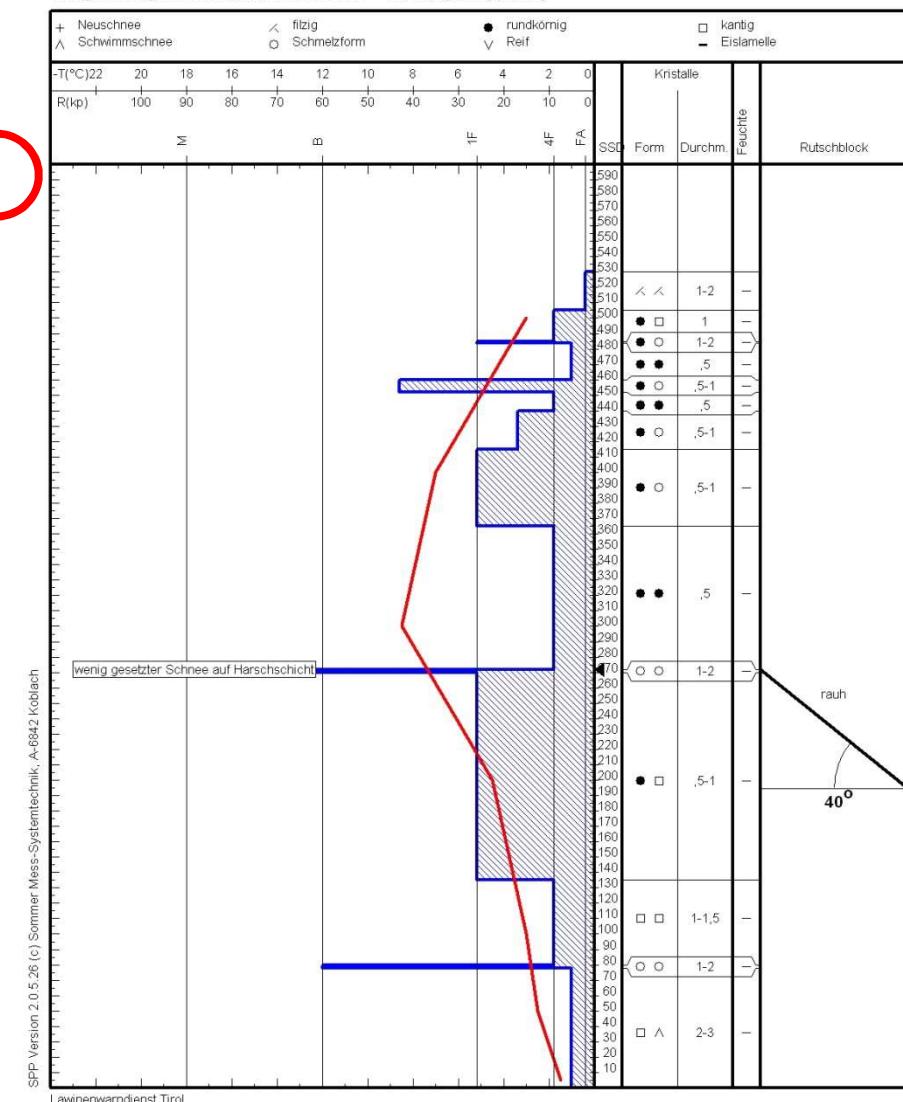
Beobachter: Rudi Mair

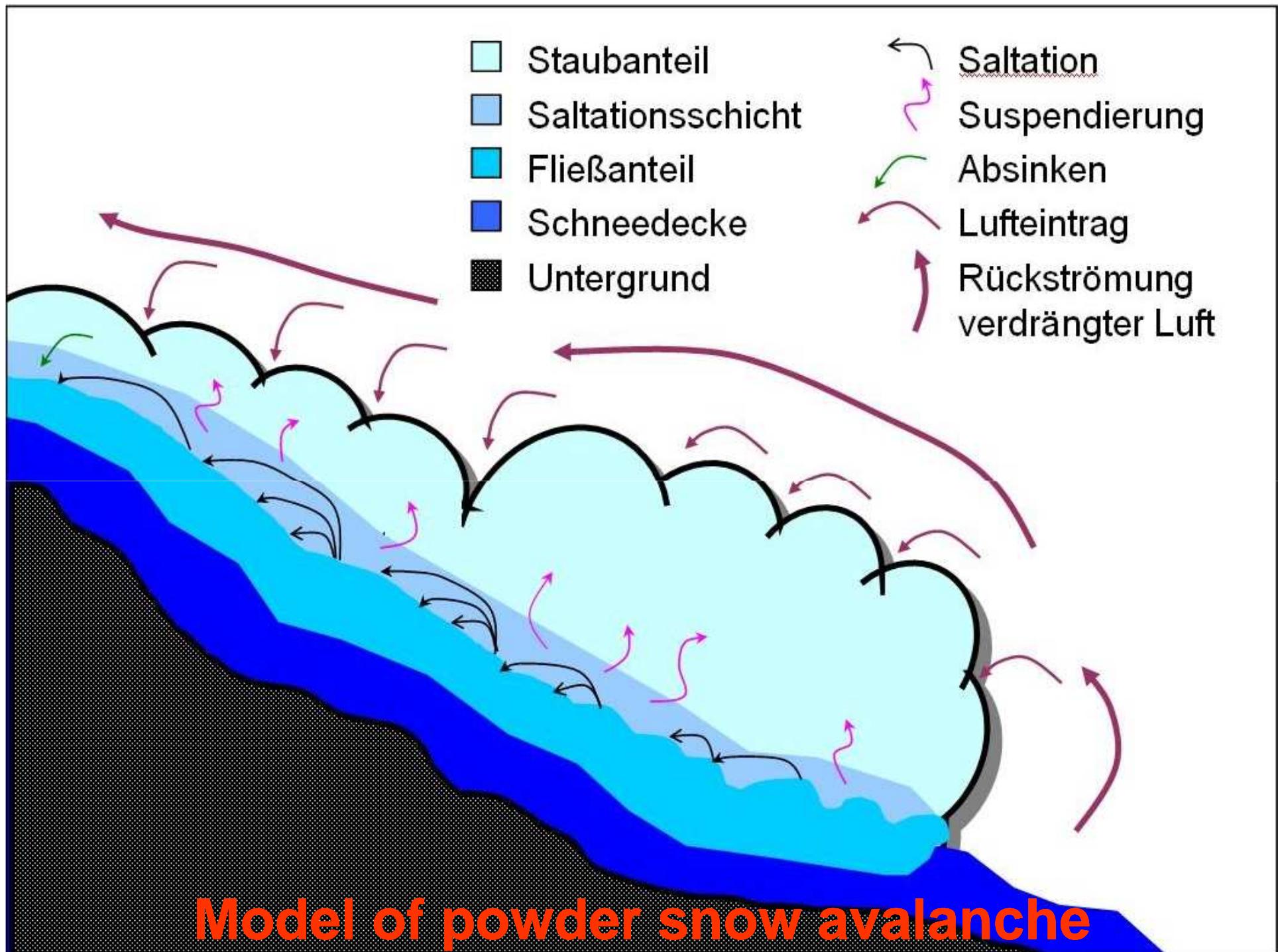
Exposi

Lage Gleitschicht: 272 cm Neigung: 40 Grad

Windst: 25 km/h -richtg: 305 Gra

Sonstiges: Anrissgebiet Katastrophenlawine 23.02.1999

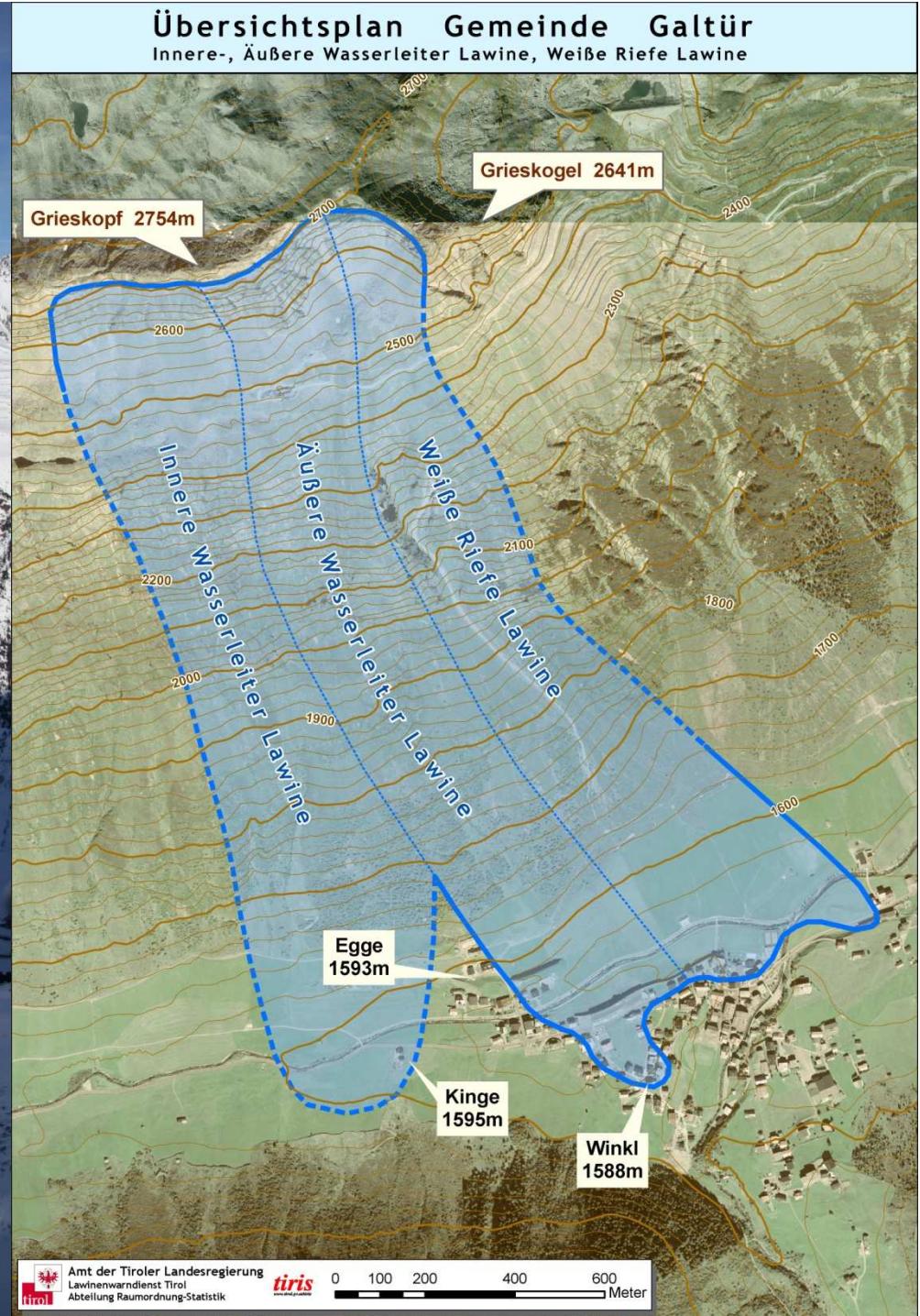
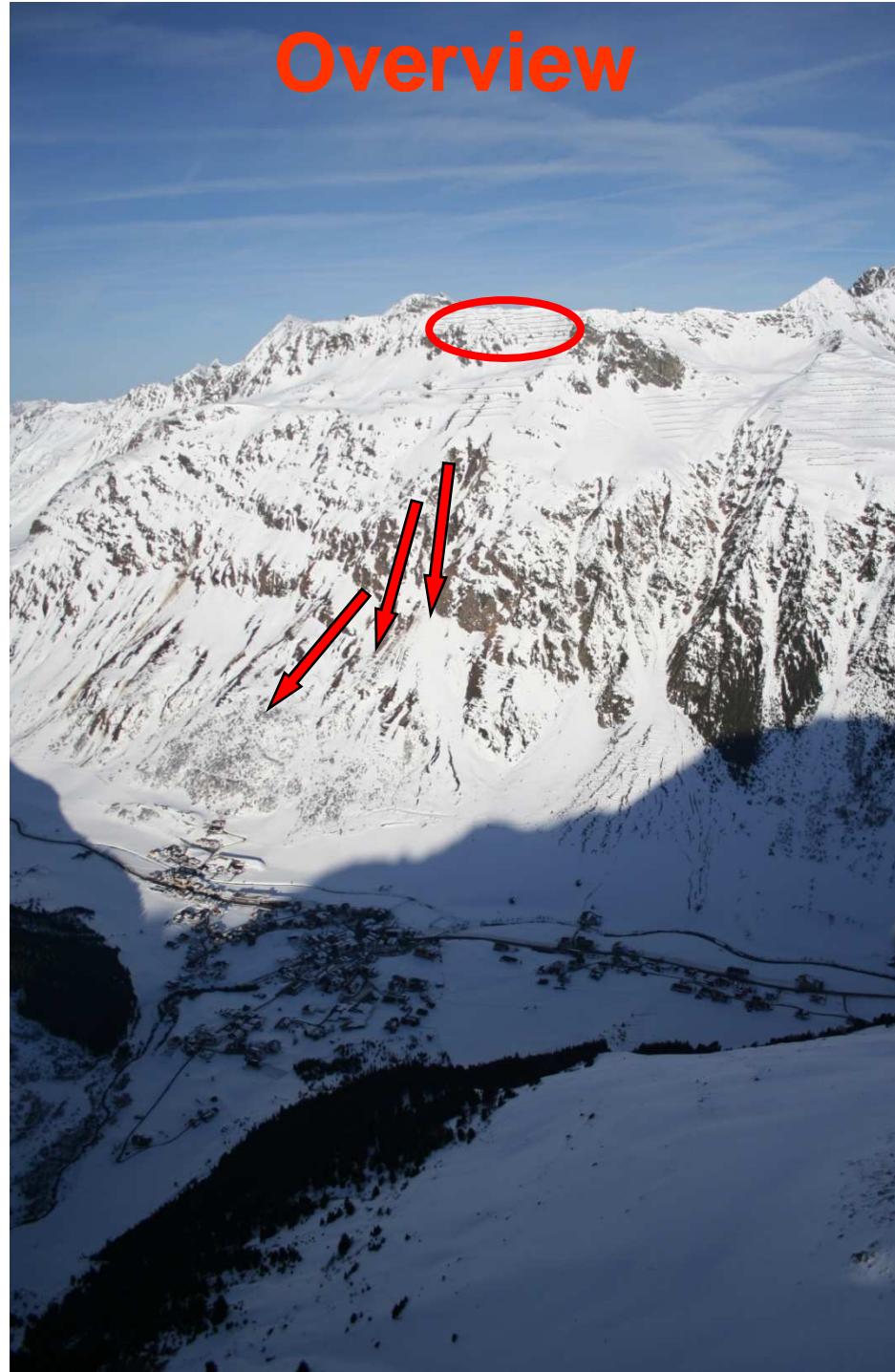




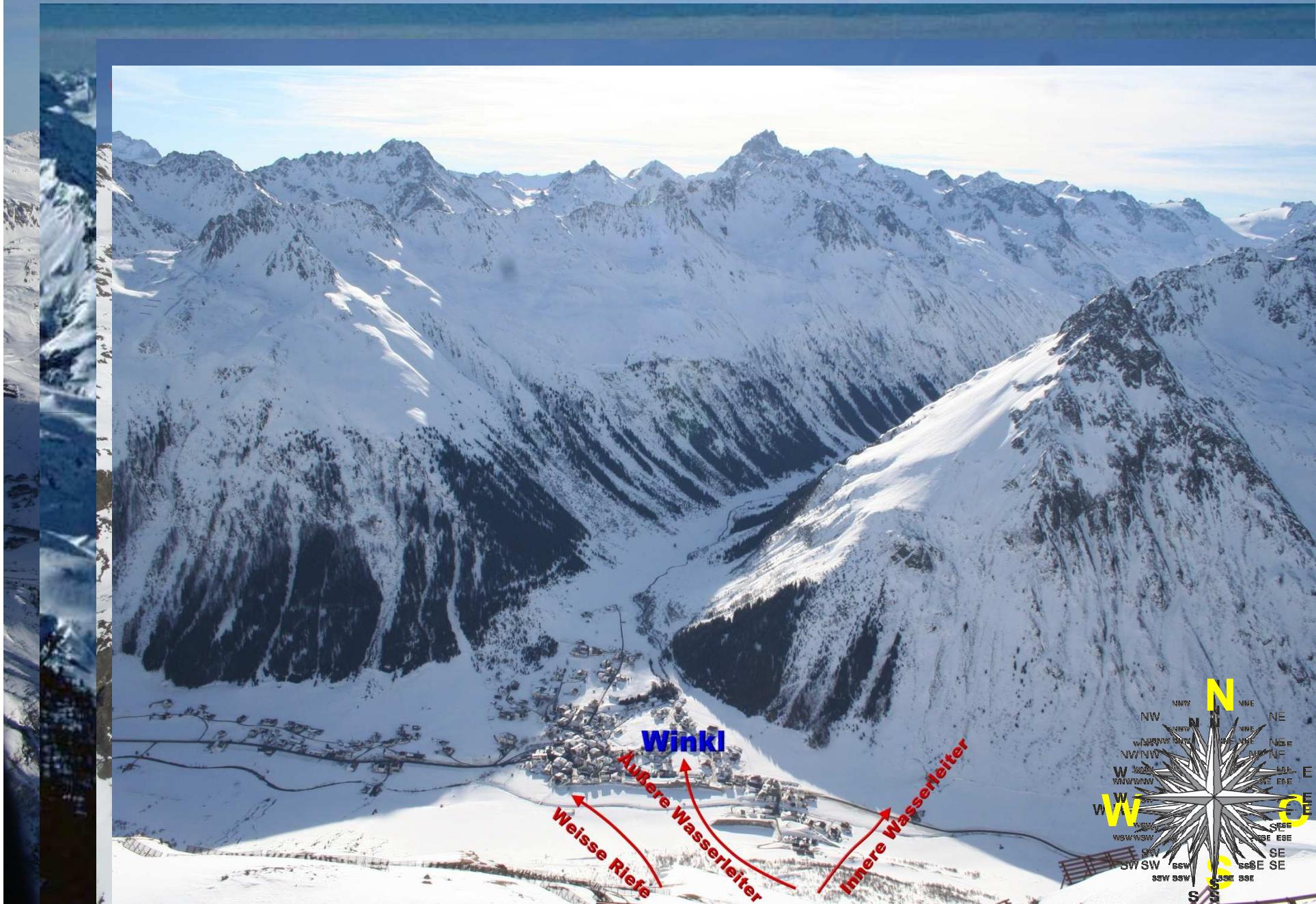
# Powder Snow Avalanche Hochfuegen 24-02-1999



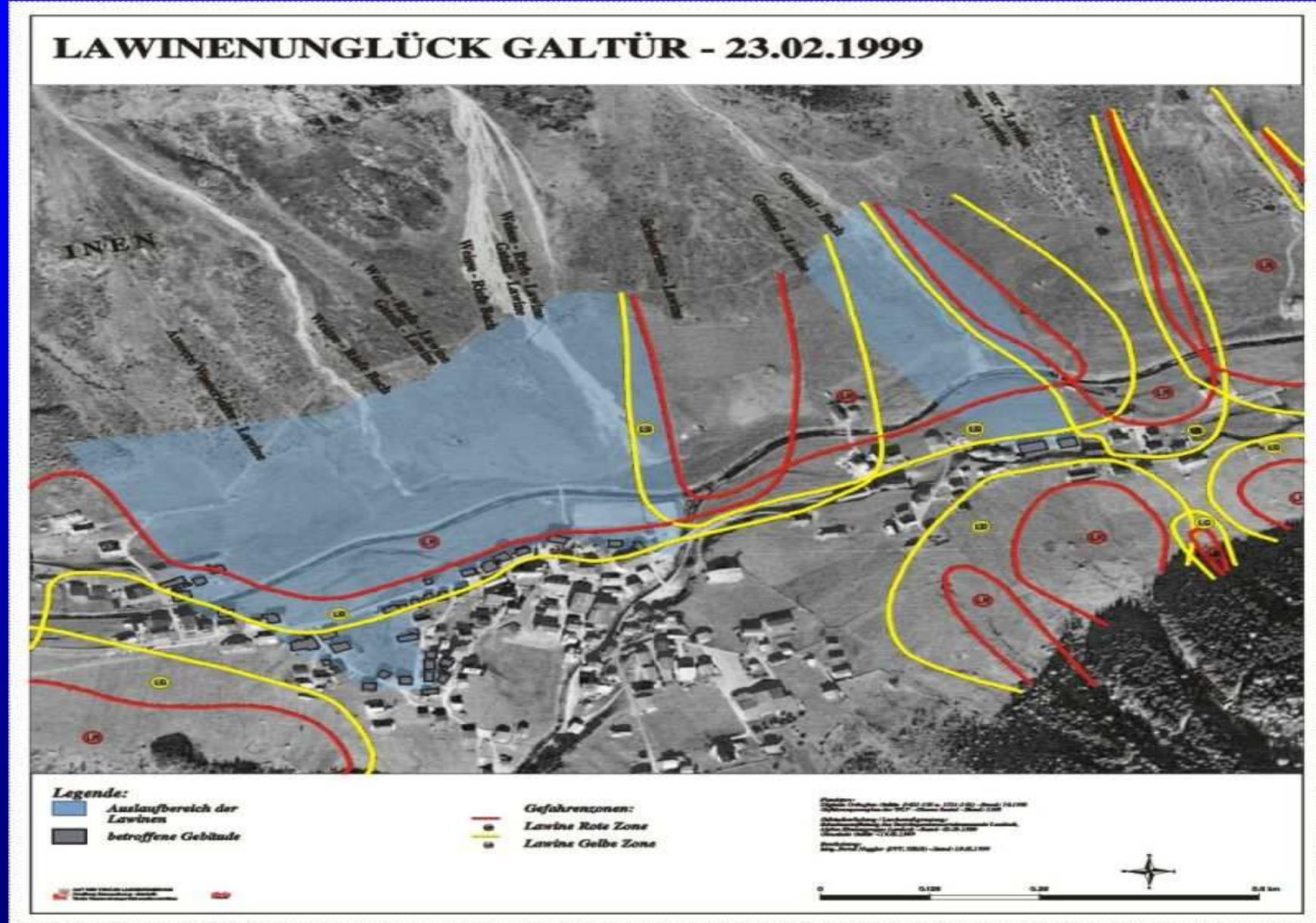
# Overview



# Fracture area and avalanche flow lanes



# Danger zone map Galtuer

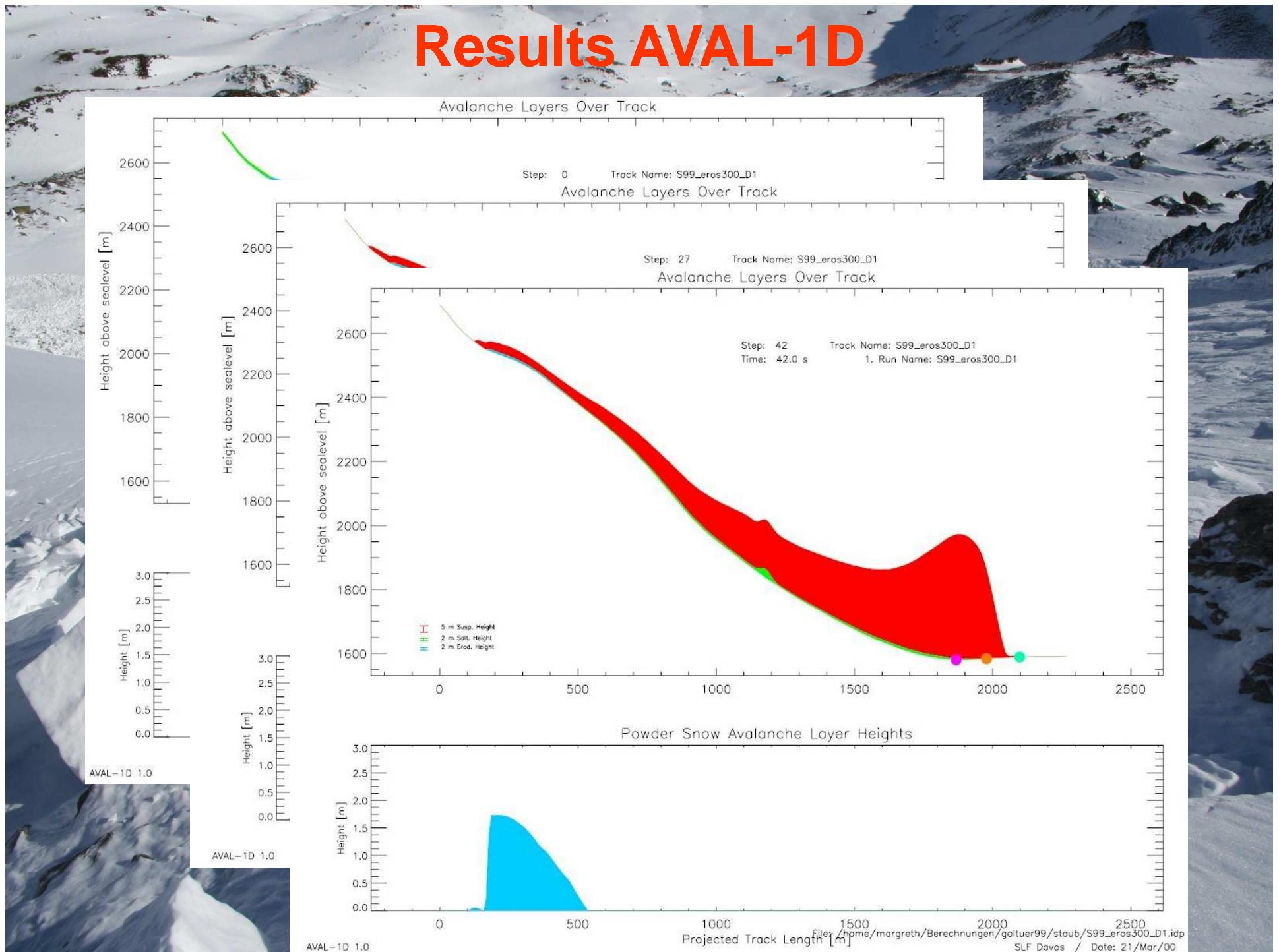


# Avalanche simulation with AVAL-1D

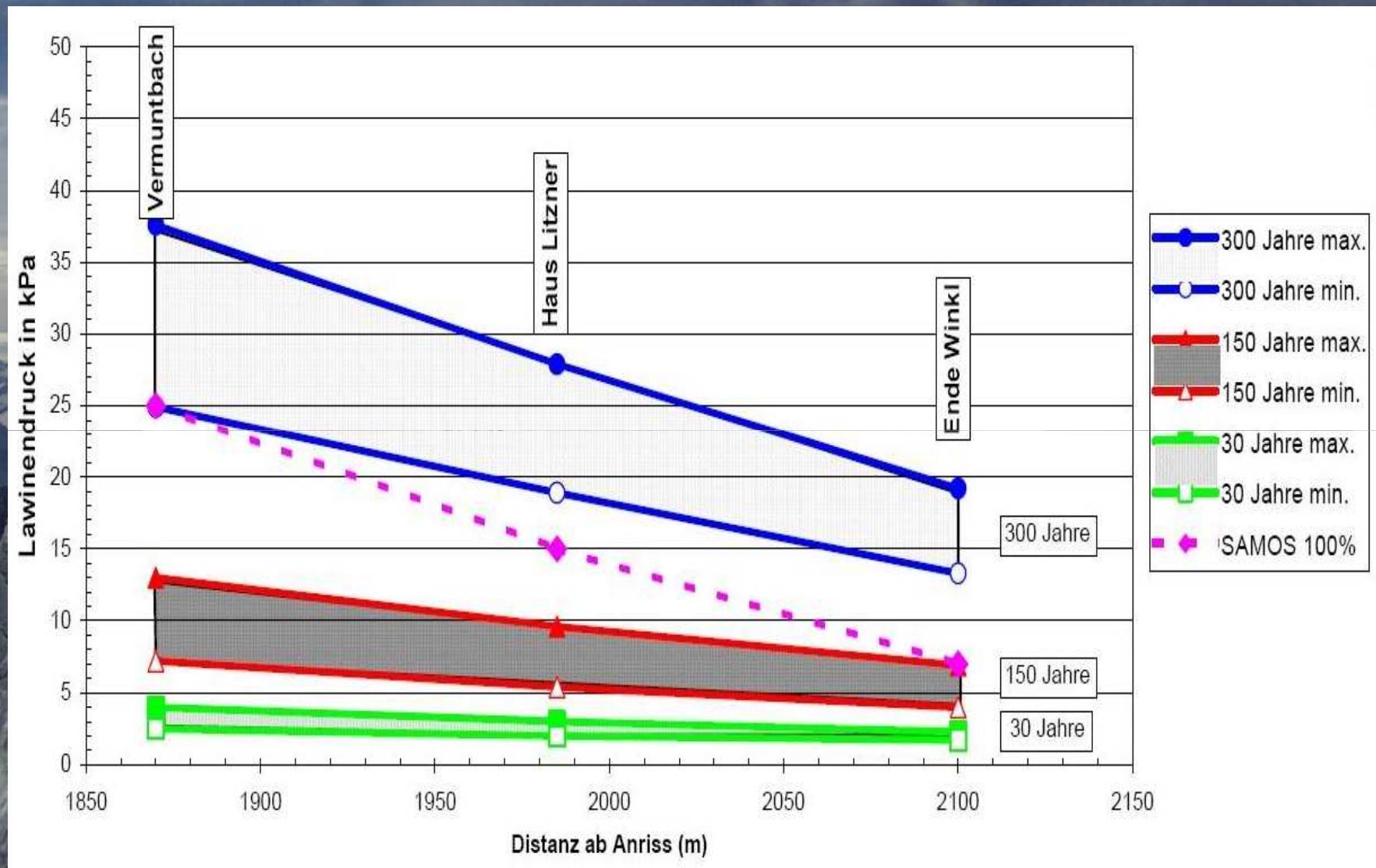
Primary fracture area:	2690 m-2550 m
Fracture depth:	2.8 m
Suspension gradient:	15%
fracture area:	170 kg/m <sup>3</sup>
Density of snowpack flow lane:	190 kg/m <sup>3</sup>
Erodable snow depth and erodability parameter for various flow lane sectors:	2550m-2200m: 2.3-2.0m, 0.23-0.26 m/s 2200m-1900m: 0.8-0.7m, 0.26-0.28 m/s 1900m-1700m: 1.0-0.5m, 0.29-0.30 m/s

Location	Vermuntbach	House Litzner	End Winkl
Max. speed:	116 m/s	117 m/s	116 m/s
Saltation layer: max. density	65.0 kg/m <sup>3</sup>	63.0 kg/m <sup>3</sup>	61.0 kg/m <sup>3</sup>
Saltation layer: max. pressure	62.3 kPa	47.3 kPa	32.4 kPa
Suspension layer: max. density	9.5 kg/m <sup>3</sup>	9.0 kg/m <sup>3</sup>	8.5 kg/m <sup>3</sup>
Suspension layer: max. pressure	30 kPa	27 kPa	24 kPa
Height of avalanche:	95 m	100 m	105 m

# Results AVAL-1D

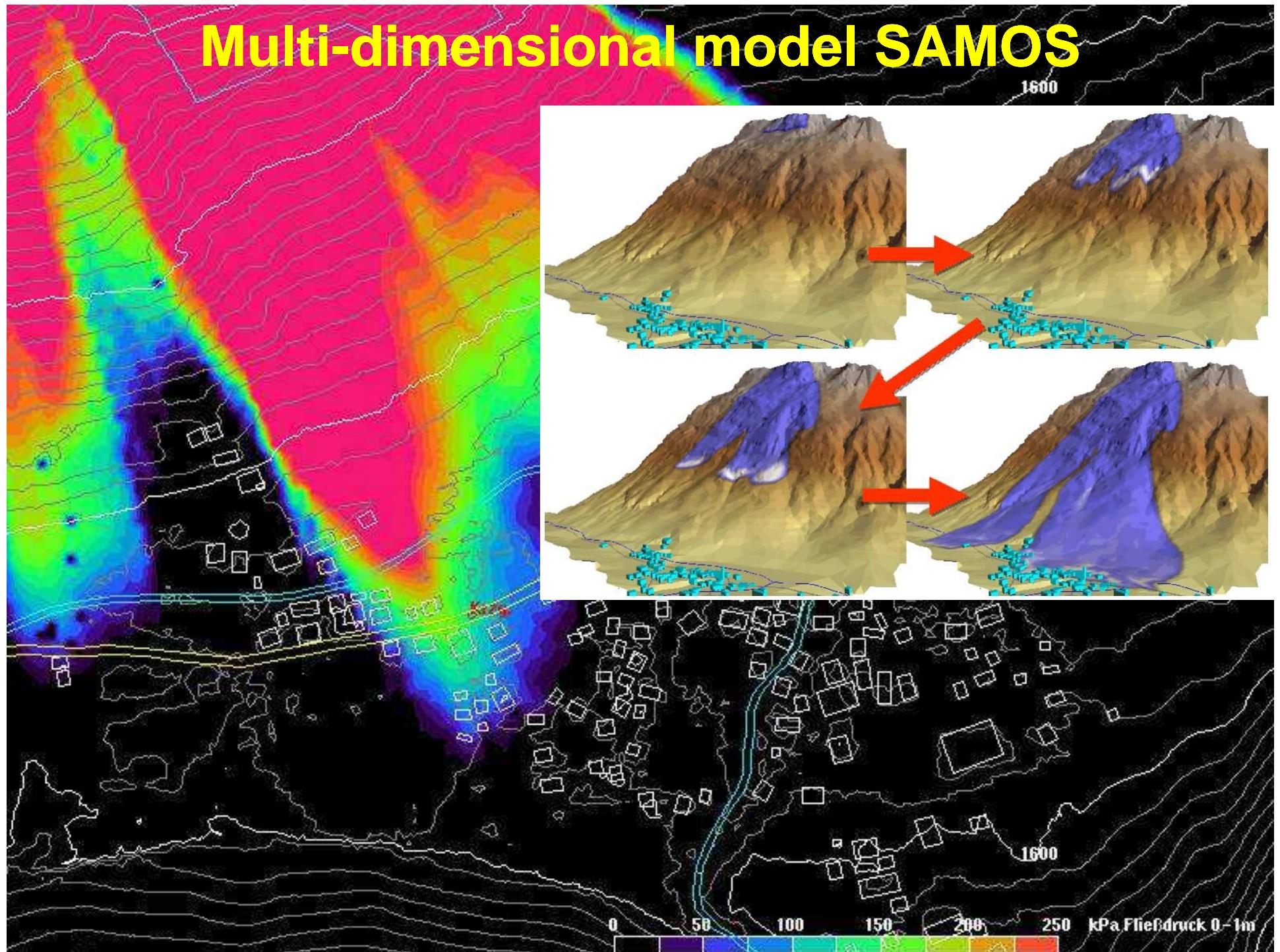


# Calculated Avalanche Pressures...



...and pictures of destruction: estimated pressures >30 - 50 kPa!

# Multi-dimensional model SAMOS



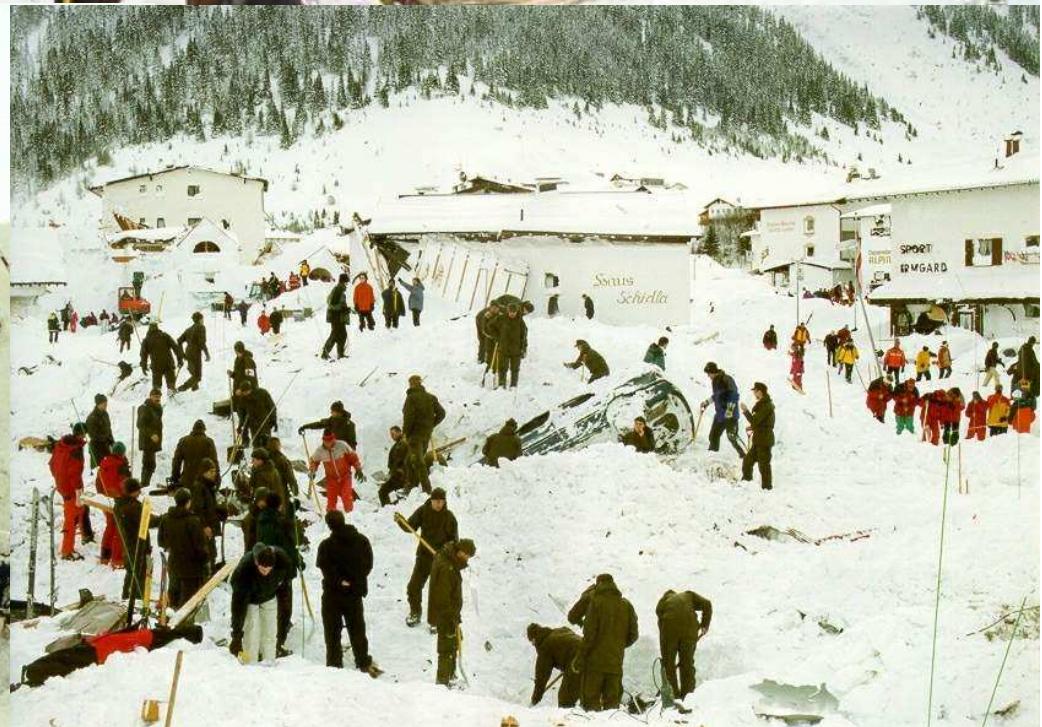


**... the consequences...**

... House 'Litzner' ...



# ... Hotel `Walter`, terrace houses...



# ... Hotel `Luggi` ...

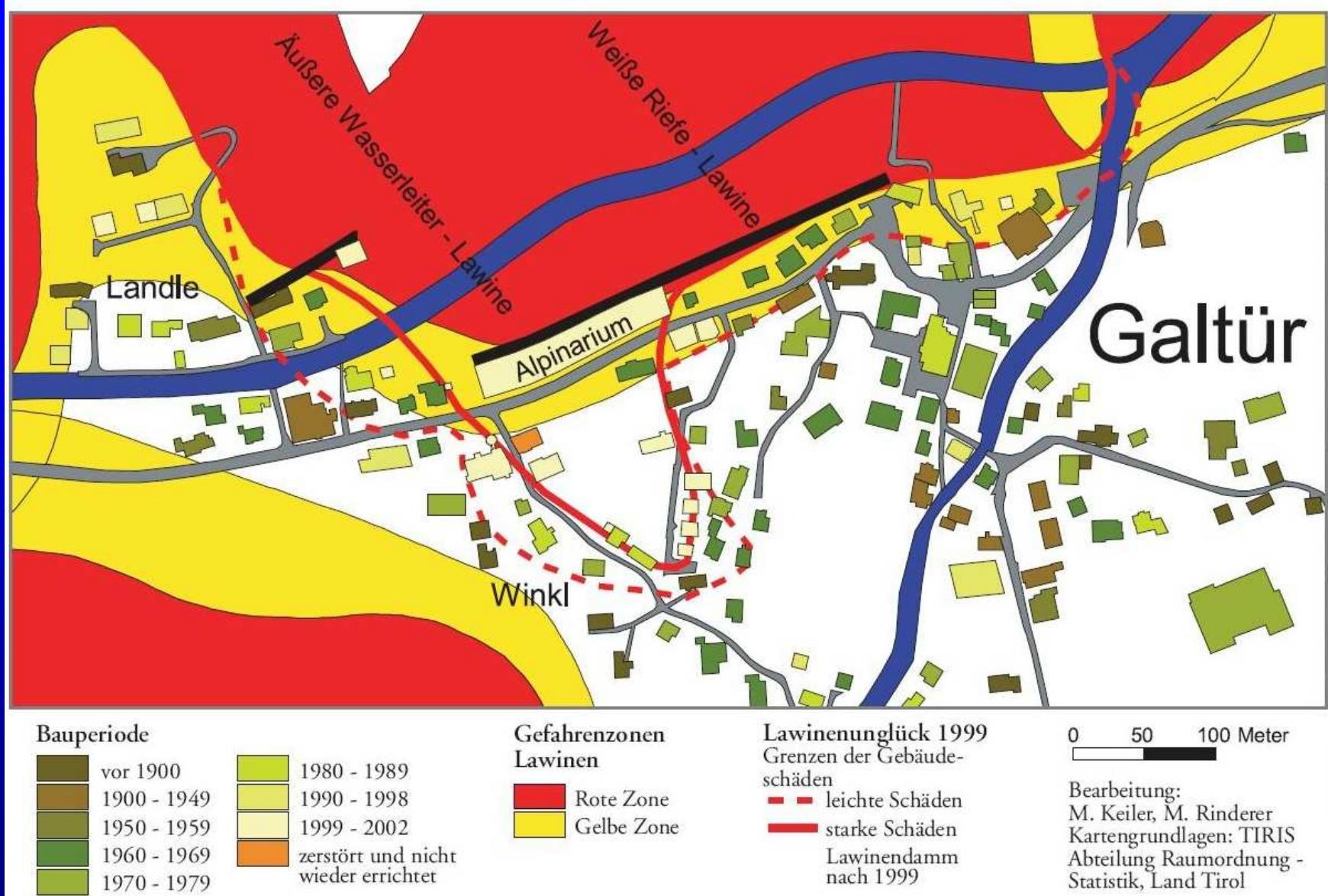






**.. and at 17.03.1999 (3 weeks after catastrophe)...**

# The results: re-mapped danger zones



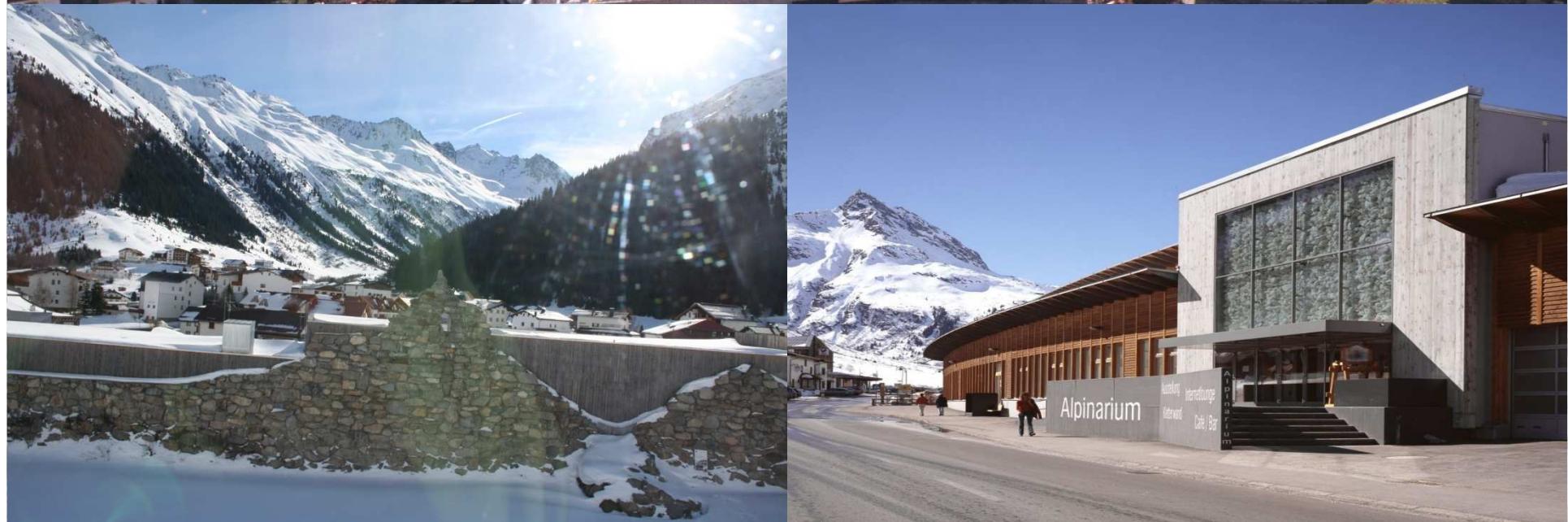
Red Zone limit of 25kPa reduced to 10 Kpa!

**... Protectors of fracture area...**

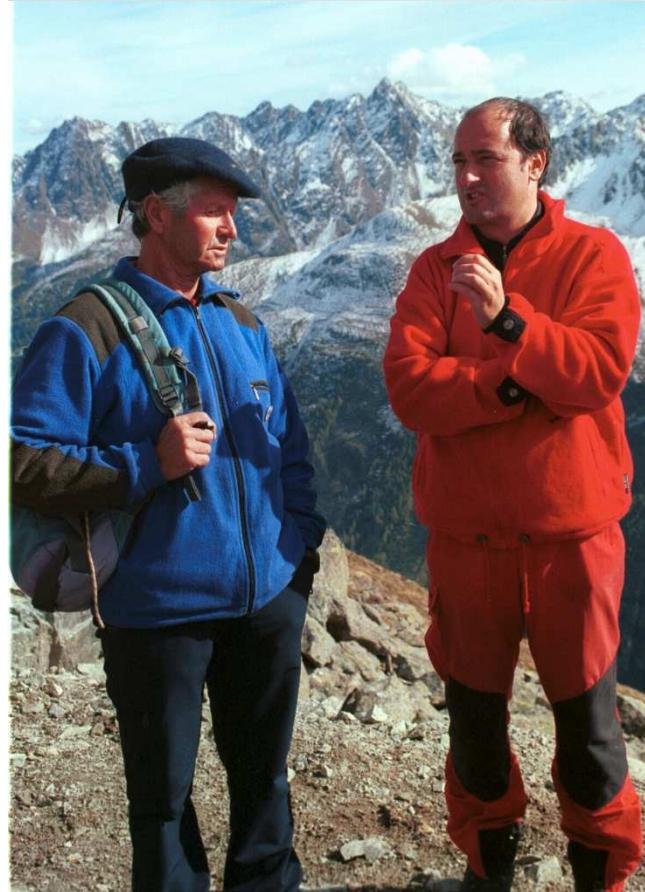




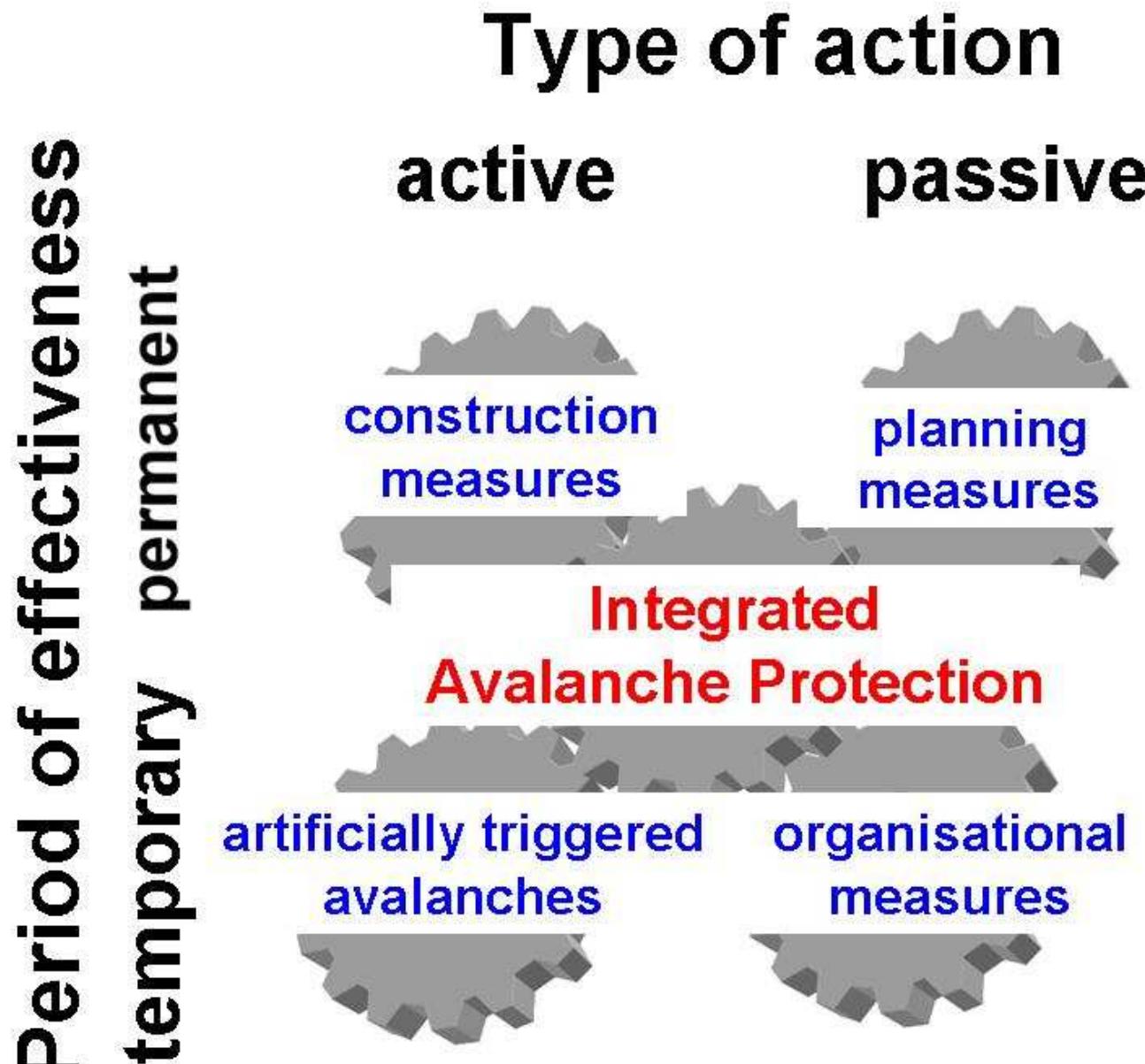
... Protective dams...



**... with automated weather station!**



# Future imperative: integrated avalanche protection!



**Thank you for your attention...**

**The End**