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Preparation of alpine ski pistes

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This Power Point Presentation is intended for FIS alpine technical delegated persons. It has been written by Mathieu Fauve and Hansueli Rhyner from the Swiss Federal Institute for Snow and Avalanche Research, Davos and completed by Thomas Gurzeler. It is a tool for the alpine race supervisors, officials, coaches and Athletes, who strive for a safe race. The use and modifications of this presentation are possible only with permission from Hansueli Rhyner.

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Preparation of alpine ski pistes

Aim

The aim is to transform a soft snow into a:

- hard
- homogeneous

piste

Proceed

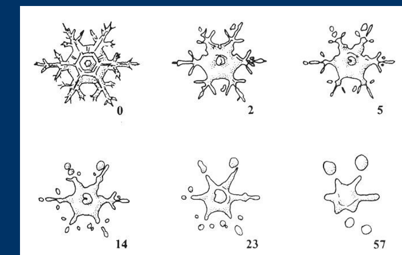
Use of mechanical equipment taking into account the physical properties of snow and the meteorology

Special

Race pistes have to be prepared with special methods in order to obtain very high strength

Preparation of alpine skiing slopes

physical properties of snow



snow and meteorology

mechanical handling of snow

preparation and maintenance of race pistes

Physical properties of snow

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Snow is a very particular material:

➔ composed of air and water in all its forms: solid (ice), gas (water vapour) and possibly liquid (liquid water)

➨ near its melting point (0°C), so extremely sensitive to variations of temperature and pressure and reacts rapidly

➨ exists in different forms and is subjected to a continuous transformation

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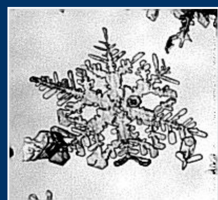
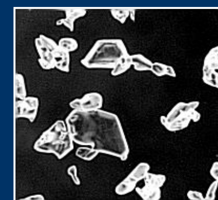
Snow grains

new snow



+

faceted crystals



□

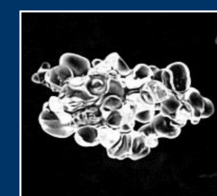
fragmented precipitation particles

/

surface hoar

V

melt-freeze snow



○

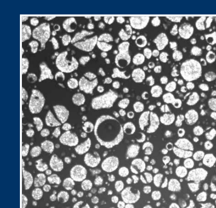
rounded grains

●

depth hoar

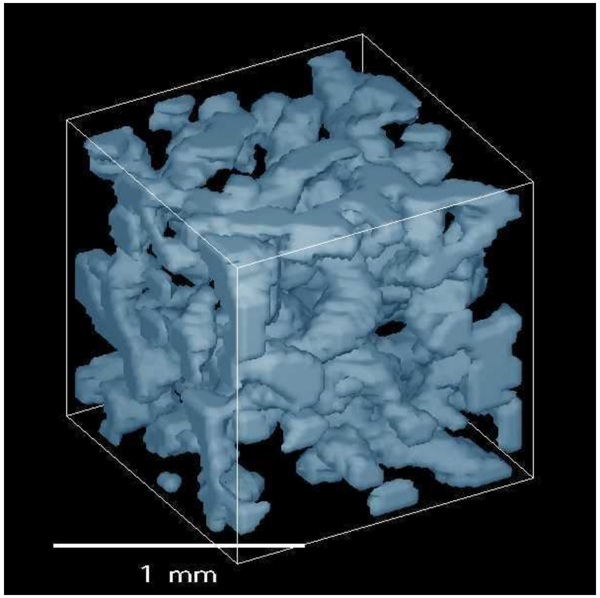
Λ

machine-made snow

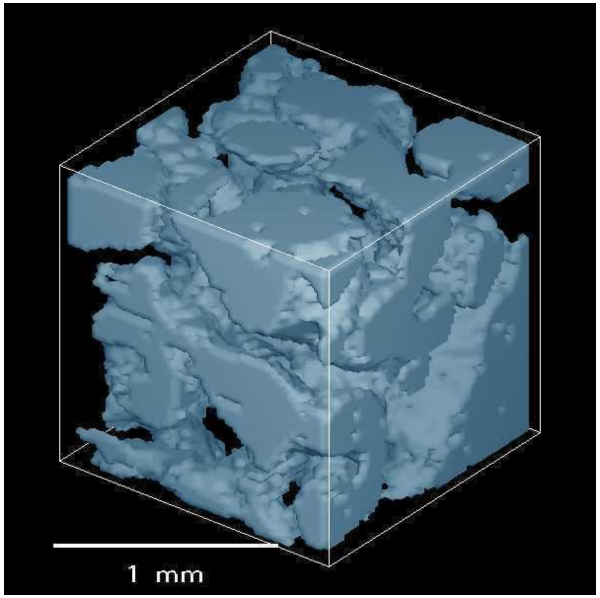


◎

Snow density



low density snow (220 kg/m³)



high density snow (516 kg/m³)

- new snow density: between 50 and 250 kg/m^3
- average ski slope density : 480 kg/m^3
- downhill racing slope density: 300 - 500 kg/m^3
- super-G racing slope density: approx. 550 kg/m^3
- slalom racing slope density: approx. 600 kg/m^3

Snow strength

snow

- grain type
- density
- bonds between the grains:

strength

dry snow:
stellar interlocking
sintering

wet snow:
capillary
freezing

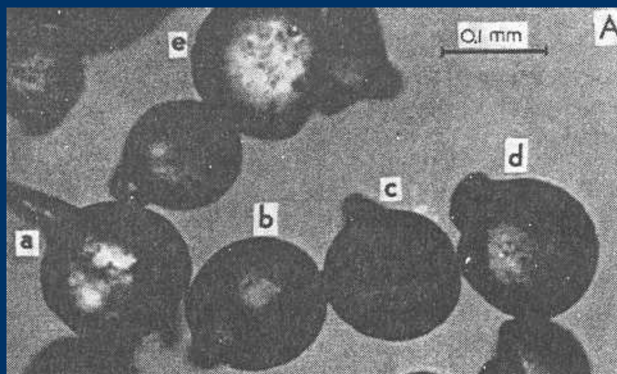
Strength by stellar interlocking

- concerns only new snow stellar crystals
- branches are connected to each other

➔ **weak and non-lasting strength**

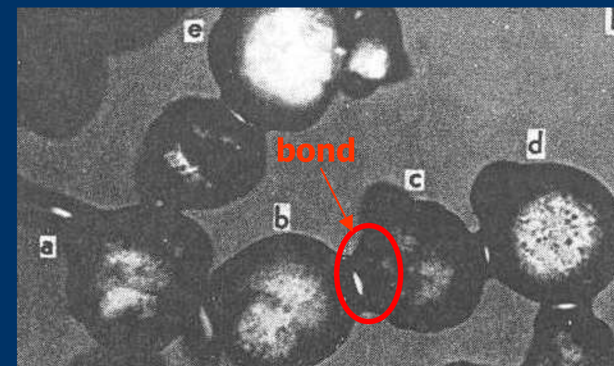
Strength by sintering

sintering: building of solid bonds between snow grains by water vapour transport



T = -1.5°C

after 165 min



(Kuroiwa, 1974)

➡ the building of the bonds and the increasing of their size depend on the following parameters:

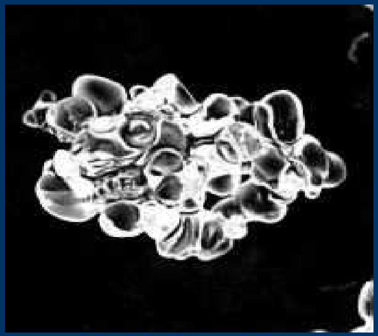
- **temperature** (process faster near 0°C)
- **grain type** (shape, mean size, size distribution)
- **density** (number of contact points)
- **time** (process needs time)

Strength of wet snow

- liquid water is held on grains by capillarity as long as its volume is lower than 5 to 10% (depending on the grain size) of the total volume. Small grains can hold more water than bigger ones.

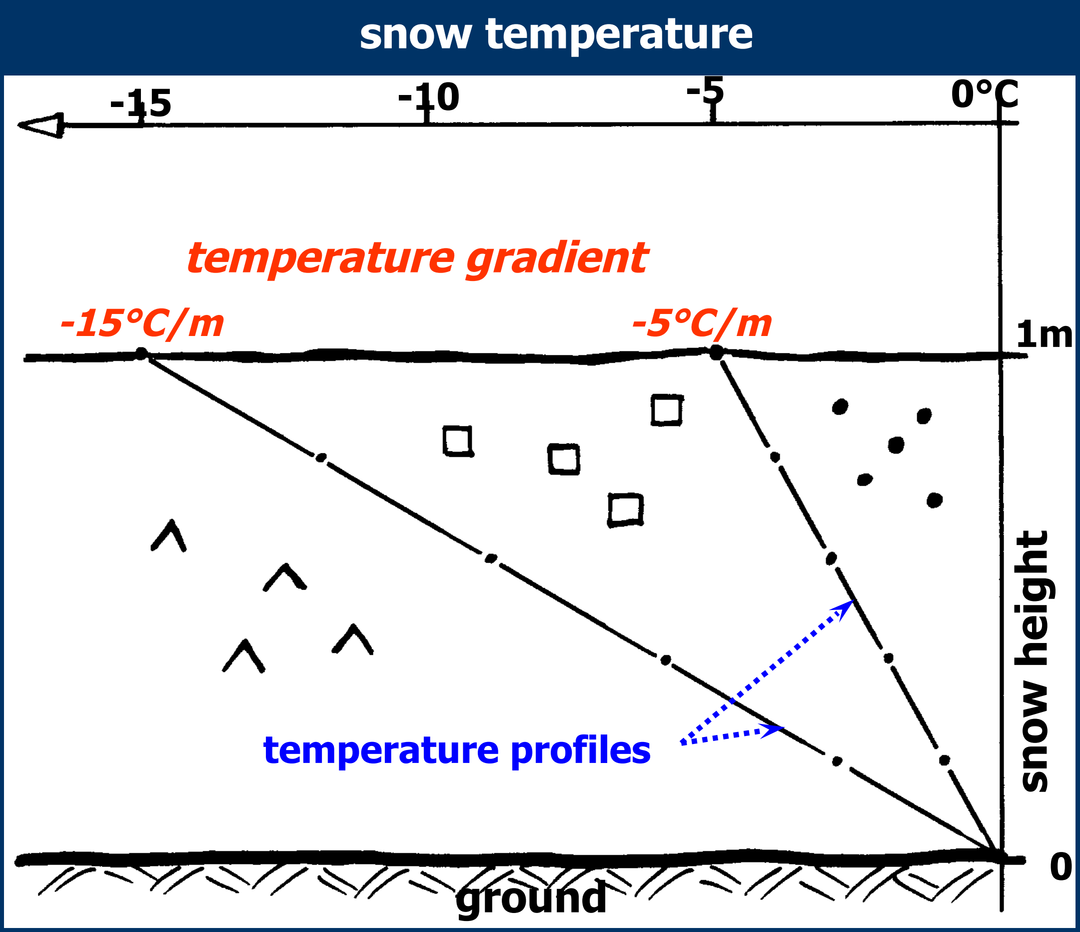
- when the liquid water content (L.W.C.) is high, bonds melt and snow becomes softer

- when the liquid water freezes, strong bonds built between the grains



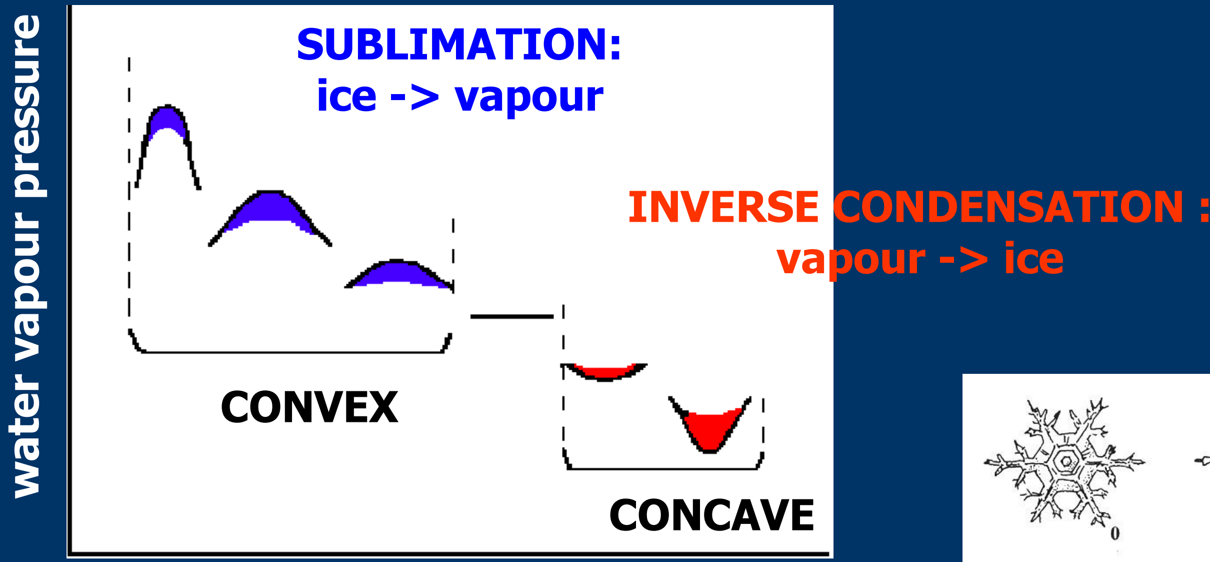
Snow metamorphism

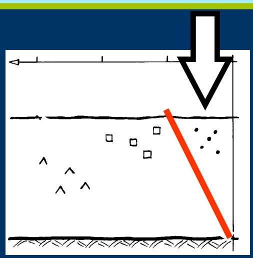
Snow metamorphism depends on the temperature gradient in the snowpack



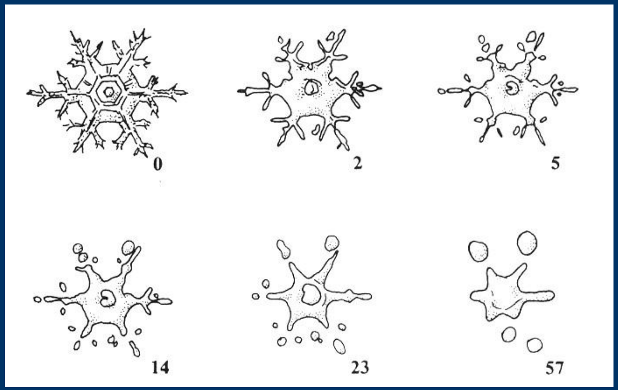
$$T_G = \frac{dT}{dz}$$

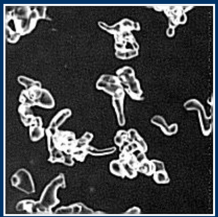
Destructive metamorphism





$T_G < 5$ °C/m

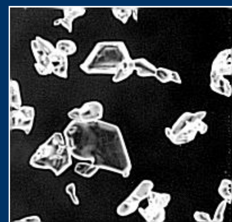




- mass transport from convex to concave zones
- building of small (0.2 to 0.75 mm) round grains
- formation and size increase of inter-granular bonds (sintering)
- slow process

Constructive metamorphism

medium gradient



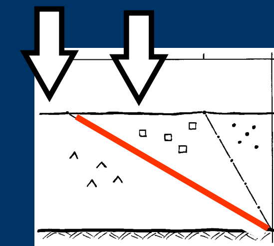
□

faceted grains
(1 to 3 mm)

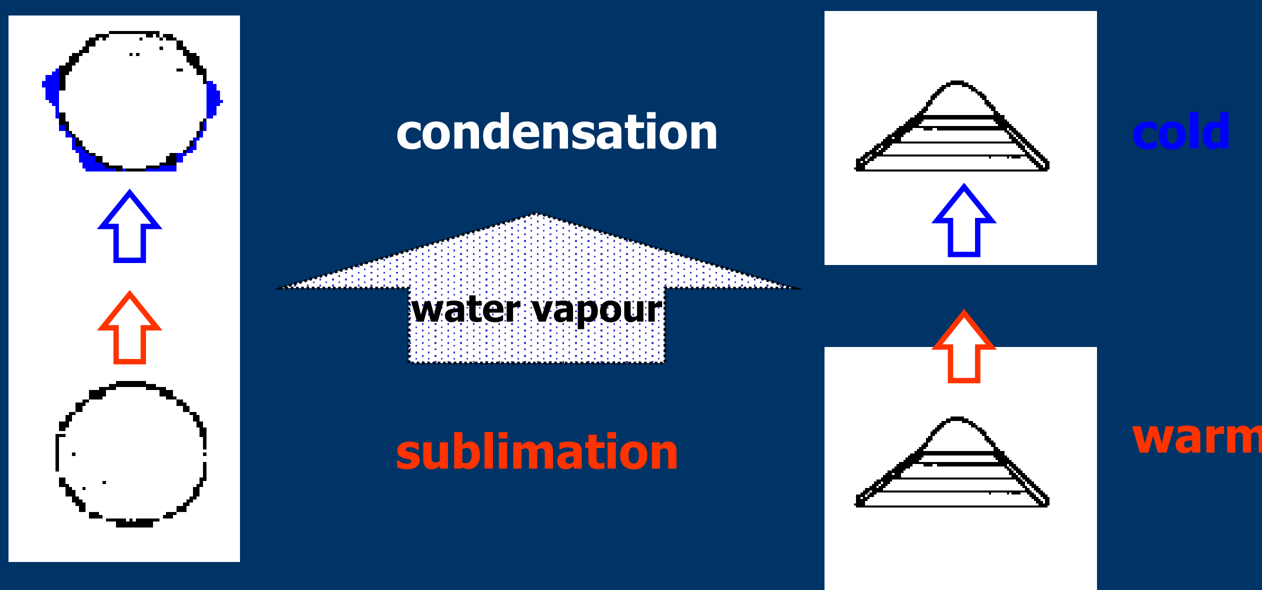
high gradient

Λ

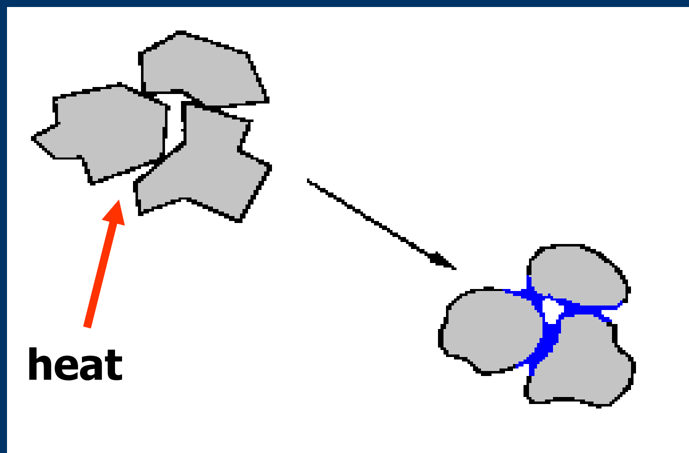
depth hoar
(1.5 to 5 mm)

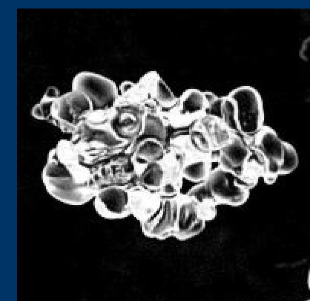


$T_G > 5$ °C/m

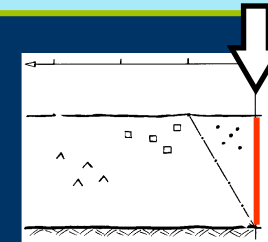


Melt-freeze metamorphism





0.5 to 4 mm ○



T = 0°C
L.W.C. > 0

- grains become rounder and bigger
- influence of the liquid water content:

  - non-saturated snow (L.W.C. < 8 to 15% vol.)
    ➔ clusters
  - saturated snow (L.W.C. > 8 to 15% vol.)
    ➔ no cohesion

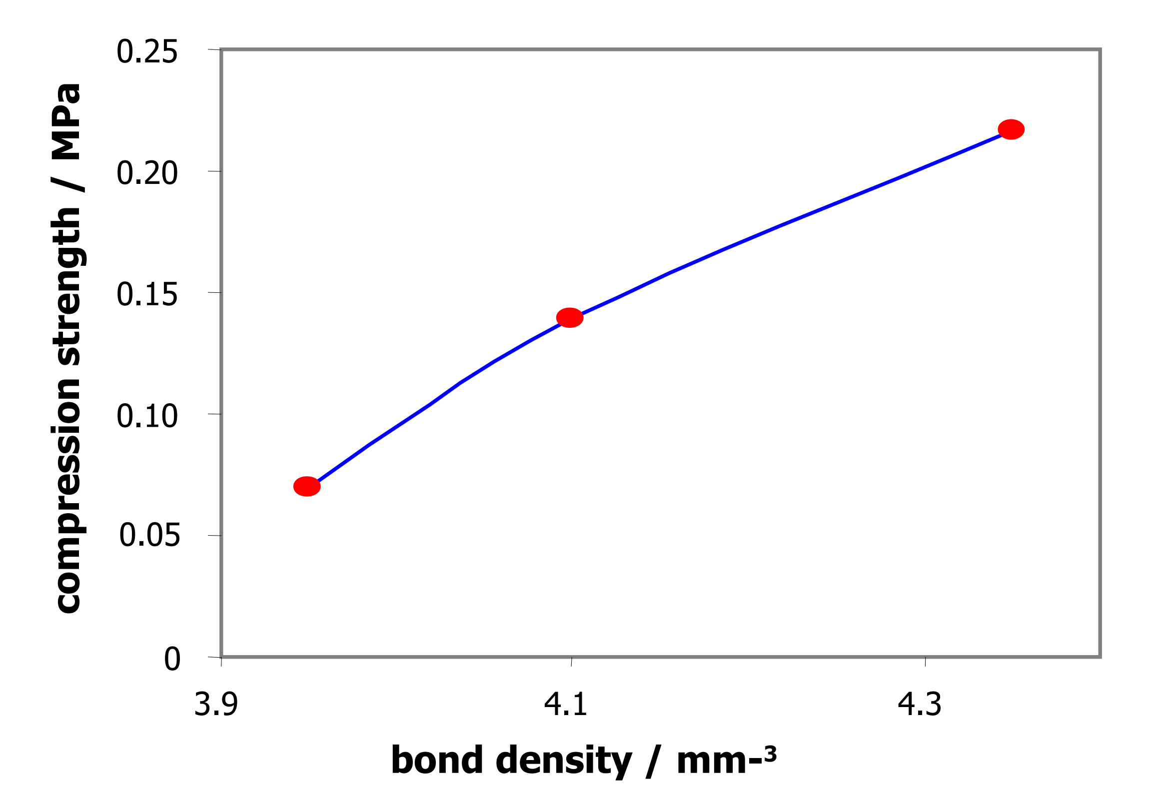
Mechanical properties of snow

The mechanical properties of snow mostly depend on the following parameters:

- bonds
- density
- temperature
- liquid water content

Mechanical properties of snow

bonds



➨ the more bonds that exist and the larger they are, the higher the snow's resistance is

Mechanical properties of snow

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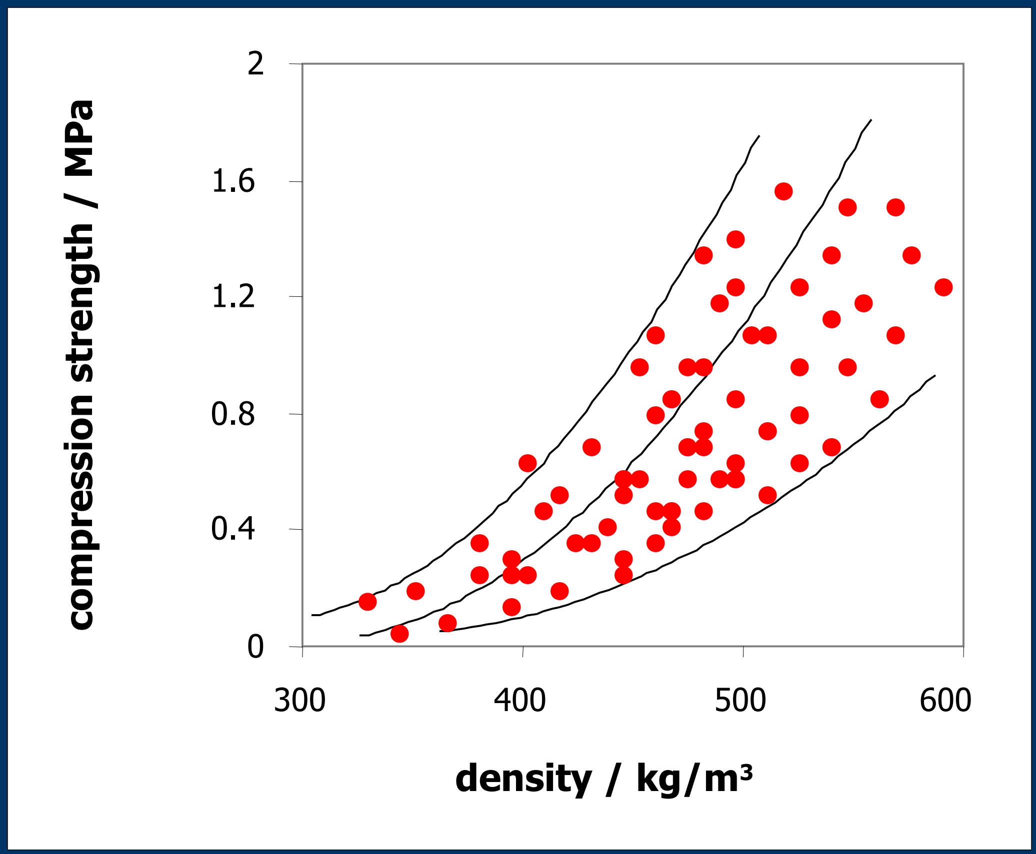
density



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➨ usually, the denser the snow, the more resistant and tough it is

Mechanical properties of snow

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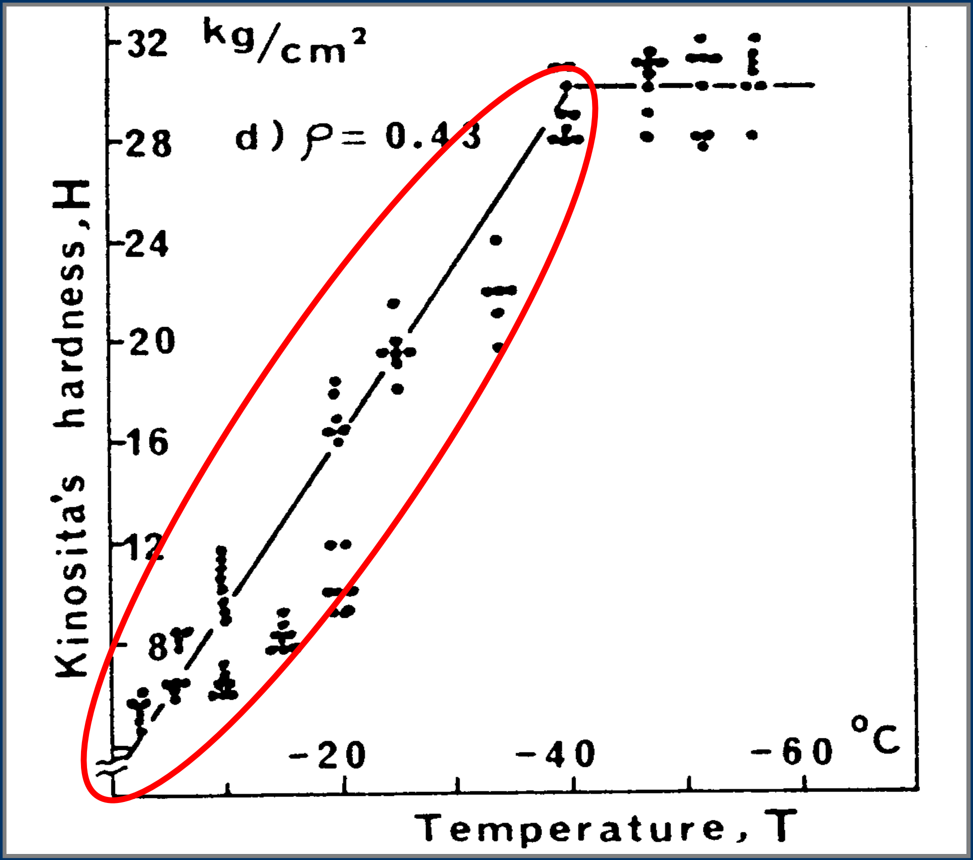
temperature

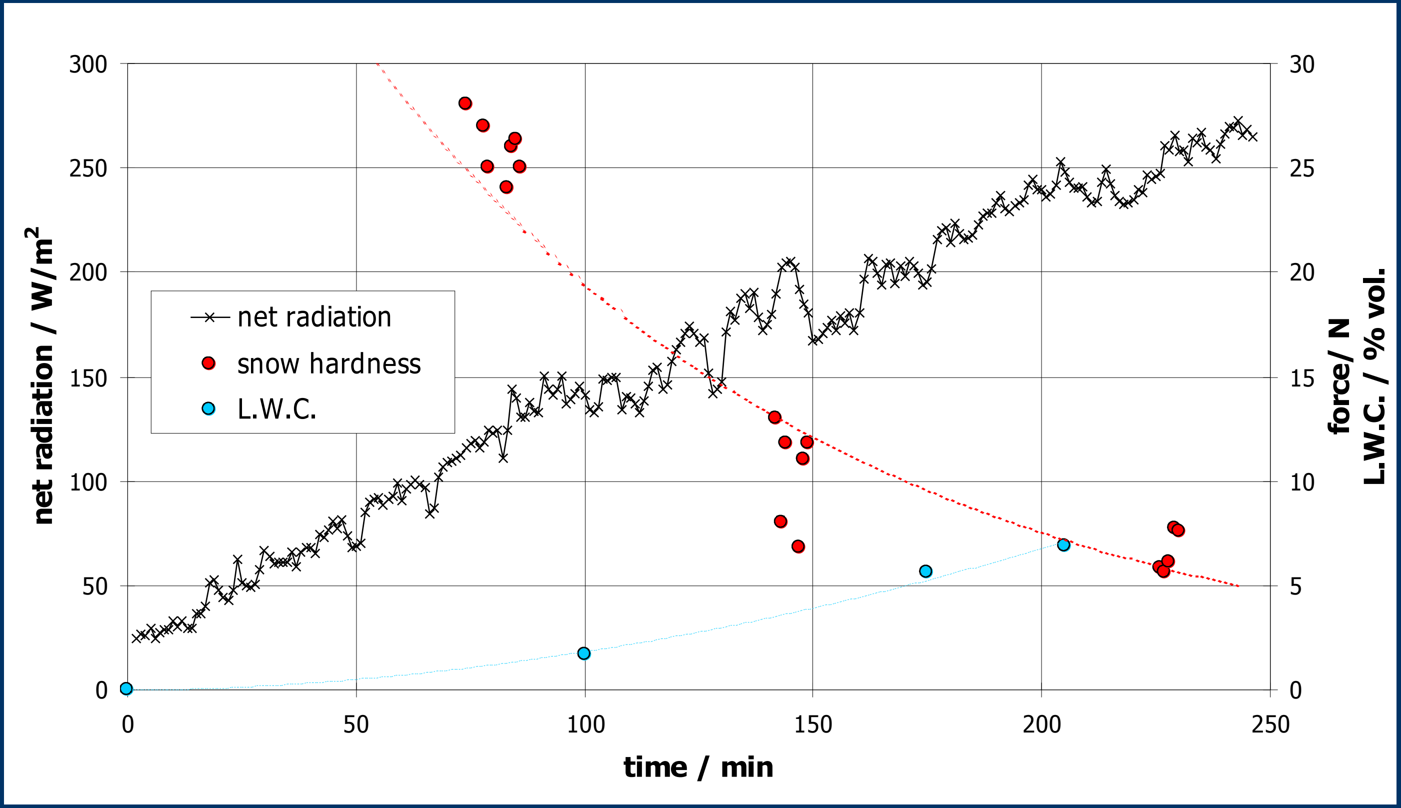


(Tusima, 1974)

➨ the colder dry snow is, the more resistant and tough it becomes

Mechanical properties of snow

liquid water content ($T_{snow}=0°C$)



➨ for a snow at 0°C and high solar incoming radiation, the liquid water content at the snow surface increases rapidly and snow becomes softer

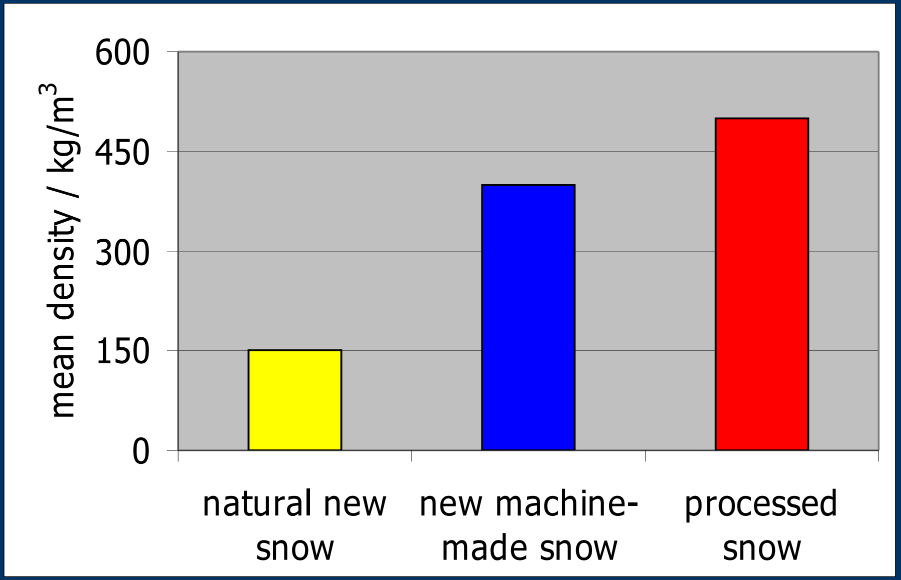
machine-made snow

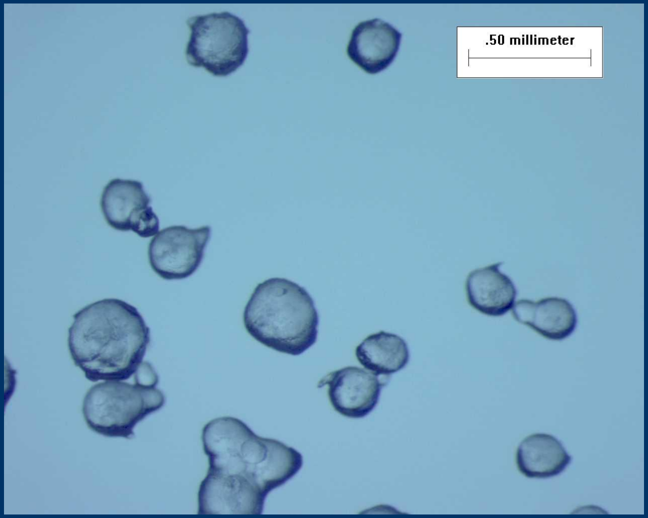
characteristics

- high density: 300 to 500 kg/m³

- small and round grains (0.1 to 0.9 mm)

➡ resistant snow
➡ needs little compaction

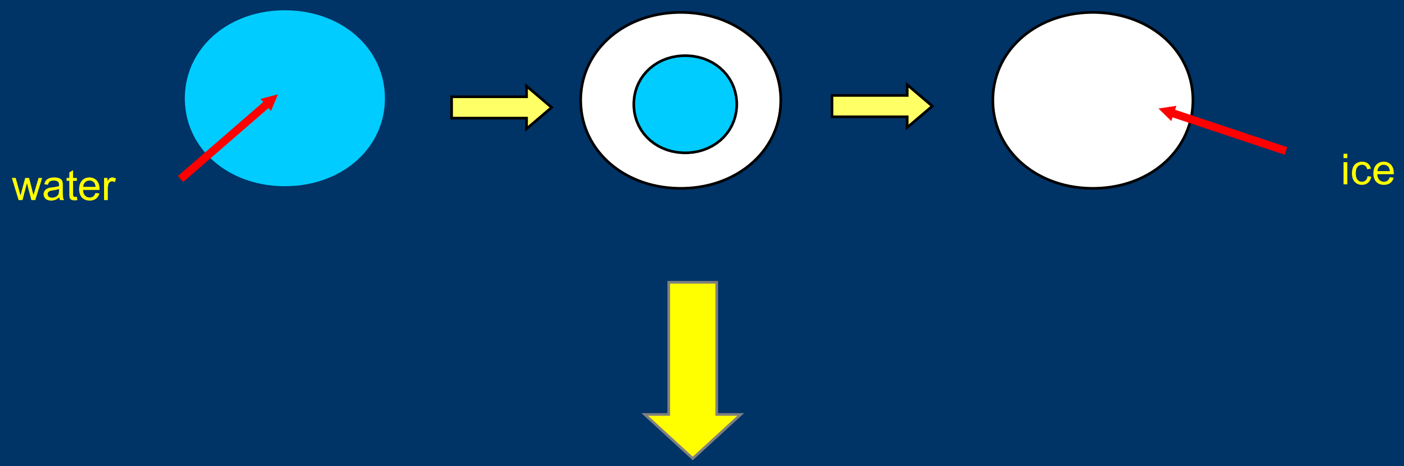




machine-made snow

characteristics

- Warning: risks of incomplete freezing of water droplets



➡ a curing time (for complete freezing) is needed before grooming the snow

Snow and meteorology

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The different properties of snow depend mostly on one parameter: its temperature.
Snow temperature depends on heat exchanges between snow and air: heat balance

The heat balance at the snow surface = difference between gain and loss of heat energy

balance is positive
snow temperature increases
at 0°C: snow starts melting

balance is negative
snow temperature decreases

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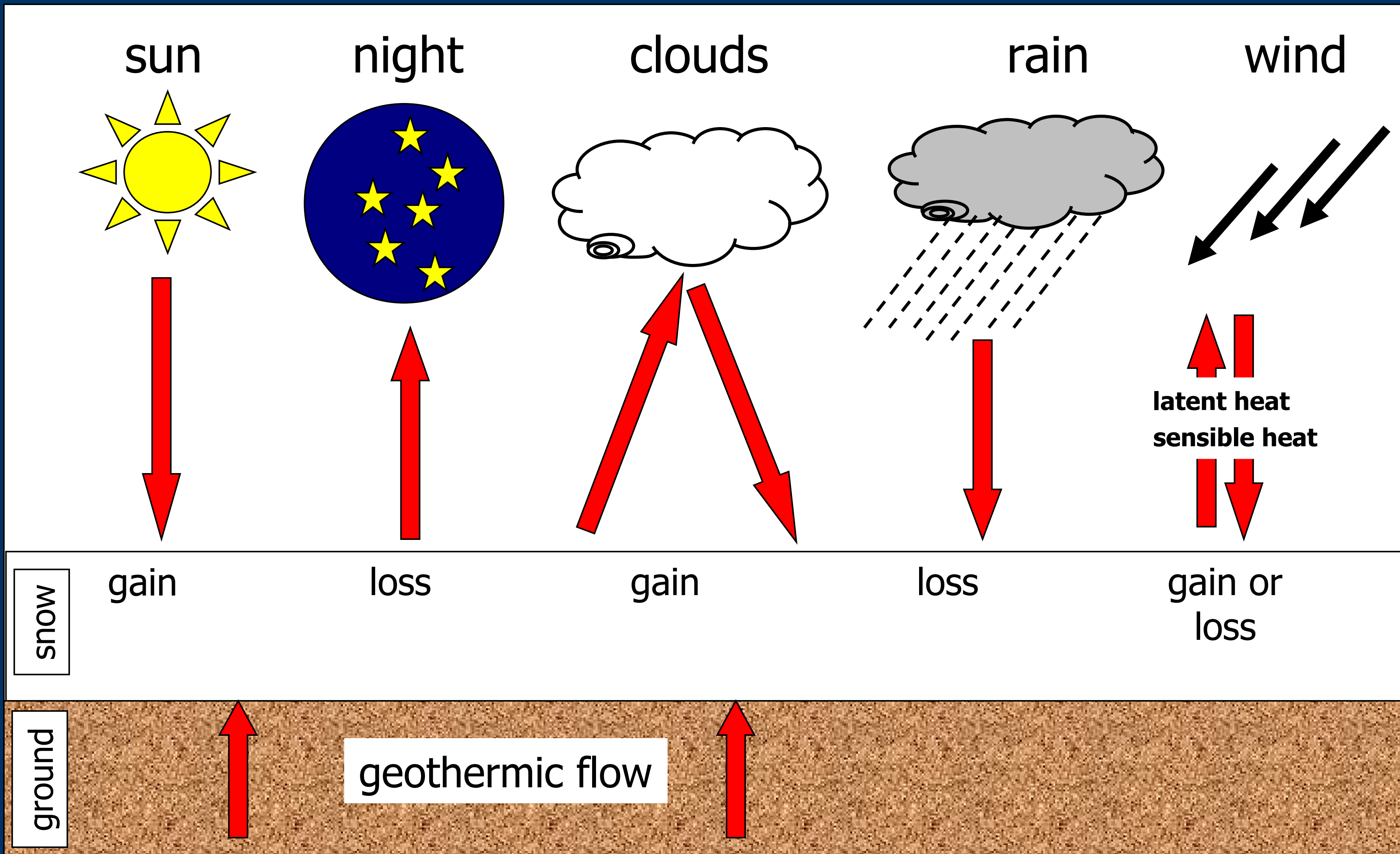
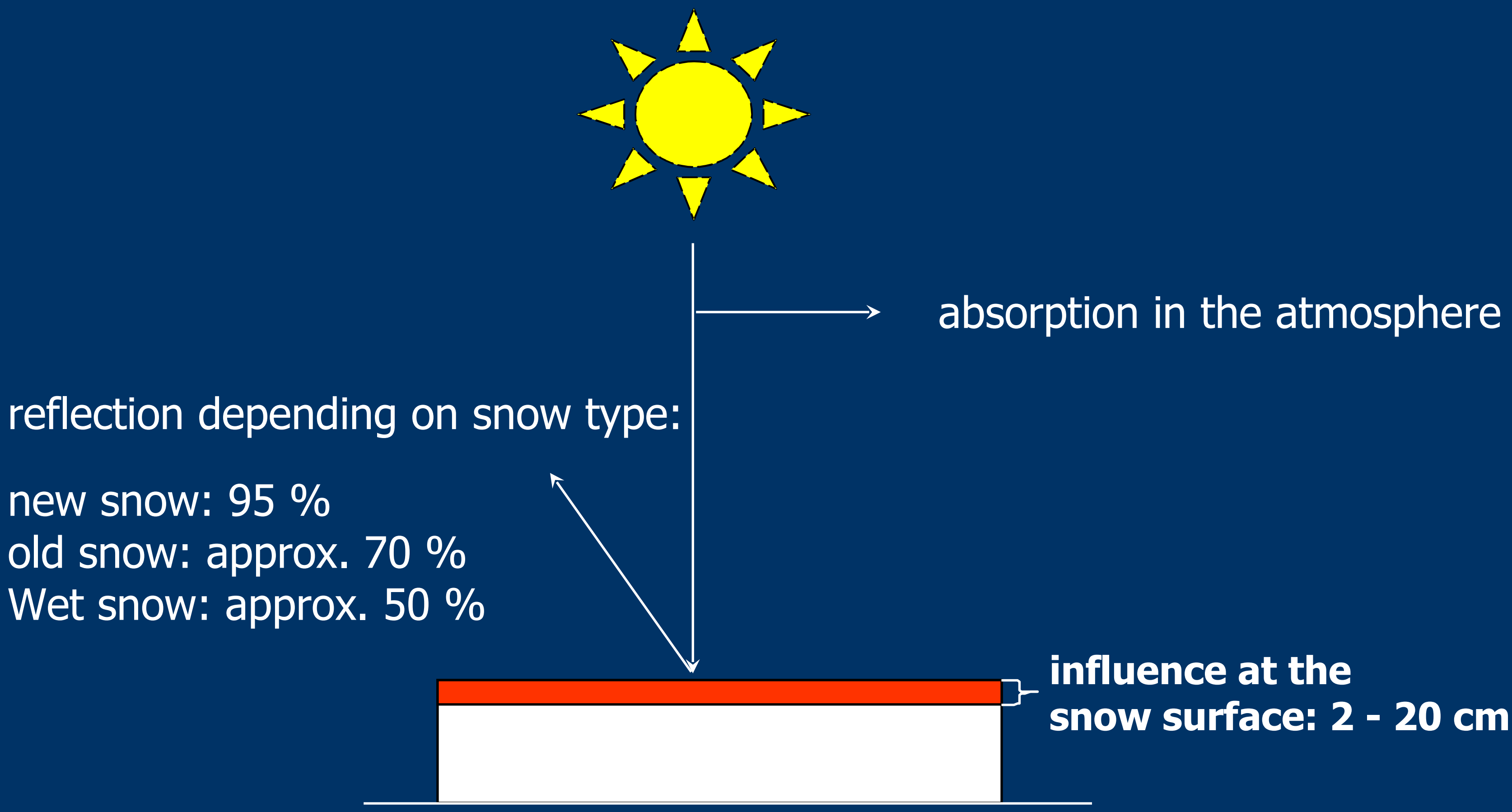
Heat balance



Gain and loss of heat energy at the snow surface

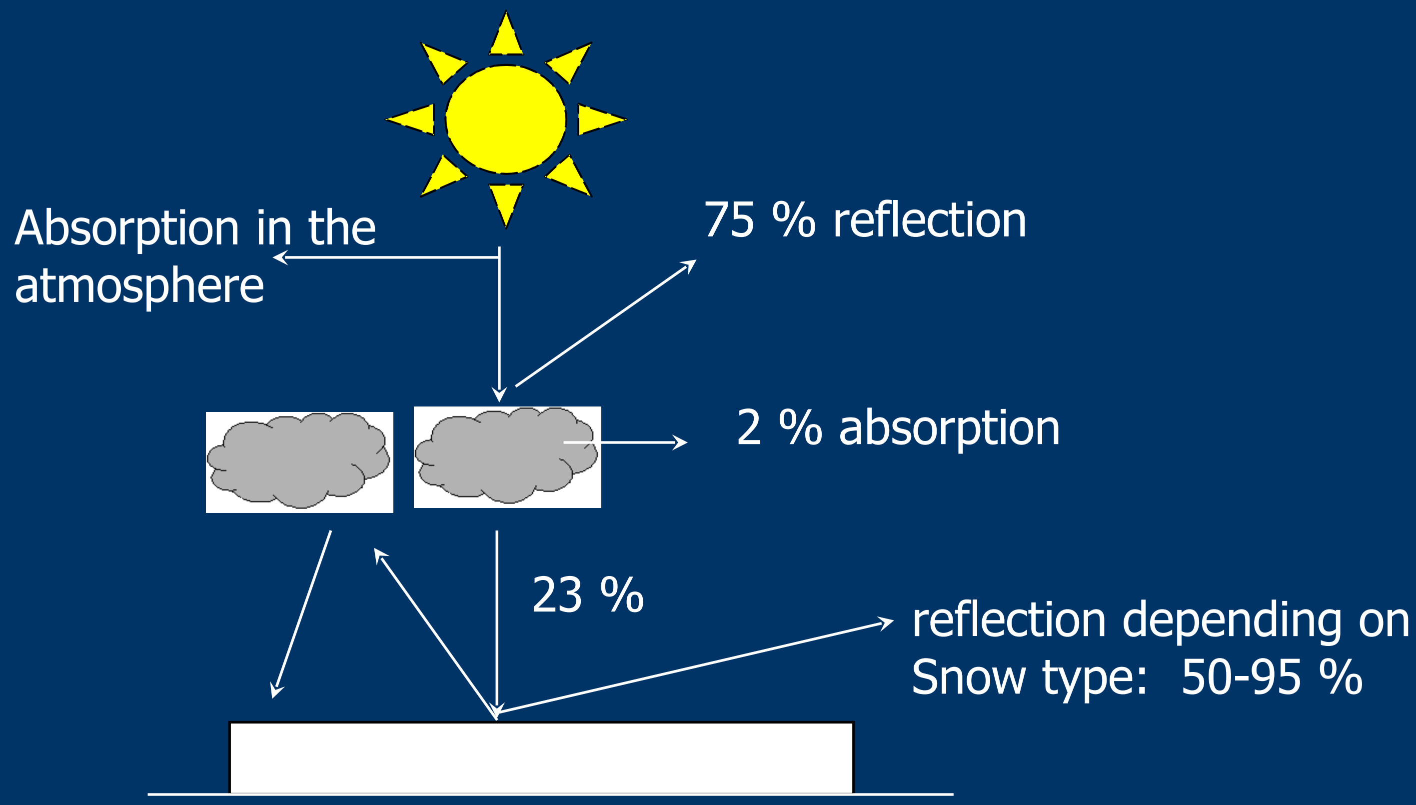
Incoming solar radiation at the earth's surface

incoming solar radiation at the snow surface on a sunny day



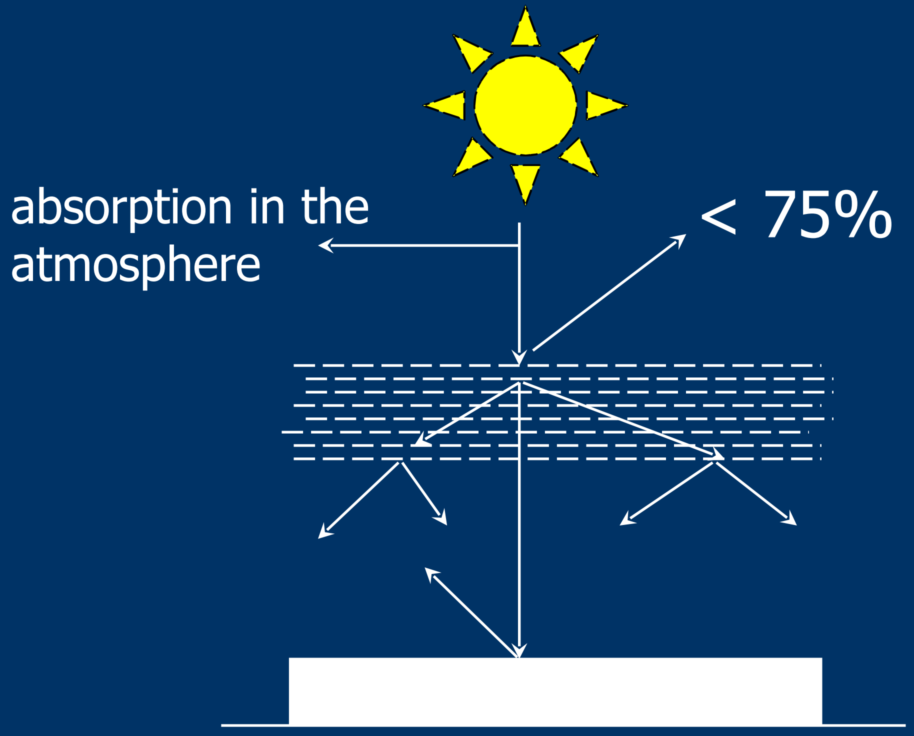
Incoming solar radiation at the earth’s surface

incoming solar radiation at the snow surface on a cloudy day

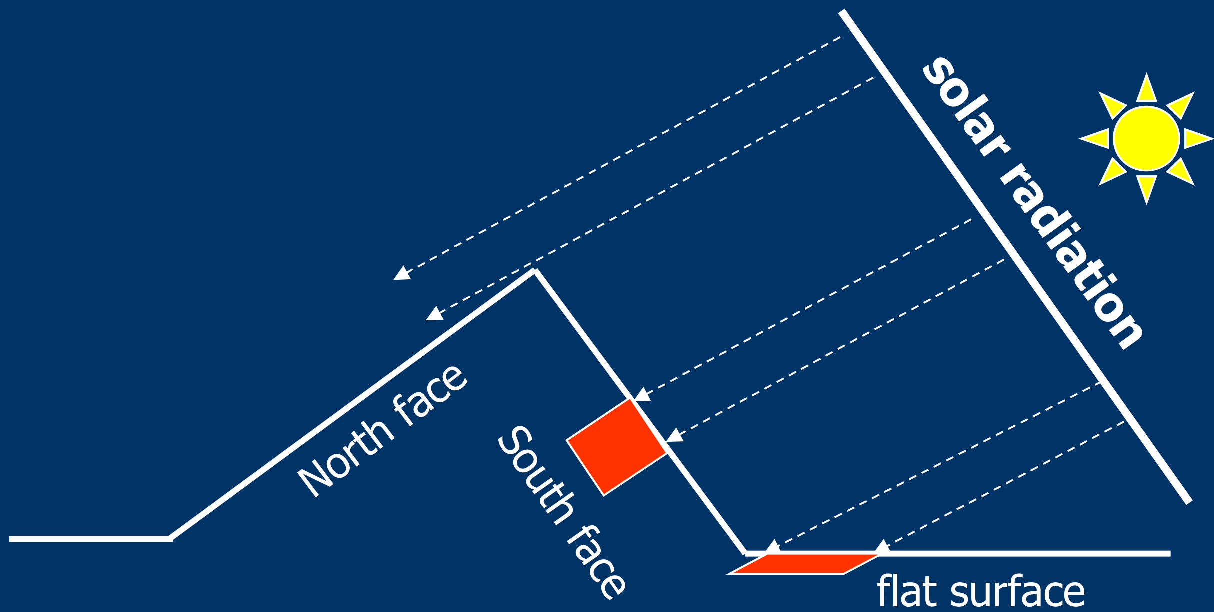


Incoming solar radiation at the earth's surface

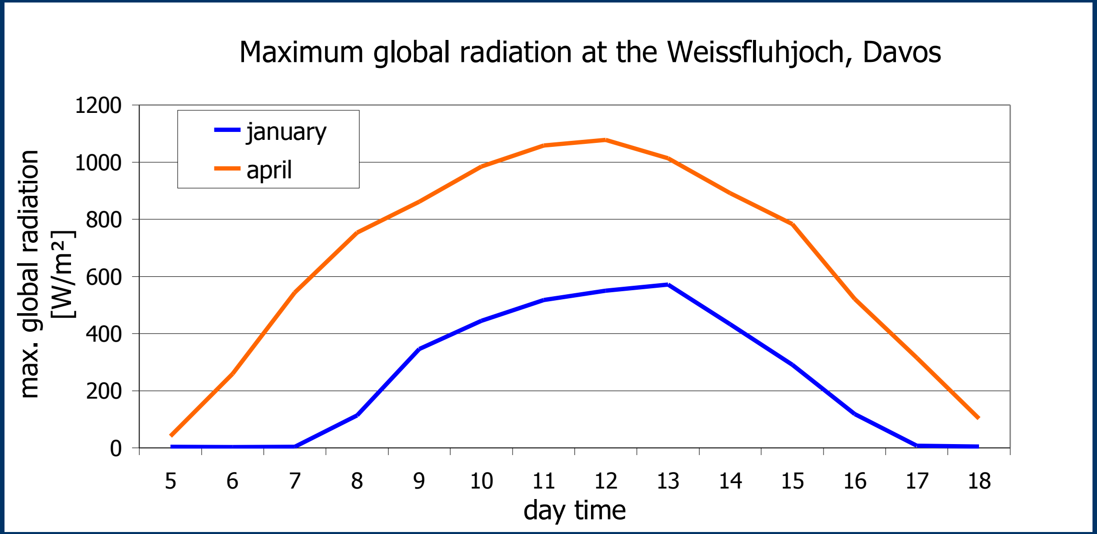
diffuse incoming solar radiation



Incoming solar radiation at the earth's surface

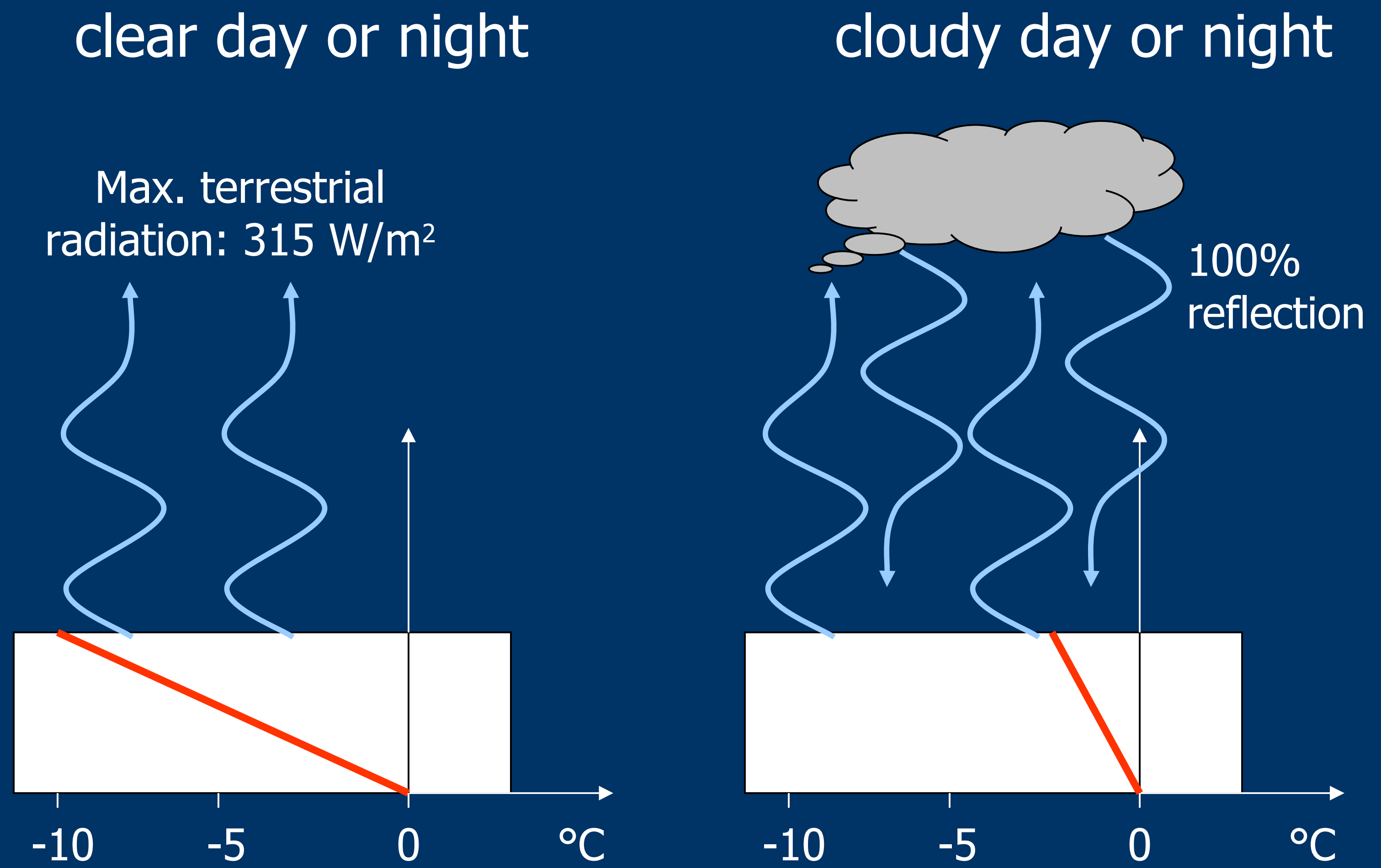


the energy input depends on the angle of incidence of the sun and on the season



Terrestrial radiation

terrestrial radiation: day and night



Short and long wave radiation

solar radiation = short wave radiation (λ = 0.5 μm)

terrestrial radiation = long wave radiation (λ = 10 μm)

snow absorbs:

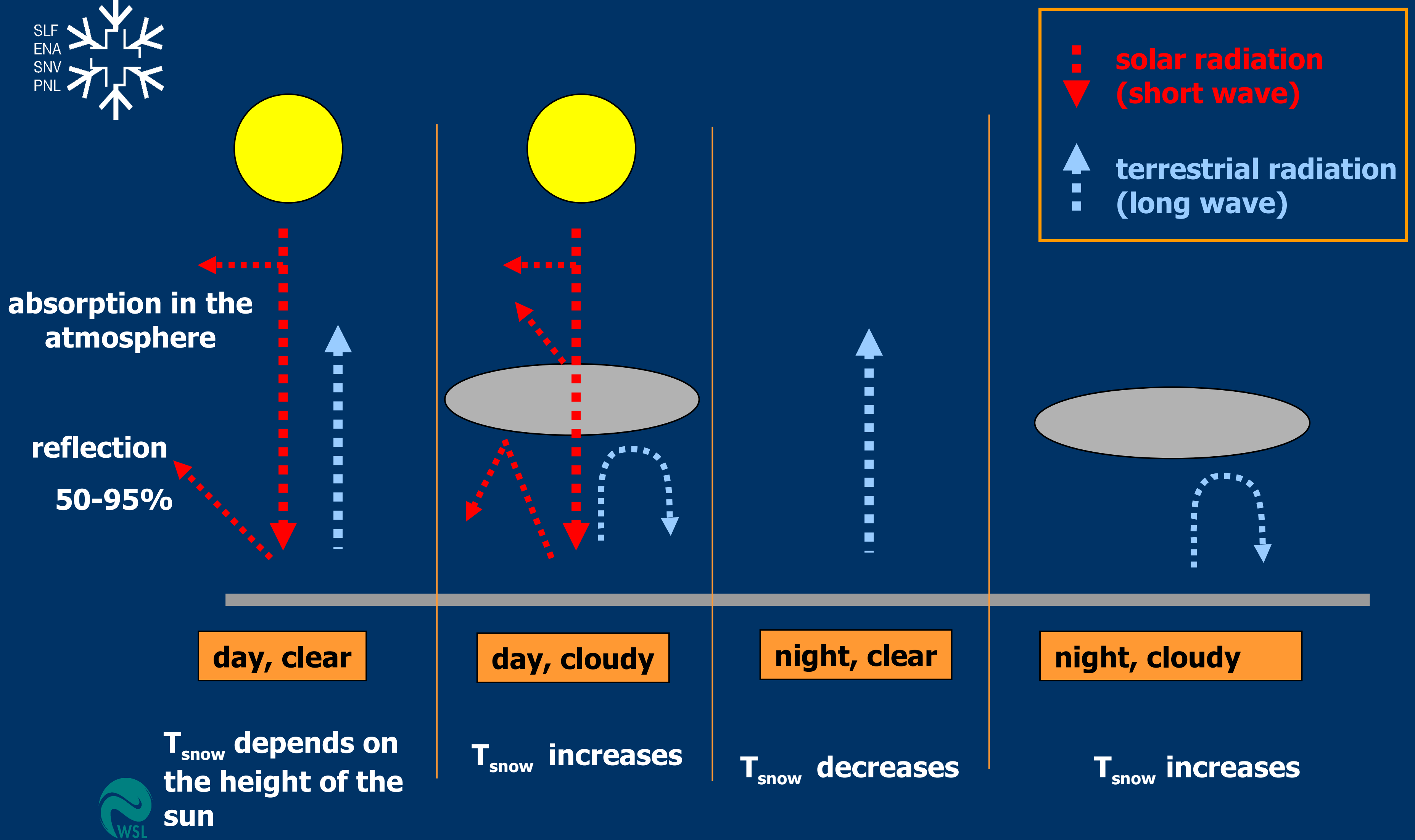
- 10 to 50 % of short wave radiation
- 99 % of long wave radiation

→ long wave radiation has a bigger influence on the melting of snow than short wave radiation

→ on a cloudy day, the snow's temperature increases faster due to the reflection of long wave radiation

Radiation balance at the snow surface

summary



Mechanical handling of snow

Mechanical handling of snow

What do we have ?

snow ✓

What do we want ?

ski piste:

- **hard** → bonds, density, temperature, L.W.C.
- **homogeneous**

in order to obtain a good quality piste, we need to :

- prepare the snow mechanically
- optimise the preparation time
- use the natural snow transformation process

Mechanical handling of snow

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combination of man and nature

mechanical handling is a PREPARATION for the natural snow solidification process

- diminution of mean grain size
- obtaining of different grain sizes
- grains become rounder
- increase of snow density

man

snow hardening

natural snow solidification

- settlement and sintering

nature

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When does the snow have to be prepared?

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The preparation time depends on:

- **type of snow** (temperature, liquid water content, grain shape)
- **weather forecasts** (air temperature, air humidity, net radiation)

The preparation time must be chosen so that the snow hardening is the highest

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When does the snow have to be prepared?

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dry snow

- snow hardening by sintering needs time (settling time is crucial before using the piste)

wet snow

- with a high liquid water content, the mechanical handling produces a water layer at the snow surface, which can freeze afterwards
- the best preparation time is just before the freezing starts

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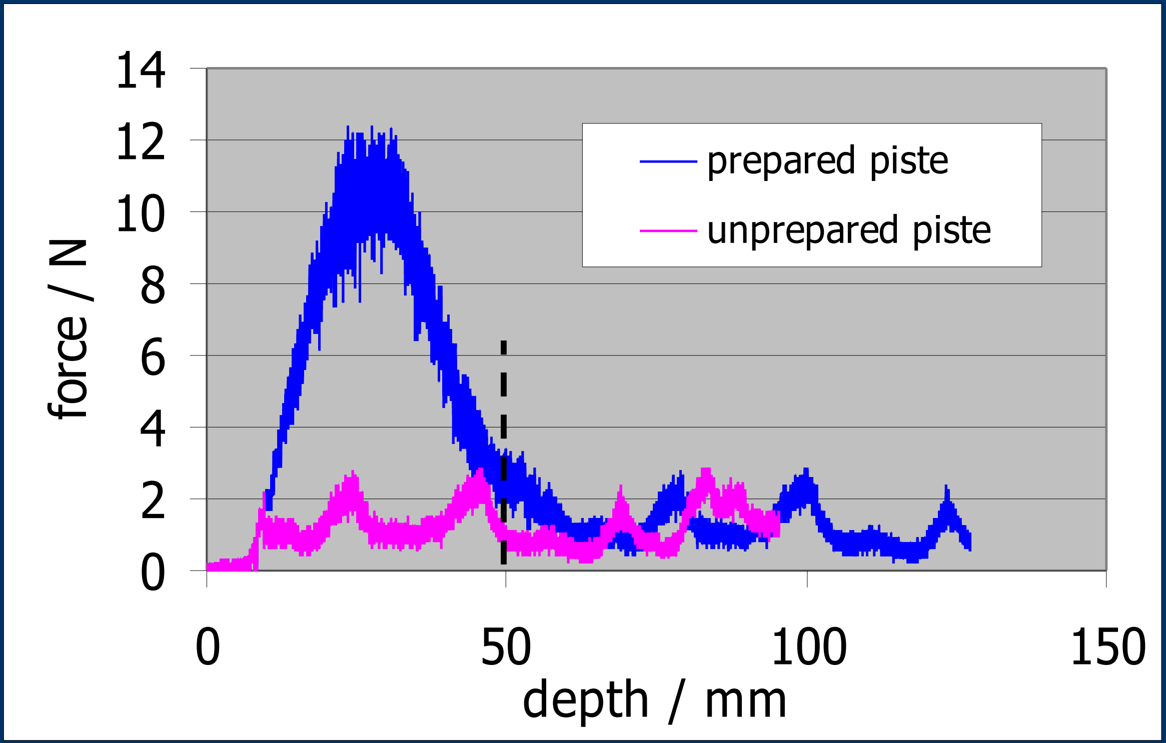
Influence of settling time on the sintering process

2 hours settling

10 hours settling

Impact of grooming machines on the snow

example: preparation of new snow, T_{snow} = -15°C



➔ impact of the machine only at the surface (5 – 20 cm)

➔ depends on: snow density, type of grain and snow temperature

Preparation and maintenance of race pistes

(photo: Stöckli)

Race pistes must have high strengths in order to support the high forces produced by the skiers and the meteorological influences without transformation and therefore allowing a fair competition. → hard piste

Preparation and maintenance of race pistes

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3 major tasks:

- building a hard fundament
- hardening the snow surface
- repairing the piste during the race

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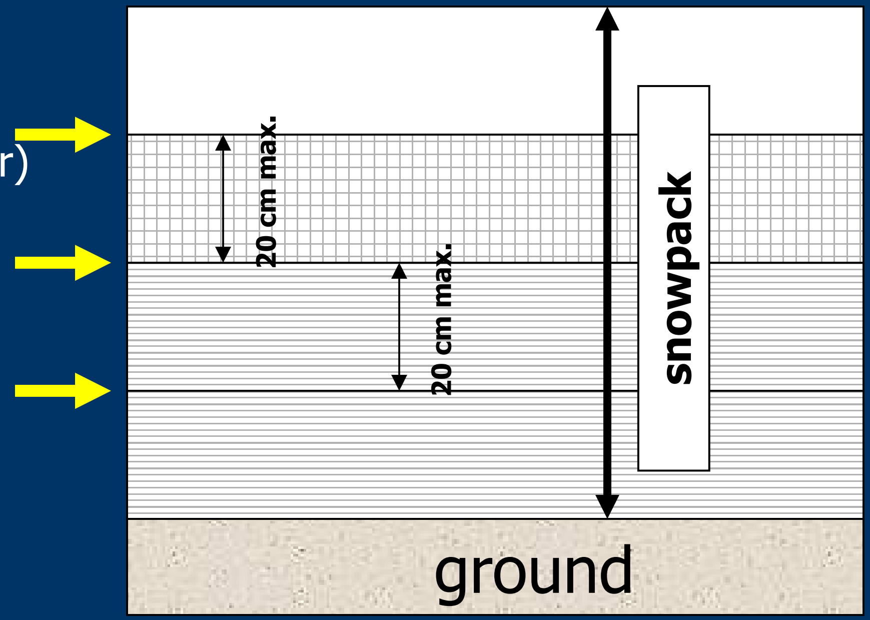
Building a hard fundament

- since machine-made snow has high mechanical strength, it can constitute a good fundament
- preparation of new snow: compaction of successive snow layers (max. 20 cm thickness per layer)

preparation layer N°3
(machine, front blade and tiller)

preparation layer N°2
(machine and front blade)

preparation layer N°1
(machine and front blade)



Hardening the snow surface

3 methods can be used to harden the snow surface:

- mechanical handling (grooming machines and skis)
- using of water
- using of chemicals

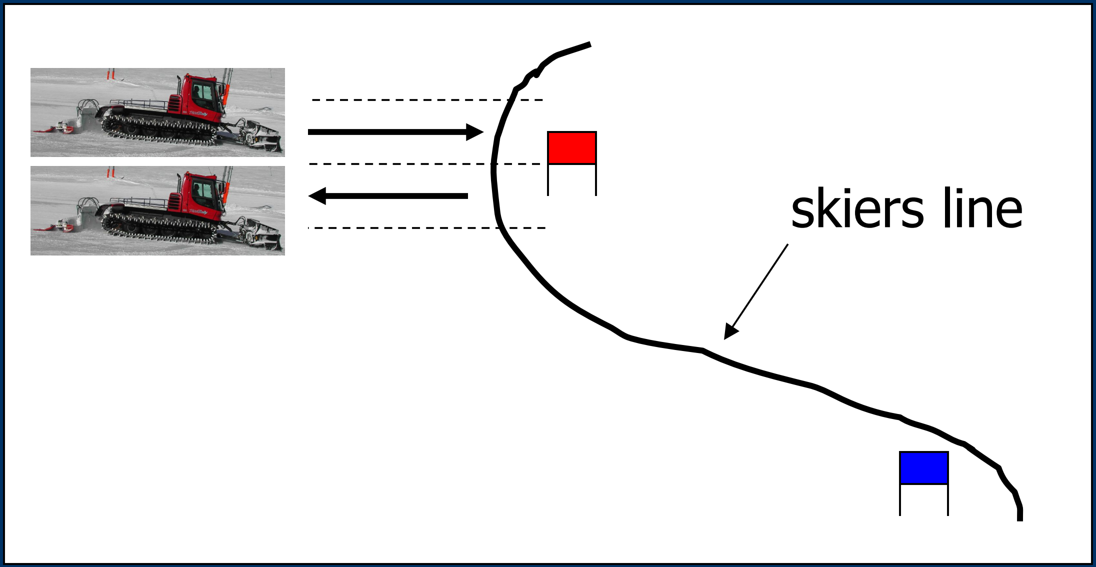
choice of the method depends on:

- snow type
- weather conditions
- race (downhill, super-G, slalom)

Hardening the snow surface

mechanical handling

➢ In the critical zones (curves, compressions, etc.) the piste must be, if possible, groomed perpendicular to the skiers line. The piste will therefore be more homogeneous and harder.



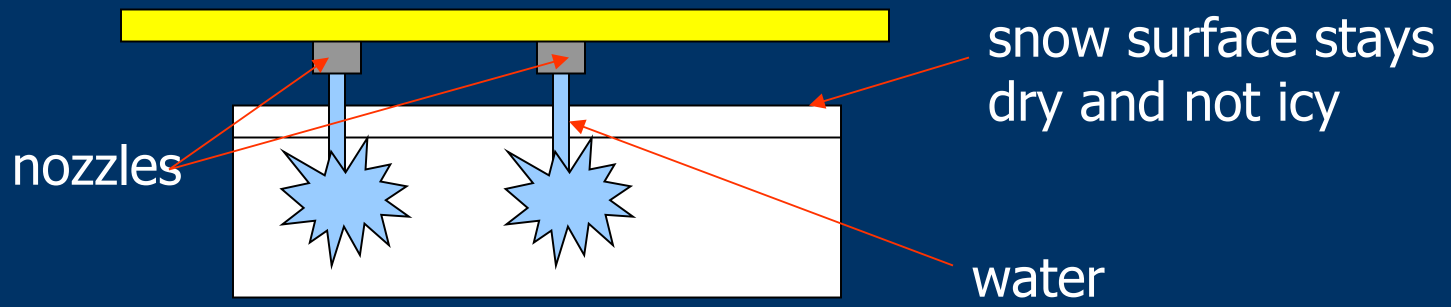
Hardening by water injection

aim

- ➨ increase snow density and amount and size of bonds between snow grains

method

- ➨ injection of water with high pressure thru nozzles in the compacted snowpack
- ➨ Maximum:
  - 20 l/m² for fine grained snow ($\phi < 0.5$ mm)
  - 10 l/m² for coarse grained snow ($\phi > 1$ mm)
- ➨ pressure and flow can be modified



Hardening by water injection

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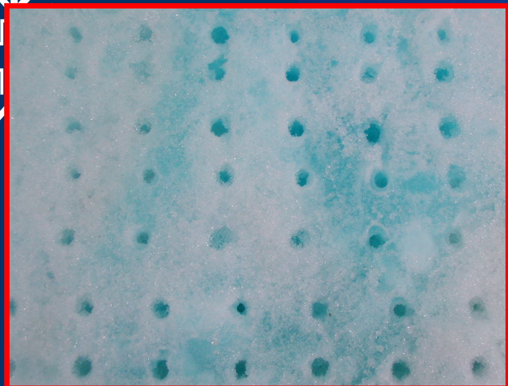

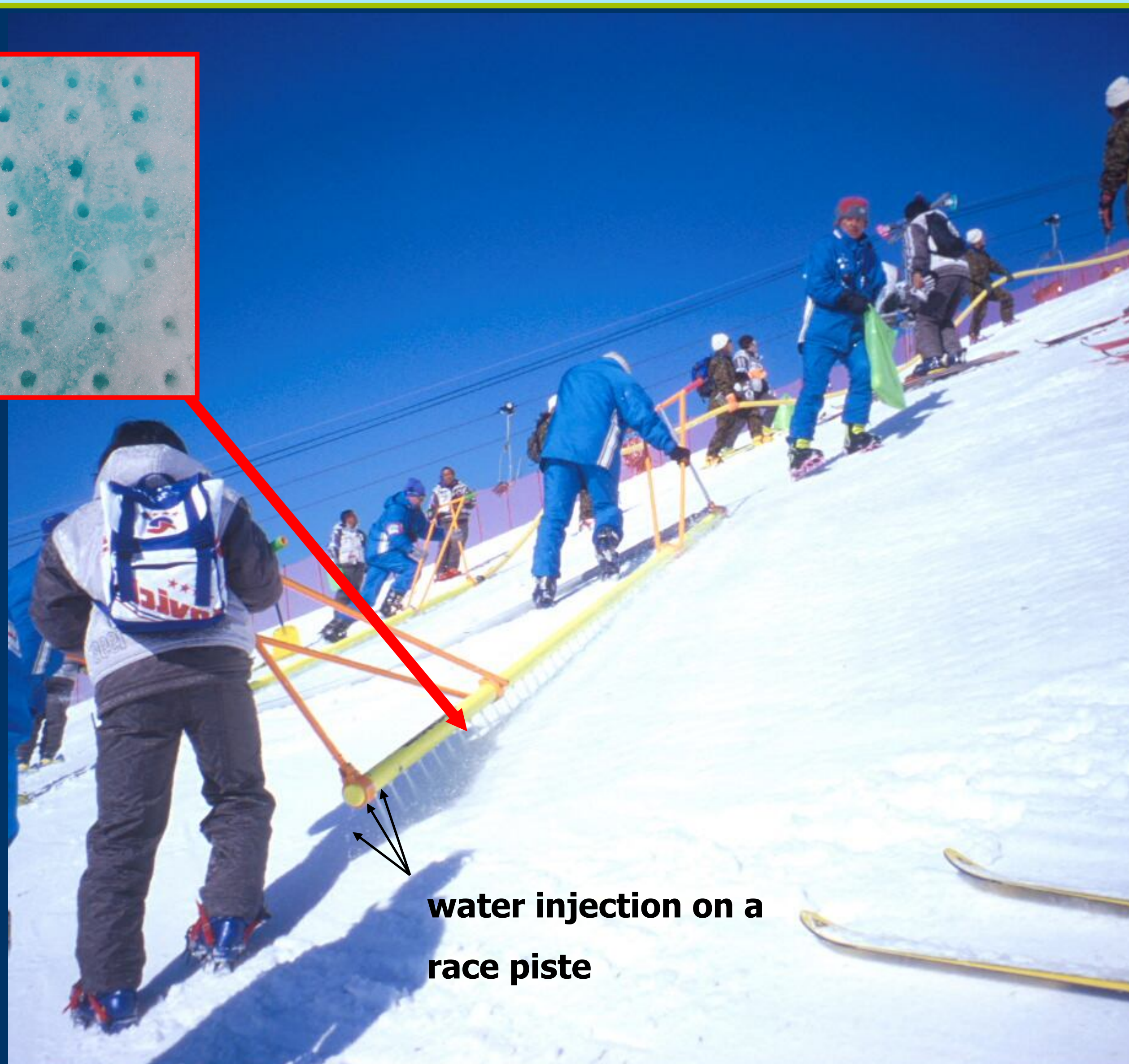

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Hardening by water injection

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physical process

increase of snow density

freezing of liquid water with $T_{snow} < 0°C$

heat is released

heat is conducted out of the snowpack mostly by radiation and evaporation

conditions

- snow temperature < 0°C
- negative heat balance
- hard fundament

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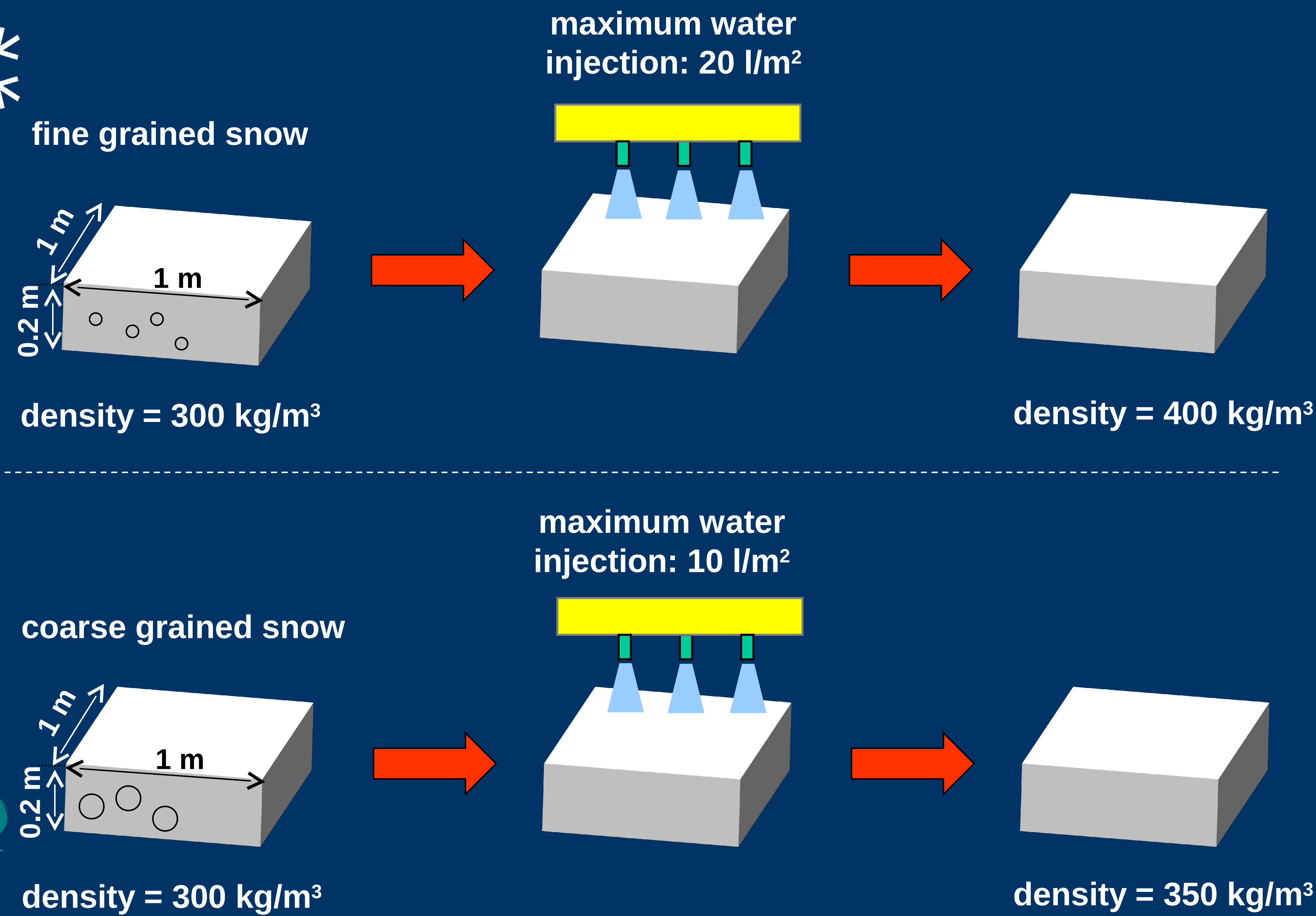
Hardening by water injection

Example: 1m x 1m x 0.2m



Hardening by application of chemicals

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physical process

dissolution of the chemicals in the liquid water

\+ melting of an amount of snow

needs heat

temperature sinks

freezing of the solution (water + chemicals)

heat release that must be conducted out of the snowpack (mostly by radiation energy)

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Hardening by application of chemicals

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most widely used chemicals

- ➨ sodium chloride (cooking salt)
- ➨ ammonium nitrate
- ➨ combinations

method

- ➨ application of a defined amount (see manufacturer's guide) of chemicals on the snow surface
- ➨ side slipping with skis (by high solar radiation: instant slipping, by high terrestrial radiation: slipping after crystallisation)

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⚠ The amount of chemicals has a big influence on the process.

Hardening by application of chemicals

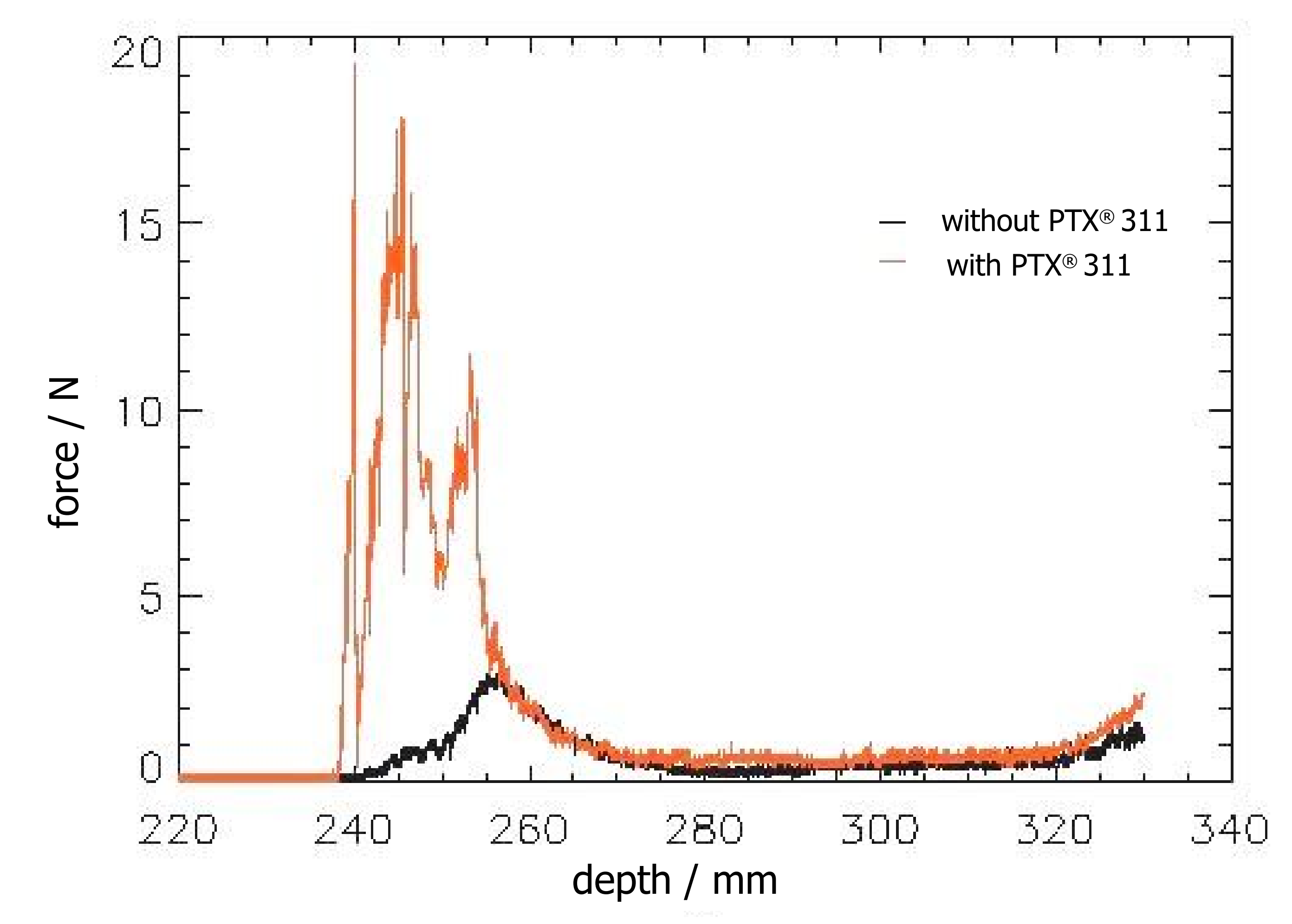
conditions

- wet snow
- negative heat balance

! When snow is dry and no water can be sprayed to harden it, chemicals that release heat when they are mixed with snow, like calcium chloride, can be used to melt the snow.

Hardening by application of chemicals

example: application of PTX® 311 on a wet snow surface



Special race piste preparation methods

summary

dry new snow density < 400 kg/m³	dry snow density > 400 kg/m³	wet snow
water (several applications) + chemicals (fasten the freezing process)	water (event. several applications)	chemicals

Reparation of the piste during the race

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possible damages

- holes
- ruts
- chatters

reparations

- level the piste
- fill in the holes
- spread the snow
- limit the damage

(lengthen the blended area)

shovels
rakes
skis

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Practical example N°1

Preparation of a downhill race piste – new snow – cloudy night

snow conditions

- 20 cm new snow at the surface
- snow density = 150 kg/m^3
- T_{snow}= -4°C
- hard fundament

weather forecasts

- cloudy night = constant snow temperature
- air temperature : between -1°C and -3°C

Practical example N°1

Preparation of a downhill race piste – new snow – cloudy night

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preparation

glide zones:

- preparation with grooming machines directly after the snowfall
- settling time of at least 8 hours in order to obtain a sufficient natural snow consolidation

curves/jumps/compressions:

- remove the snow out of the track with shovels or eventually snow tillers
- warning: snow on fall-zones (side of the track) must also be prepared and the nets must be snow-free

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Practical example N°2

Preparation of a slalom piste – dry and weak snow

SLF
ENA
SNV
PNL

snow conditions

- snow surface density = 450 kg/m^3
- fine grained snow (ϕ < 0.5 mm)
- T_{snow} = -8°C

weather forecasts

- clear day (high terrestrial radiation)

WSL

Practical example N°2

Preparation of a slalom piste – dry and weak snow

SLF
ENA
SNV
PNL

preparation

- water injection No. 1 with max. 20 l/m^2 (density: 450 -> 550 kg/m^3)
- freezing time (minimum 6 hours)

- water injection No. 2 with max. 10 l/m^2 (density: 550 -> 600 kg/m^3)
- freezing time (minimum 4 hours)

WSL

Practical example N°3

Preparation of a super-G piste – wet and weak snow – competition day

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snow conditions

- snow surface density = 550 kg/m^3
- coarse grained snow
- wet, liquid water content = 7%, T_{snow} = 0°C

weather conditions

- clear day (terrestrial radiation)
- high solar radiation (spring)

preparation

- application of PTX® 311
- packing and slipping with skis

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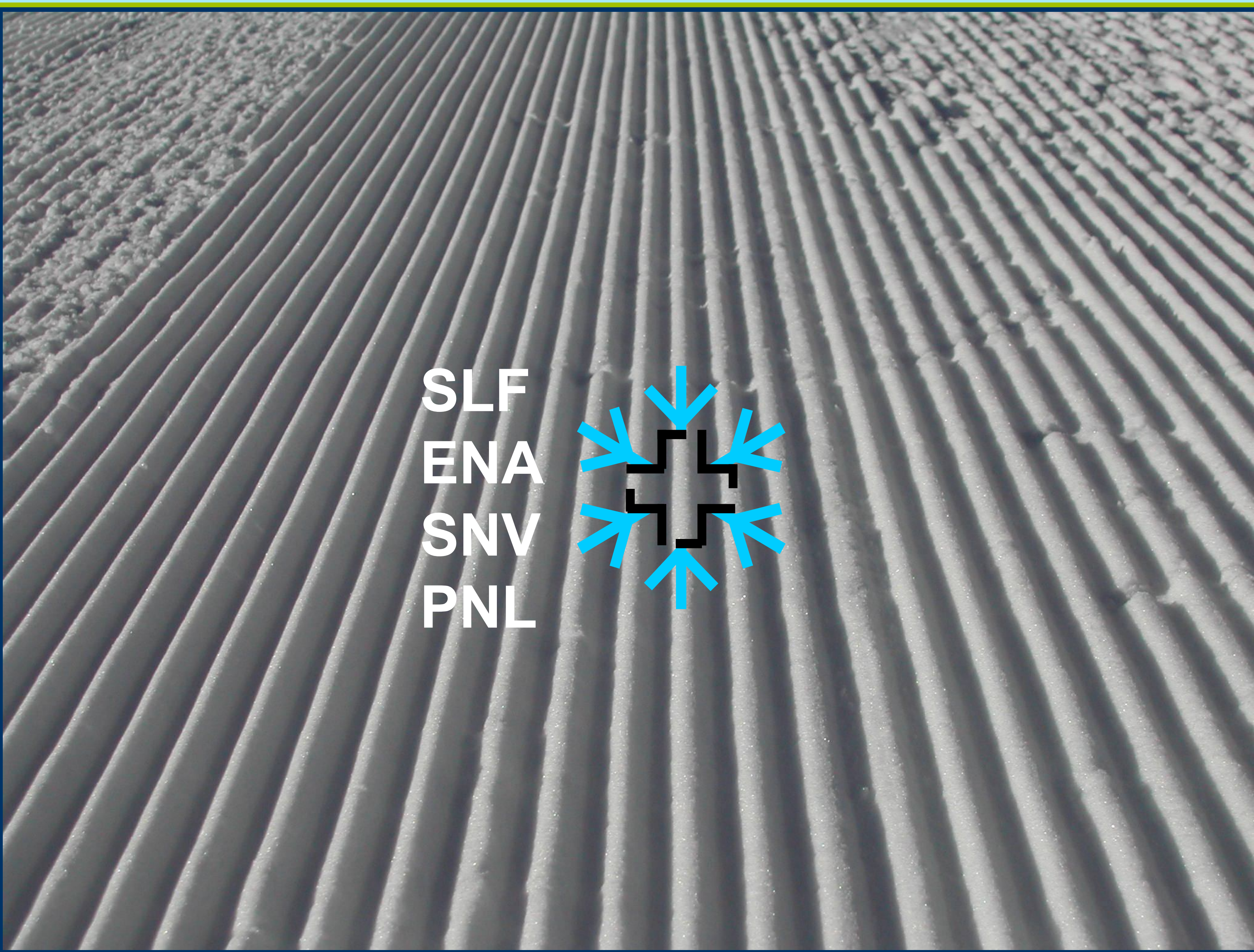
Thank you for your attention



Swiss Federal Institute for Snow and Avalanche Research SLF

Preparation of alpine ski pistes

Preparation of alpine ski pistes

This Power Point Presentation is intended for FIS alpine technical delegated persons. It has been written by Mathieu Fauve and Hansueli Rhyner from the Swiss Federal Institute for Snow and Avalanche Research, Davos and completed by Thomas Gurzeler. It is a tool for the alpine race supervisors, officials, coaches and Athletes, who strive for a safe race. The use and modifications of this presentation are possible only with permission from Hansueli Rhyner.

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Preparation of alpine ski pistes

Aim

The aim is to transform a soft snow into a:

- hard
- homogeneous

piste

Proceed

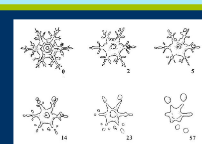
Use of mechanical equipment taking into account the physical properties of snow and the meteorology

Special

Race pistes have to be prepared with special methods in order to obtain very high strength

Preparation of alpine skiing slopes

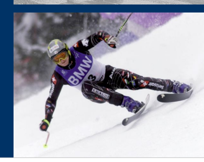
physical properties of snow



snow and meteorology

mechanical handling of snow

preparation and maintenance of race pistes



Physical properties of snow

Snow is a very particular material:

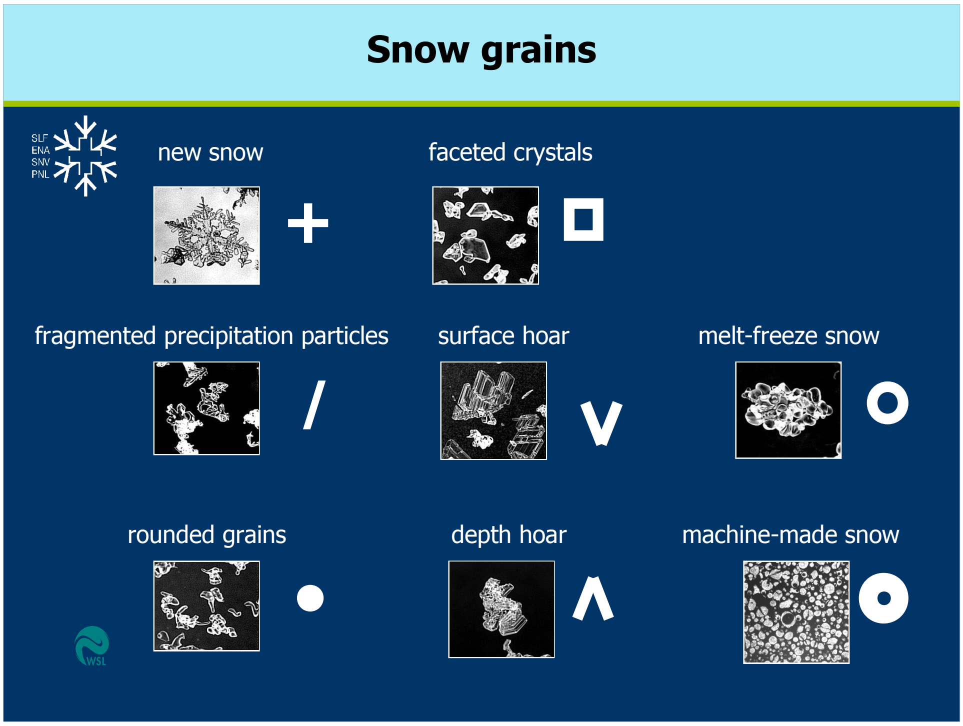
➔ composed of air and water in all its forms: solid (ice), gas (water vapour) and possibly liquid (liquid water)

➨ near its melting point (0°C), so extremely sensitive to variations of temperature and pressure and reacts rapidly

➨ exists in different forms and is subjected to a continuous transformation

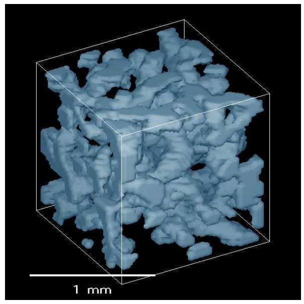
Comparision: If we bring the temperature of a metal, e.g. aluminium, to 20°C below its melting point, it becomes unstable and reacts strongly to influences of the environment.

A snow crystal transforms itself continouisly from its formation until its melting.

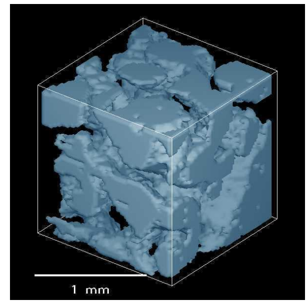


Depth hoar does not built up on ski pistes. Dense snow does not allow grain size to increase considerably.

Snow density



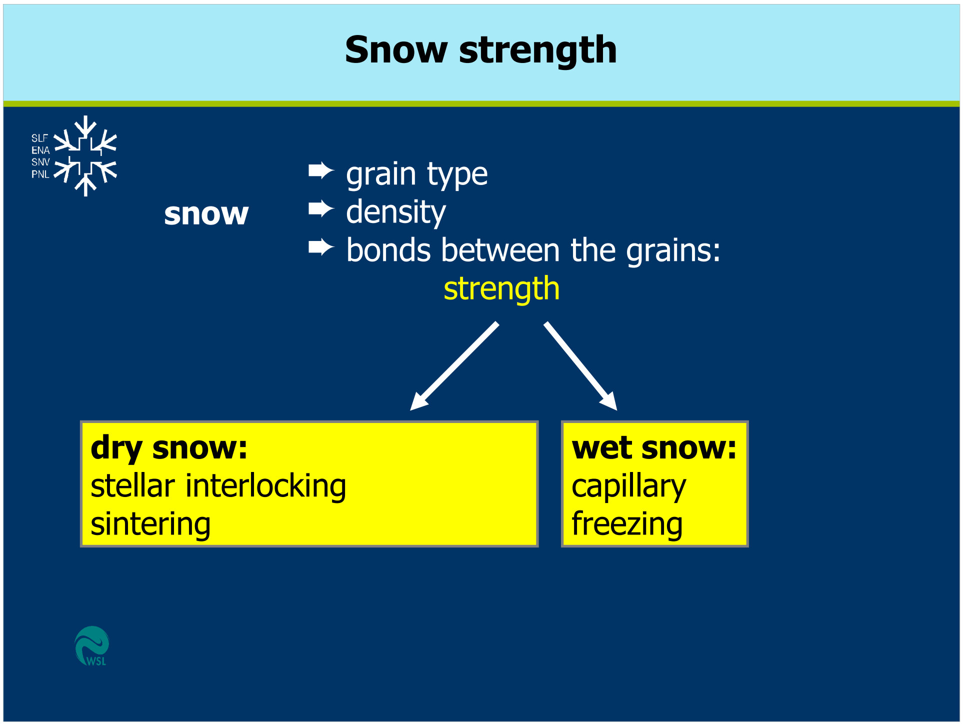
low density snow (220 kg/m³)



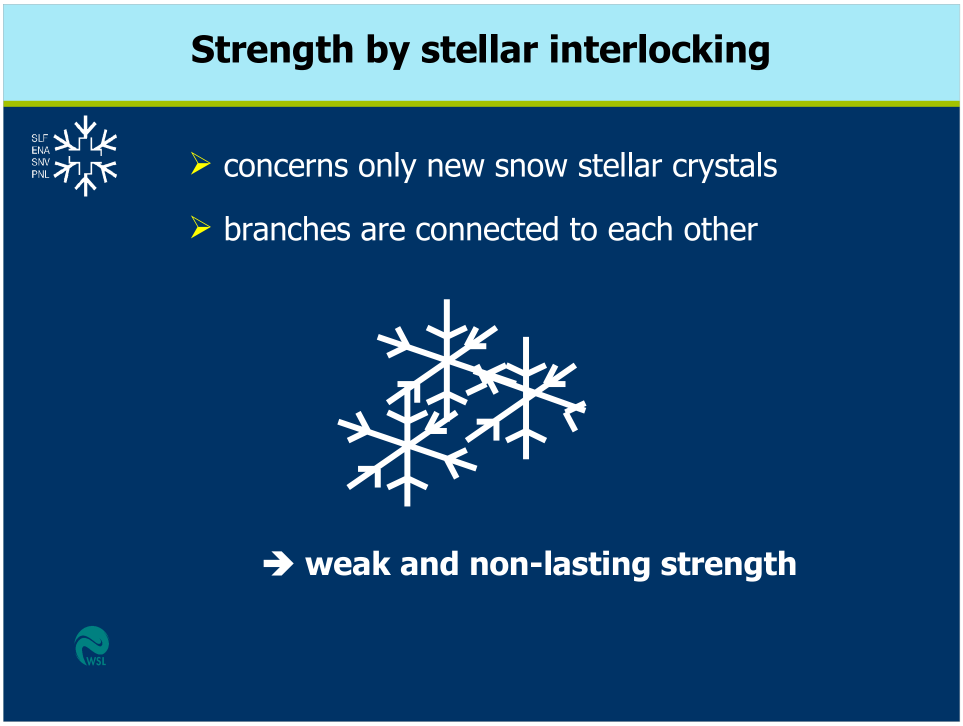
high density snow (516 kg/m³)

- new snow density: between 50 and 250 kg/m³
- average ski slope density : 480 kg/m³
- downhill racing slope density: 300 - 500 kg/m³
- super-G racing slope density: approx. 550 kg/m³
- slalom racing slope density: approx. 600 kg/m³

Warning: high density does not always mean high strength



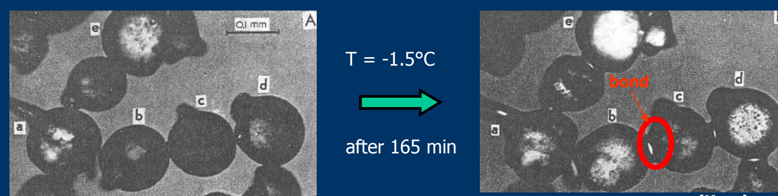
The bonds between snow grains are the most important parameter responsible for the resistance of snow



Not relevant on ski slopes

Strength by sintering

sintering: building of solid bonds between snow grains by water vapour transport



(Kuroiwa, 1974)

➨ the building of the bonds and the increasing of their size depend on the following parameters:

- **temperature** (process faster near 0°C)
- **grain type** (shape, mean size, size distribution)
- **density** (number of contact points)
- **time** (process needs time)

Grain shape: as round as possible

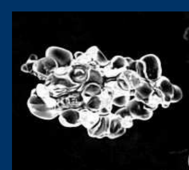
Grain size distribution: different grain sizes in order to fill as many pores as possible

Strength of wet snow

- liquid water is held on grains by capillarity as long as its volume is lower than 5 to 10% (depending on the grain size) of the total volume. Small grains can hold more water than bigger ones.

- when the liquid water content (L.W.C.) is high, bonds melt and snow becomes softer

- when the liquid water freezes, strong bonds built between the grains

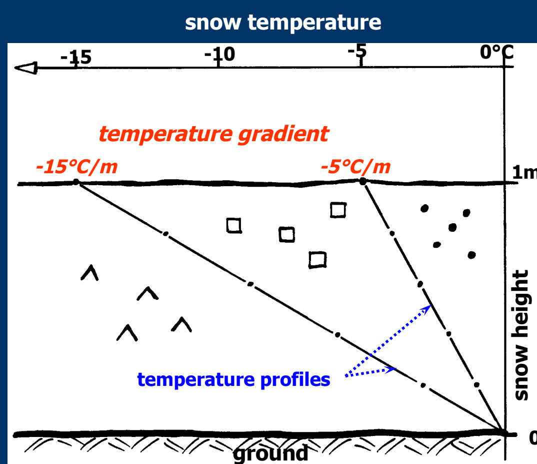


Most of the equipments used in the field do not measure the liquid water content.

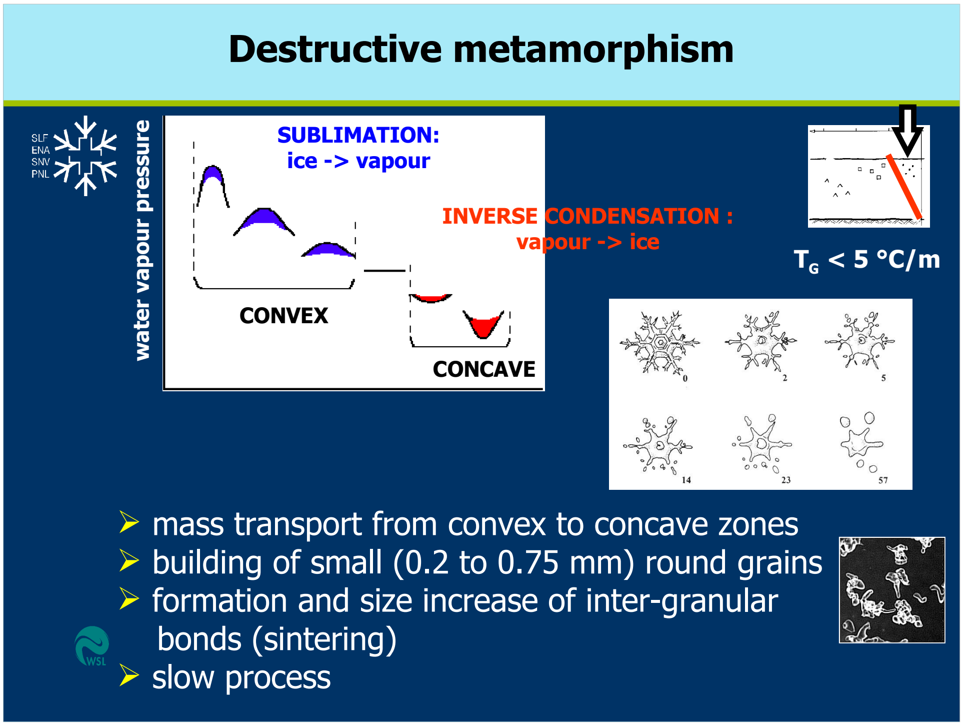
In order to determine the liquid water content of snow by measuring its dielectric constant, we must know its density.

Snow metamorphism

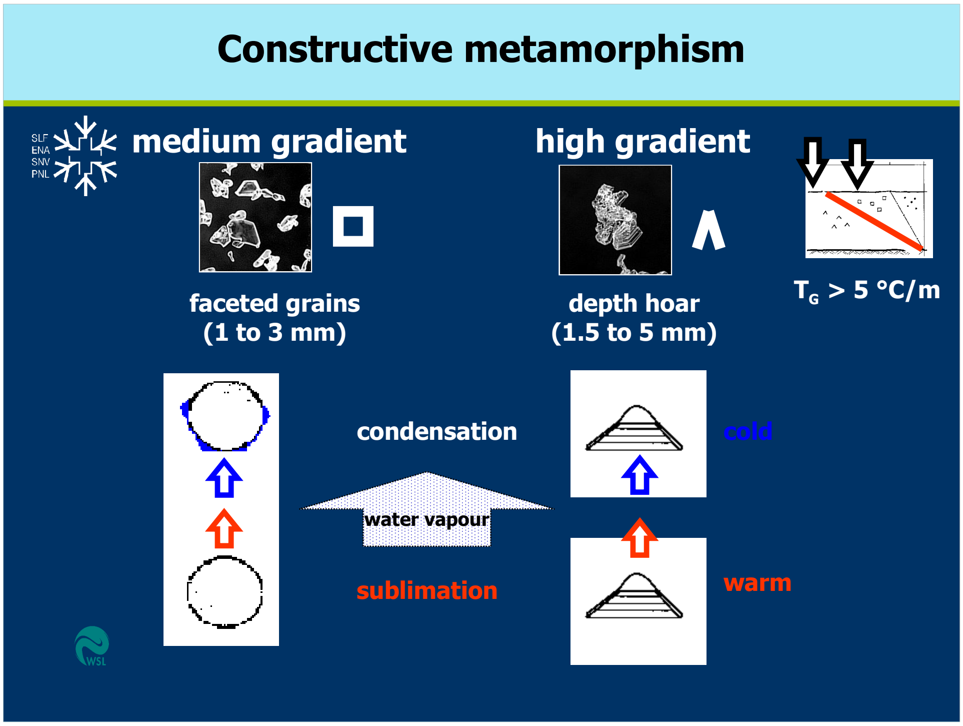
Snow metamorphism depends on the temperature gradient in the snowpack



$$T_G = \frac{dT}{dz}$$

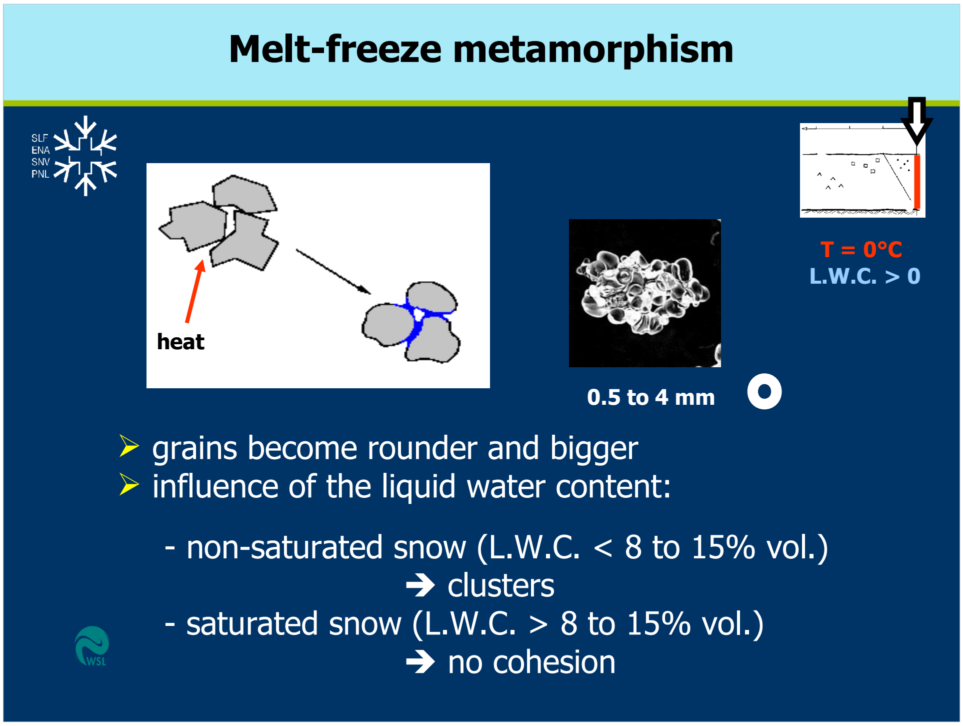


Destructive metamorphism leads to the settlement of snow and to its solidification



Constructive metamorphism = increase of grain size and loss of resistance

No formation of depth hoar on ski pistes (too high density)



Snow can contain liquid water only when its temperature is equal 0°C

Mechanical properties of snow

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The mechanical properties of snow mostly depend on the following parameters:

- bonds
- density
- temperature
- liquid water content

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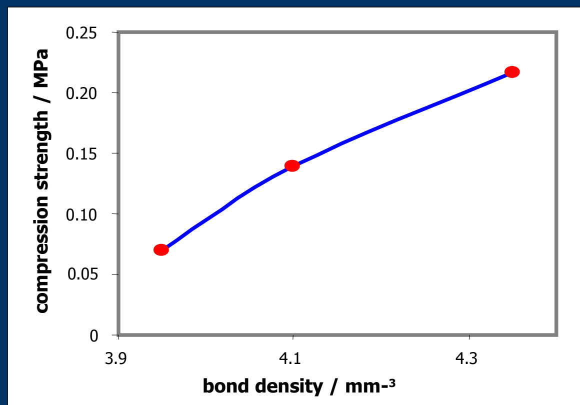
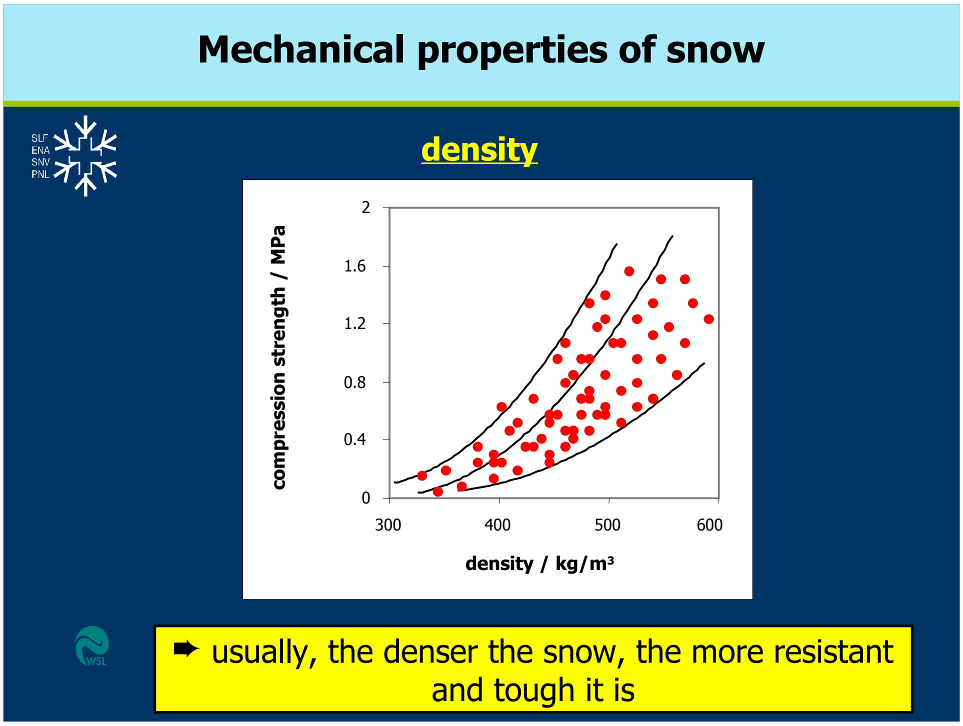
Mechanical properties of snow

bonds



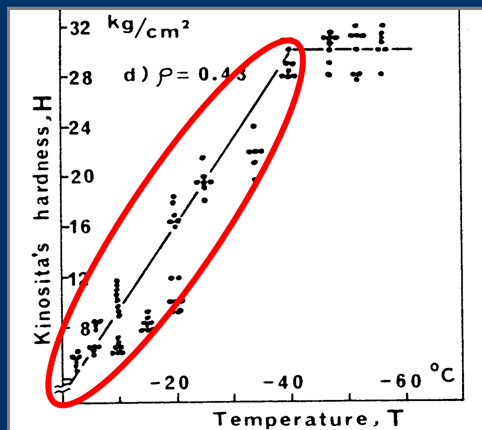
➨ the more bonds that exist and the larger they are, the higher the snow's resistance is



Example: wet spring snow has high density but low strength

Mechanical properties of snow

temperature

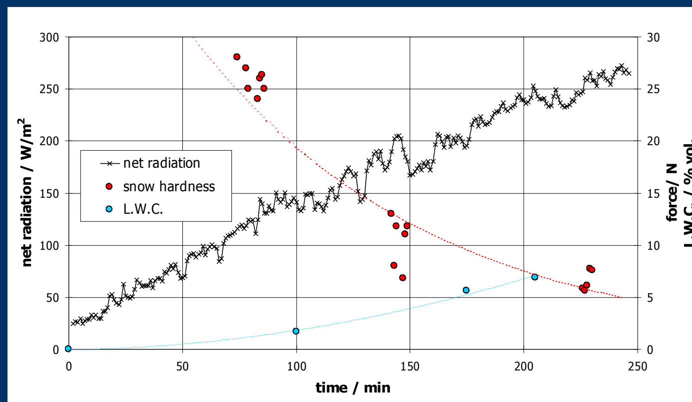


(Tusima, 1974)

➨ the colder dry snow is, the more resistant and tough it becomes

Mechanical properties of snow

liquid water content (T$_{snow}$=0°C)



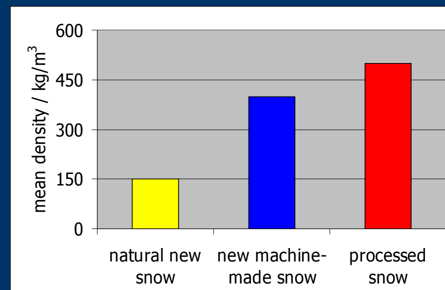
➨ for a snow at 0°C and high solar incoming radiation, the liquid water content at the snow surface increases rapidly and snow becomes softer

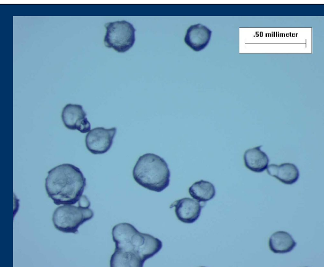
machine-made snow

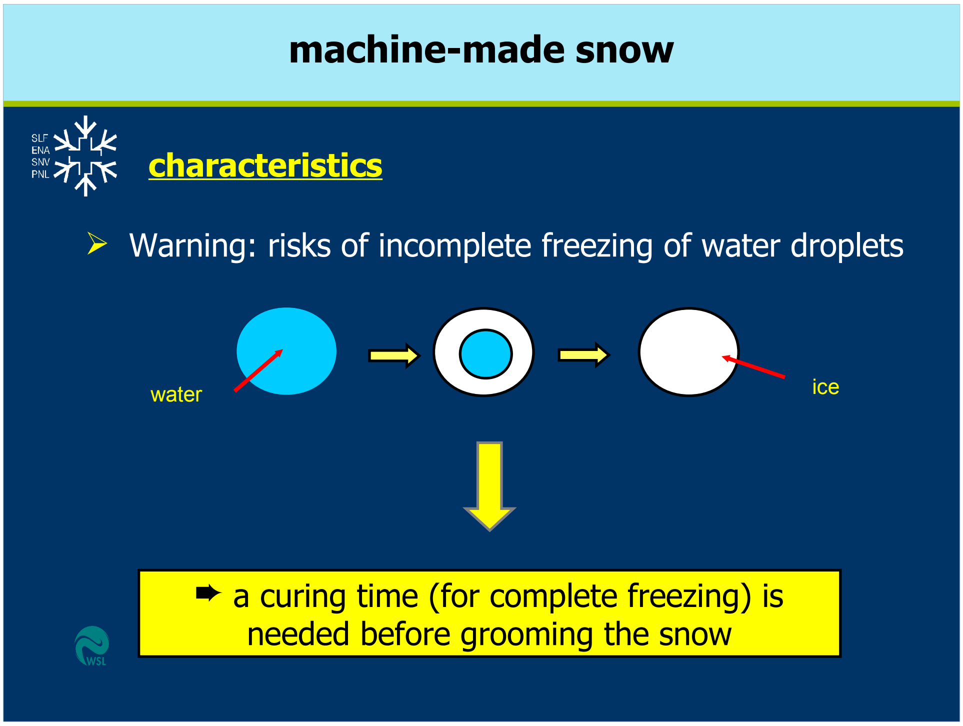
characteristics

- high density: 300 to 500 kg/m³
- small and round grains (0.1 to 0.9 mm)

➡ resistant snow
➡ needs little compaction







In comparision with natural snow, machine-made snow freezes from the outside to the inside

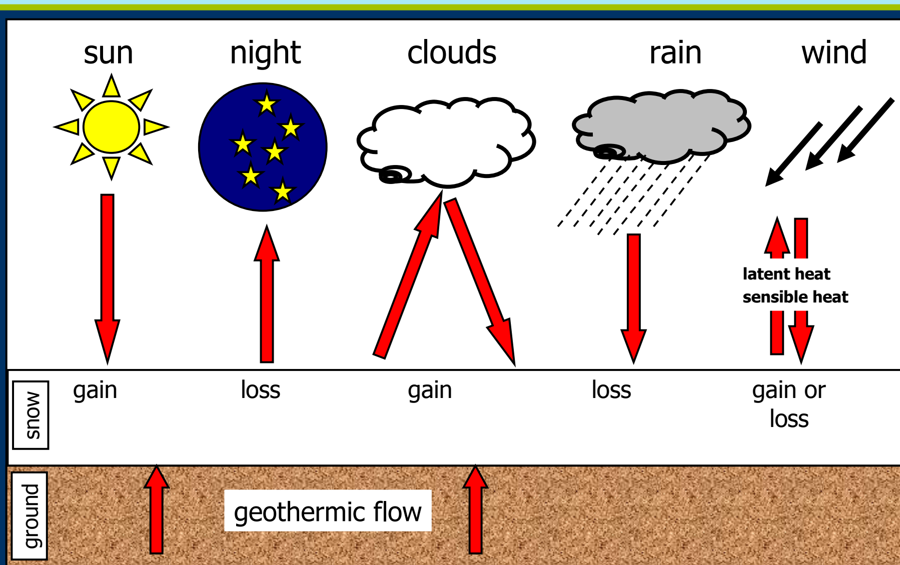
Snow and meteorology

The different properties of snow depend mostly on one parameter: its temperature.
Snow temperature depends on heat exchanges between snow and air: heat balance

The heat balance at the snow surface = difference between gain and loss of heat energy

balance is positive	balance is negative
snow temperature increases at 0°C: snow starts melting	snow temperature decreases

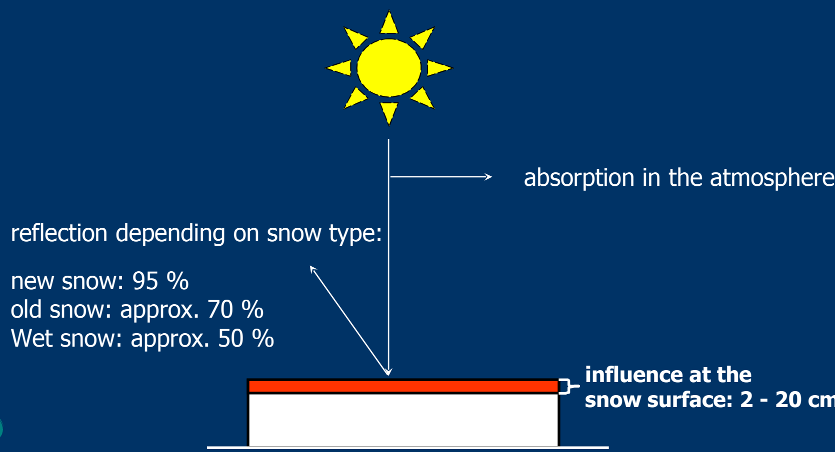
Heat balance

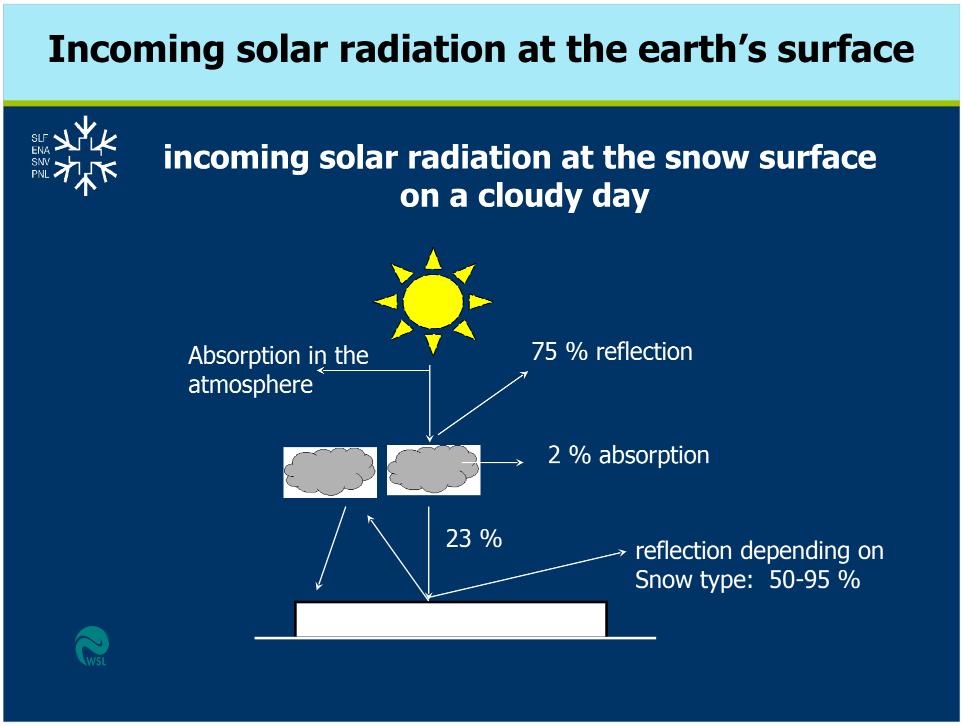


Gain and loss of heat energy at the snow surface

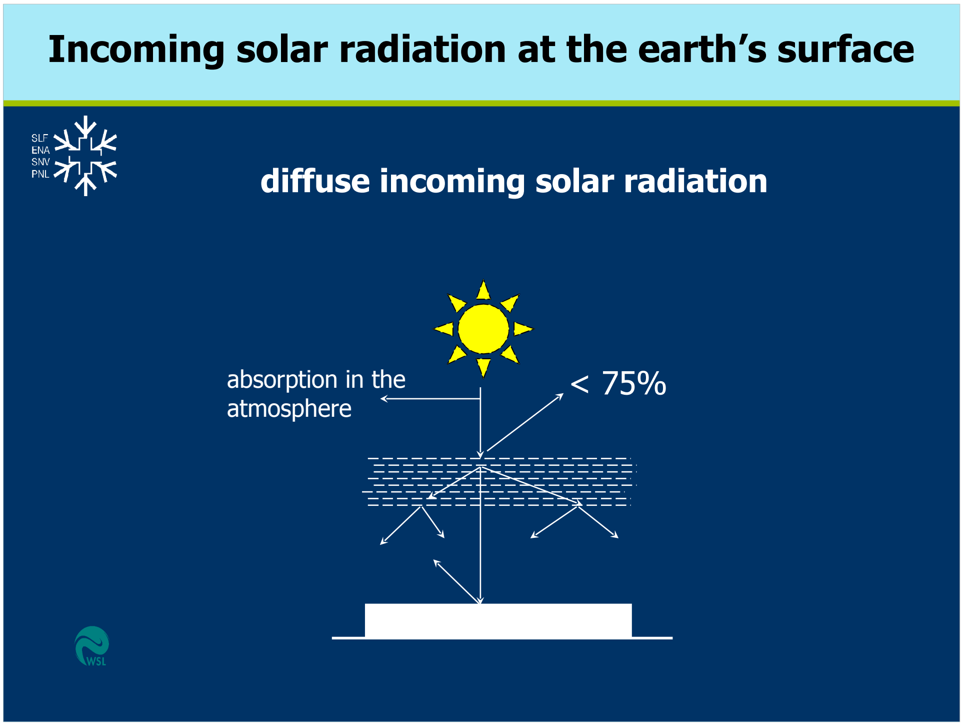
Incoming solar radiation at the earth's surface

incoming solar radiation at the snow surface on a sunny day

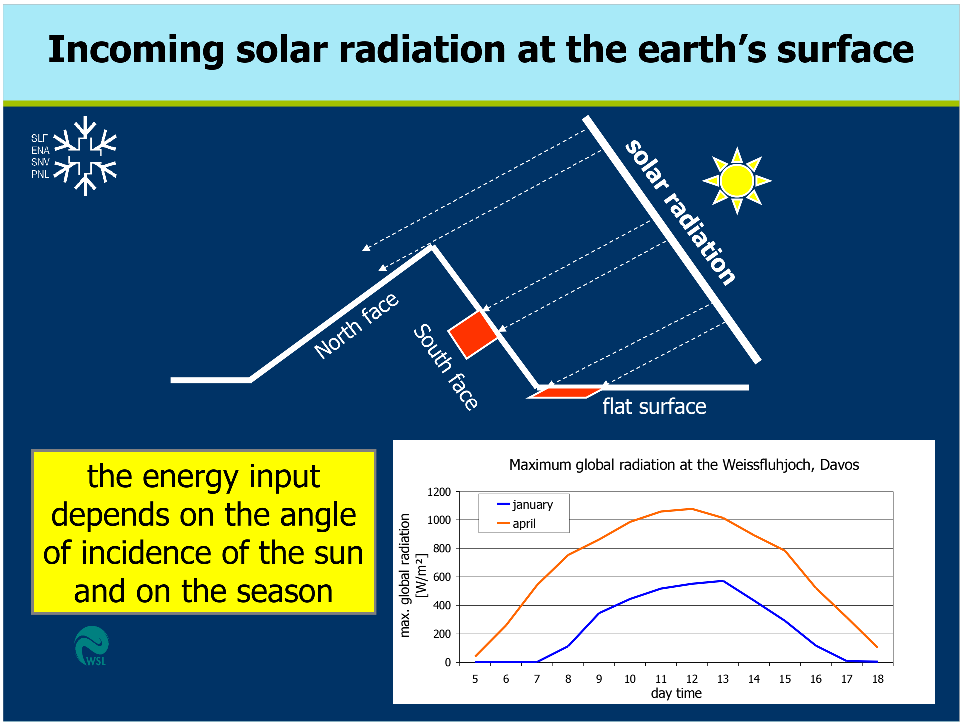




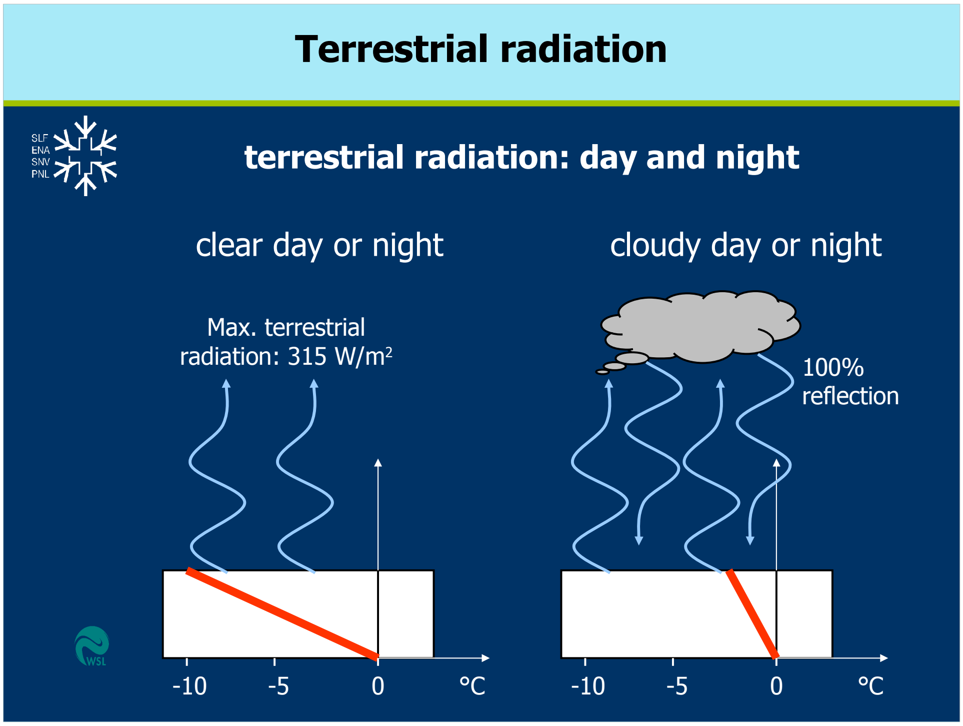
Involves an increase of snow temperature on all slope orientations



Involves an increase of snow temperature on all slope orientations



Example: World championship in Crans Montana 1986, February, Women Downhill: Start slope = South face, angle of incidence: 90°: high solar radiation: melting of snow (wet snow) / Flat zone in the forest: snow temperature = -12°C (low solar radiation)



Each body on the earths surface emits radiation

Short and long wave radiation

solar radiation = short wave radiation (λ = 0.5 μm)

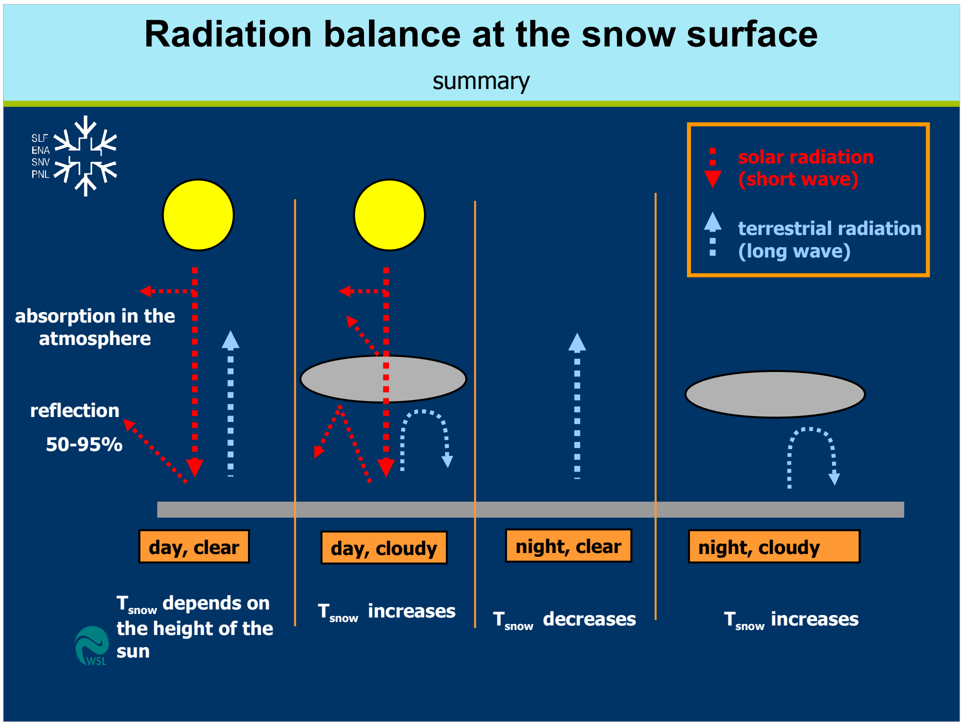
terrestrial radiation = long wave radiation (λ = 10 μm)

snow absorbs:

- 10 to 50 % of short wave radiation
- 99 % of long wave radiation

→ long wave radiation has a bigger influence on the melting of snow than short wave radiation

→ on a cloudy day, the snow's temperature increases faster due to the reflection of long wave radiation



Clear day: on locations where solar radiation is low (north face in winter), terrestrial radiation is often higher than solar radiation

Mechanical handling of snow

Mechanical handling of snow

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What do we have ? **snow** ✓

What do we want ? **ski piste:**

- **hard** → bonds, density, temperature, L.W.C.
- **homogeneous**

in order to obtain a good quality piste, we need to :

- prepare the snow mechanically
- optimise the preparation time
- use the natural snow transformation process

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Mechanical handling of snow

combination of man and nature

mechanical handling is a PREPARATION for the natural snow solidification process

- diminution of mean grain size
- obtaining of different grain sizes
- grains become rounder
- increase of snow density

man

natural snow solidification

- settlement and sintering

nature

snow hardening

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When does the snow have to be prepared?

The preparation time depends on:

- **type of snow** (temperature, liquid water content, grain shape)
- **weather forecasts**
  (air temperature, air humidity, net radiation)

↓

The preparation time must be chosen so that the snow hardening is the highest

When does the snow have to be prepared?

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dry snow

- snow hardening by sintering needs time (settling time is crucial before using the piste)

wet snow

- with a high liquid water content, the mechanical handling produces a water layer at the snow surface, which can freeze afterwards
- the best preparation time is just before the freezing starts

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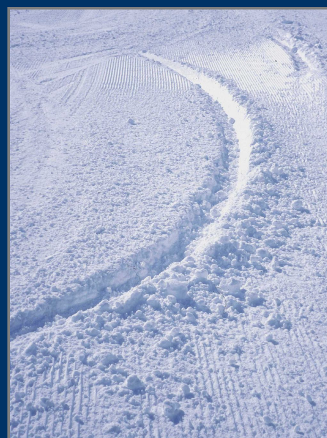
Influence of settling time on the sintering process

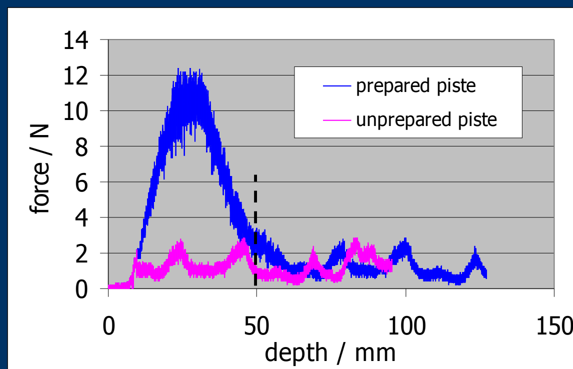


2 hours settling

10 hours settling

Impact of grooming machines on the snow

example: preparation of new snow, T_{snow} = -15°C



➔ impact of the machine only at the surface (5 – 20 cm)

➔ depends on: snow density, type of grain and snow temperature

Preparation and maintenance of race pistes

Race pistes must have high strengths in order to support the high forces produced by the skiers and the meteorological influences without transformation and therefore allowing a fair competition. ➔ hard piste

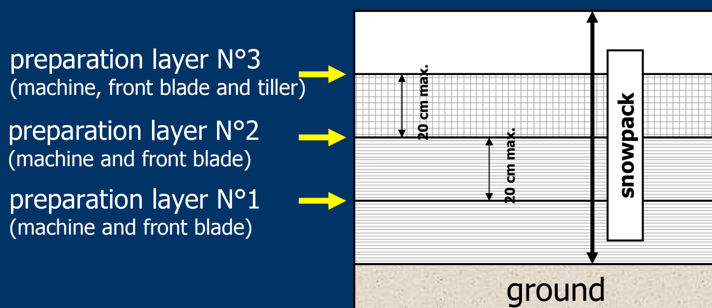
Preparation and maintenance of race pistes

3 major tasks:

- building a hard fundament
- hardening the snow surface
- repairing the piste during the race

Building a hard fundament

- since machine-made snow has high mechanical strength, it can constitute a good fundament
- preparation of new snow: compaction of successive snow layers (max. 20 cm thickness per layer)



Hardening the snow surface

3 methods can be used to harden the snow surface:

- mechanical handling (grooming machines and skis)
- using of water
- using of chemicals

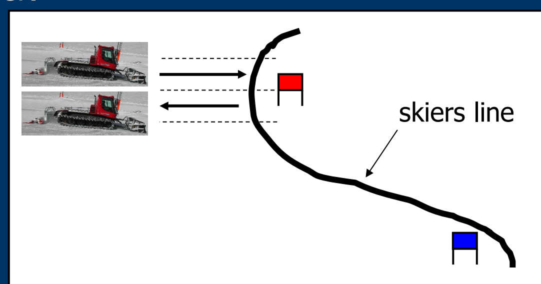
choice of the method depends on:

- snow type
- weather conditions
- race (downhill, super-G, slalom)

Hardening the snow surface

<u>mechanical handling</u>

- In the critical zones (curves, compressions, etc.) the piste must be, if possible, groomed perpendicular to the skiers line. The piste will therefore be more homogeneous and harder.



The picture is exaggerated. The preparation must take account of the topography and the machines possibilities.

Important is to prepare the snow as perpendicular as possible to the skiers line.

Hardening by water injection

aim

➨ increase snow density and amount and size of bonds between snow grains

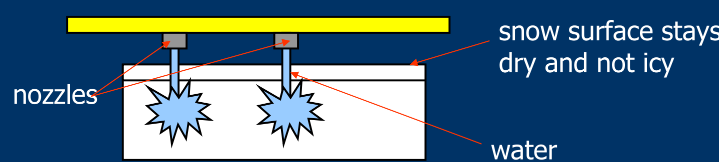
method

➨ injection of water with high pressure thru nozzles in the compacted snowpack

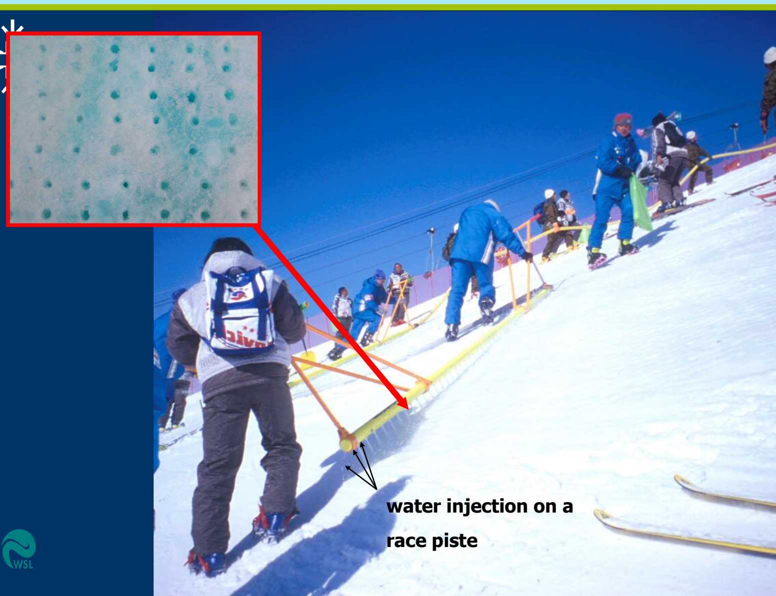
➨ Maximum:

- 20 l/m² for fine grained snow (ϕ < 0.5 mm)
- 10 l/m² for coarse grained snow (ϕ > 1 mm)

➨ pressure and flow can be modified



Hardening by water injection



Hardening by water injection

physical process

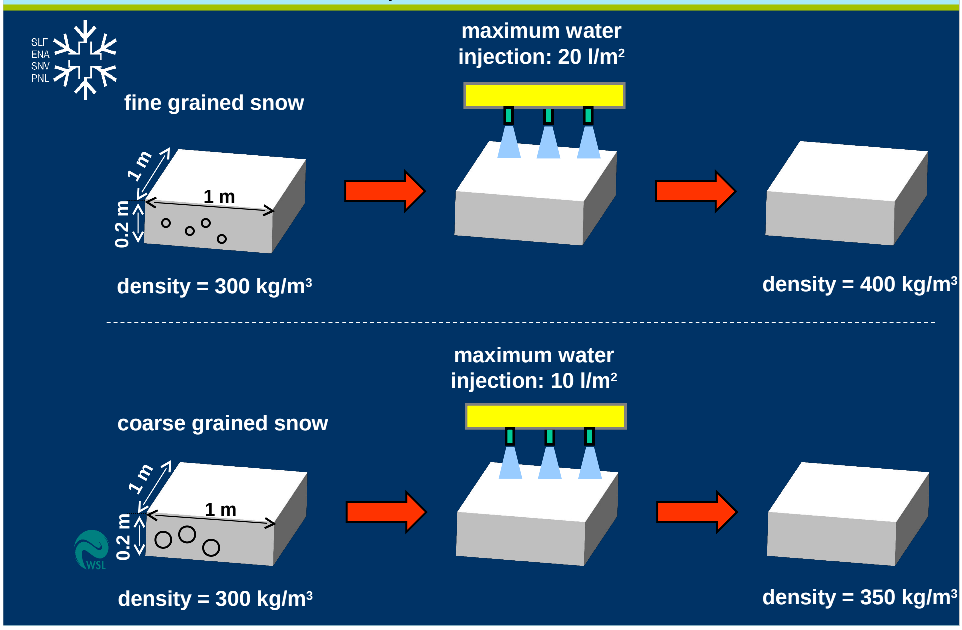
- increase of snow density
- freezing of liquid water with $T_{snow} < 0°C$
- heat is released
- heat is conducted out of the snowpack mostly by radiation and evaporation

conditions

- snow temperature < 0°C
- negative heat balance
- hard fundament

Hardening by water injection

Example: 1m x 1m x 0.2m



Hardening by application of chemicals

physical process

dissolution of the chemicals in the liquid water
+ melting of an amount of snow

needs heat

temperature sinks

freezing of the solution (water + chemicals)

heat release that must be conducted out of the snowpack (mostly by radiation energy)

Hardening by application of chemicals

most widely used chemicals

- sodium chloride (cooking salt)
- ammonium nitrate
- combinations

method

- application of a defined amount (see manufacturer's guide) of chemicals on the snow surface
- side slipping with skis (by high solar radiation: instant slipping, by high terrestrial radiation: slipping after crystallisation)

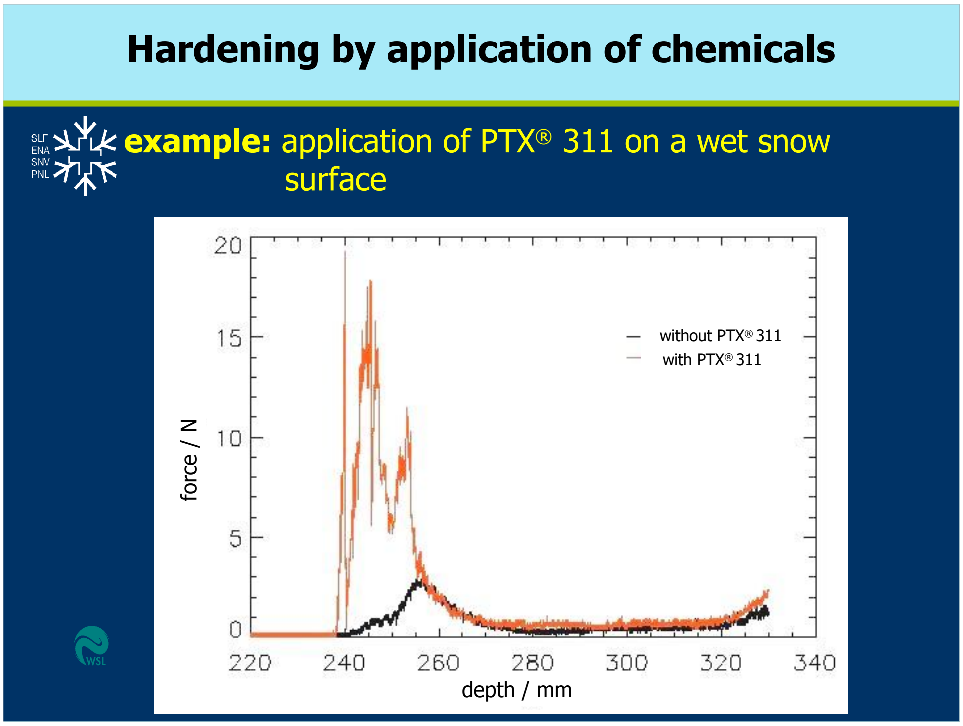
⚠ The amount of chemicals has a big influence on the process.

Hardening by application of chemicals

conditions

- wet snow
- negative heat balance

When snow is dry and no water can be sprayed to harden it, chemicals that release heat when they are mixed with snow, like calcium chloride, can be used to melt the snow.



Measurements in St-Moritz on a clear day

Special race piste preparation methods

summary

dry new snow density < 400 kg/m^3	dry snow density > 400 kg/m^3	wet snow
water (several applications) + chemicals (fasten the freezing process)	water (event. several applications)	chemicals

Reparation of the piste during the race

possible damages

- holes
- ruts
- chatters

reparations

- level the piste
- fill in the holes
- spread the snow
- limit the damage

(lengthen the blended area)

} shovels
rakes
skis

Practical example N°1

Preparation of a downhill race piste – new snow – cloudy night

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snow conditions

- 20 cm new snow at the surface
- snow density = 150 kg/m^3
- T_{snow}= -4°C
- hard fundament

weather forecasts

- cloudy night = constant snow temperature
- air temperature : between -1°C and -3°C

WSL

Practical example N°1

Preparation of a downhill race piste – new snow – cloudy night

preparation

glide zones:

- preparation with grooming machines directly after the snowfall
- settling time of at least 8 hours in order to obtain a sufficient natural snow consolidation

curves/jumps/compressions:

- remove the snow out of the track with shovels or eventually snow tillers
- warning: snow on fall-zones (side of the track) must also be prepared and the nets must be snow-free

Practical example N°2

Preparation of a slalom piste – dry and weak snow

SLF ENA SNV PNL

snow conditions

- snow surface density = 450 kg/m^3
- fine grained snow (ϕ < 0.5 mm)
- T_{snow} = -8°C

weather forecasts

- clear day (high terrestrial radiation)

WSL

Practical example N°2

Preparation of a slalom piste – dry and weak snow

preparation

- water injection No. 1 with max. 20 l/m^2
(density: 450 -> 550 kg/m^3)
- freezing time (minimum 6 hours)

- water injection No. 2 with max. 10 l/m^2
(density: 550 -> 600 kg/m^3)
- freezing time (minimum 4 hours)

Practical example N°3

Preparation of a super-G piste – wet and weak snow – competition day

snow conditions

- snow surface density = 550 kg/m³
- coarse grained snow
- wet, liquid water content = 7%, T_{snow} = 0°C

weather conditions

- clear day (terrestrial radiation)
- high solar radiation (spring)

preparation

- application of PTX® 311
- packing and slipping with skis

Thank you for your attention