



Dendrite Generator

More snow with less energy

Discussion about artificial snow production and energy demand for machine made snow

Team:

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Artificial snow enables ski tourism in Austria

Water consumption in a ski resort

Conventional transformation of water into snow

New device for making machine made snow

Outlook



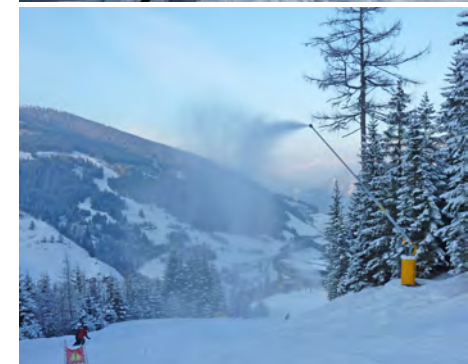
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Where does machine made snow is needed? (When & Why?)

- * ski-resorts all over the Alps (~66% in AUT)
- * 70% at the beginning of the winter season
- * assure 'success' of winter holidays for ski tourists

“Even in winters with little snow, you are guaranteed to ski since the snowmaking machines in Ischgl are some of the best and most reliable in the world.” (<http://www.ischgl.com>; 30.04.2010)

- * ski slopes are easier to machine/maintain
- * many other winter sport events





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Resources needed for machine made snow

- * water (e.g. 300.000 m³/a → 600.000 m³ snow / a)
- * snow gun (e.g. 25 kW/snow gun)
- * technical infrastructure (e.g. 600 kW/pump)
- * man power

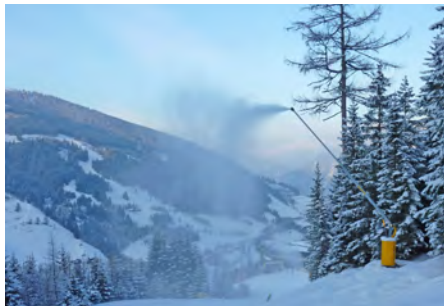




Transformation of water into snow

State of the art: Propeller-systems & lances

- atomization of water
- transporting the spray into the landscape
- waiting for droplets to freeze
- strongly dependent on deep temperatures (wet-bulb temperature)



Temp C	Good Snow Quality					Poor Snow Quality					No Snowmaking								
	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
-9	-12	-12	-12	-12	-12	-12	-12	-11	-11	-11	-11	-11	-11	-10	-10	-10	-10	-9	-9
-8	-12	-11	-11	-11	-11	-11	-11	-10	-10	-10	-10	-9	-9	-9	-9	-9	-8	-8	-8
-7	-10	-10	-10	-9	-9	-9	-9	-9	-8	-8	-8	-8	-8	-7	-7	-7	-7	-7	-7
-6	-10	-9	-9	-9	-9	-8	-8	-8	-8	-8	-8	-7	-7	-7	-7	-6	-6	-6	-6
-5	-9	-9	-8	-8	-8	-8	-8	-7	-7	-7	-7	-7	-6	-6	-6	-6	-5	-5	-5
-4	-8	-8	-8	-8	-8	-7	-7	-7	-7	-7	-6	-6	-6	-6	-5	-5	-5	-4	-4
-3	-7	-7	-7	-7	-6	-6	-6	-6	-5	-5	-5	-4	-4	-4	-4	-3	-3	-3	-3
-2	-7	-7	-6	-6	-6	-6	-5	-5	-5	-4	-4	-4	-4	-3	-3	-3	-3	-3	-2
-1	-6	-6	-5	-5	-4	-4	-4	-3	-3	-3	-3	-2	-2	-2	-2	-1	-1	-1	-1
0	-5	-5	-4	-4	-4	-4	-3	-3	-3	-3	-2	-2	-2	-1	-1	-1	-1	0	0
1	-5	-4	-4	-4	-3	-3	-3	-3	-2	-2	-2	-2	-1	-1	-1	0	0	0	1
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3	-3	-3	-3	-2	-2	-2	-1	-1	0	0	1	1	1	1	2	2	2	3	3
4	-2	-2	-1	-1	-1	0	0	1	1	1	2	2	2	3	3	3	4	4	4





SNOWwathome.com

Wet-Bulb Temperature Chart

Celsius

	Good Snow Quality									Poor Snow Quality					No Snowmaking				
	Humidity																		
	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Temp C																			
-9	-12	-12	-12	-12	-12	-12	-12	-11	-11	-11	-11	-11	-11	-10	-10	-10	-10	-9	-9
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-6	-10	-9	-9	-9	-9	-9	-8	-8	-8	-8	-8	-8	-7	-7	-7	-7	-7	-6	-6
-5	-9	-9	-8	-8	-8	-8	-8	-7	-7	-7	-7	-7	-6	-6	-6	-6	-6	-5	-5
-4	-8	-8	-8	-8	-8	-7	-7	-7	-7	-7	-6	-6	-6	-6	-5	-5	-5	-4	-4
-3	-7	-7	-7	-7	-6	-6	-6	-6	-5	-5	-5	-4	-4	-4	-4	-3	-3	-3	-3
-2	-7	-7	-6	-6	-6	-6	-5	-5	-5	-4	-4	-4	-4	-3	-3	-3	-3	-2	-2
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2	-4	-3	-3	-3	-2	-2	-2	-1	-1	-1	-1	0	1	1	1	1	2	2	2
3	-3	-3	-3	-2	-2	-2	-1	-1	-1	0	0	1	1	1	2	2	2	3	3
4	-2	-2	-1	-1	-1	0	0	1	1	1	2	2	2	3	3	3	4	4	4

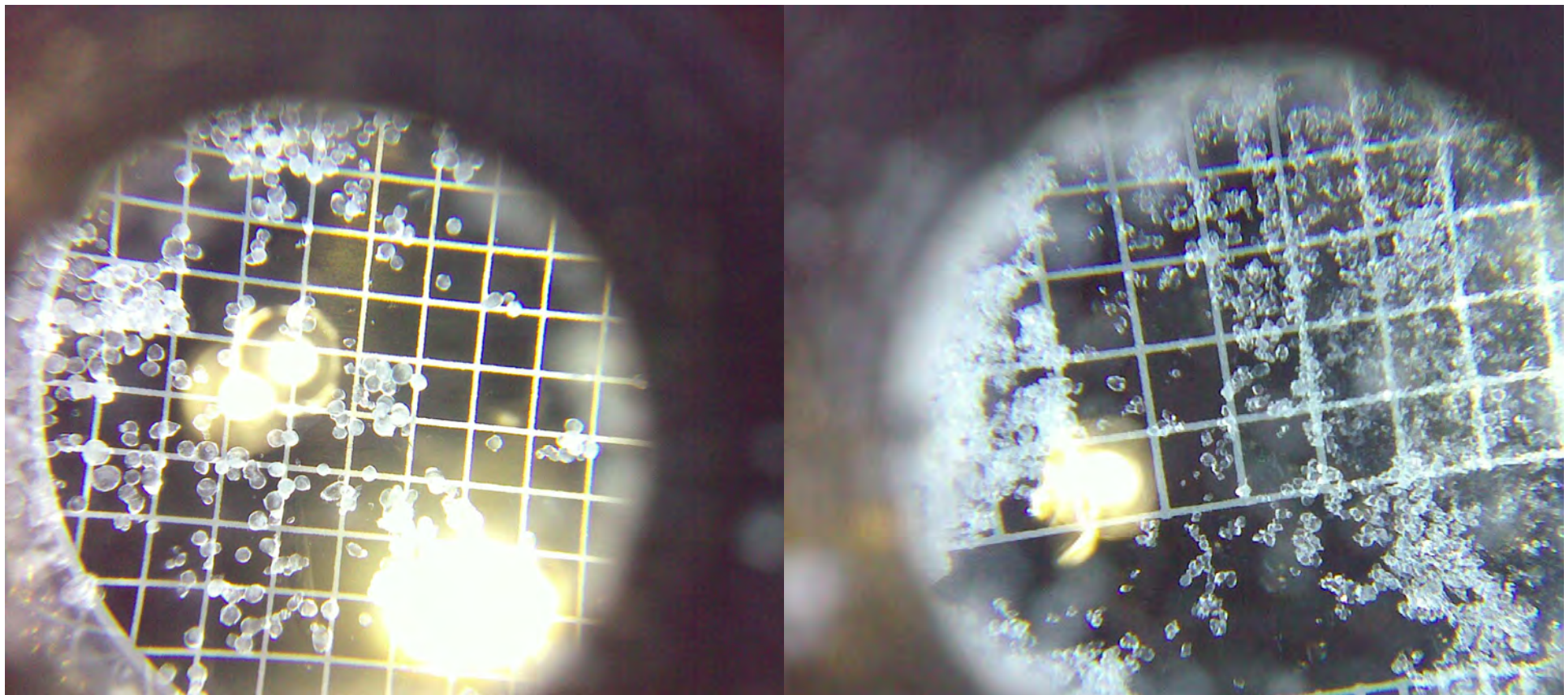
Wet bulb temperature is the lowest temperature that can be obtained by evaporating water into the air at a constant pressure. The term comes from the technique of wrapping a wet cloth around a mercury bulb thermometer and blowing air over the cloth until the water evaporates. The wet bulb temperature is always lower than the dry bulb temperature, but will be identical with 100% relative humidity. This wet bulb temperature is what snowmakers use to know when they can make snow. You can see it is possible to make snow when the temperatures are above freezing but only with very low humidity

Plot your current temperature (red numbers on the left) to the % of humidity (blue numbers on the top) and where they meet the (black numbers) is your current wet bulb temp.

Any time the wet bulb number is below -7 degrees Celsius (blue shaded area) snowmaking is at its best... nice dry snow. You can make snow from -6 degrees to -3 degrees wet bulb (purple shaded area) but the snow will be wet.



How does machine made snow looks like?

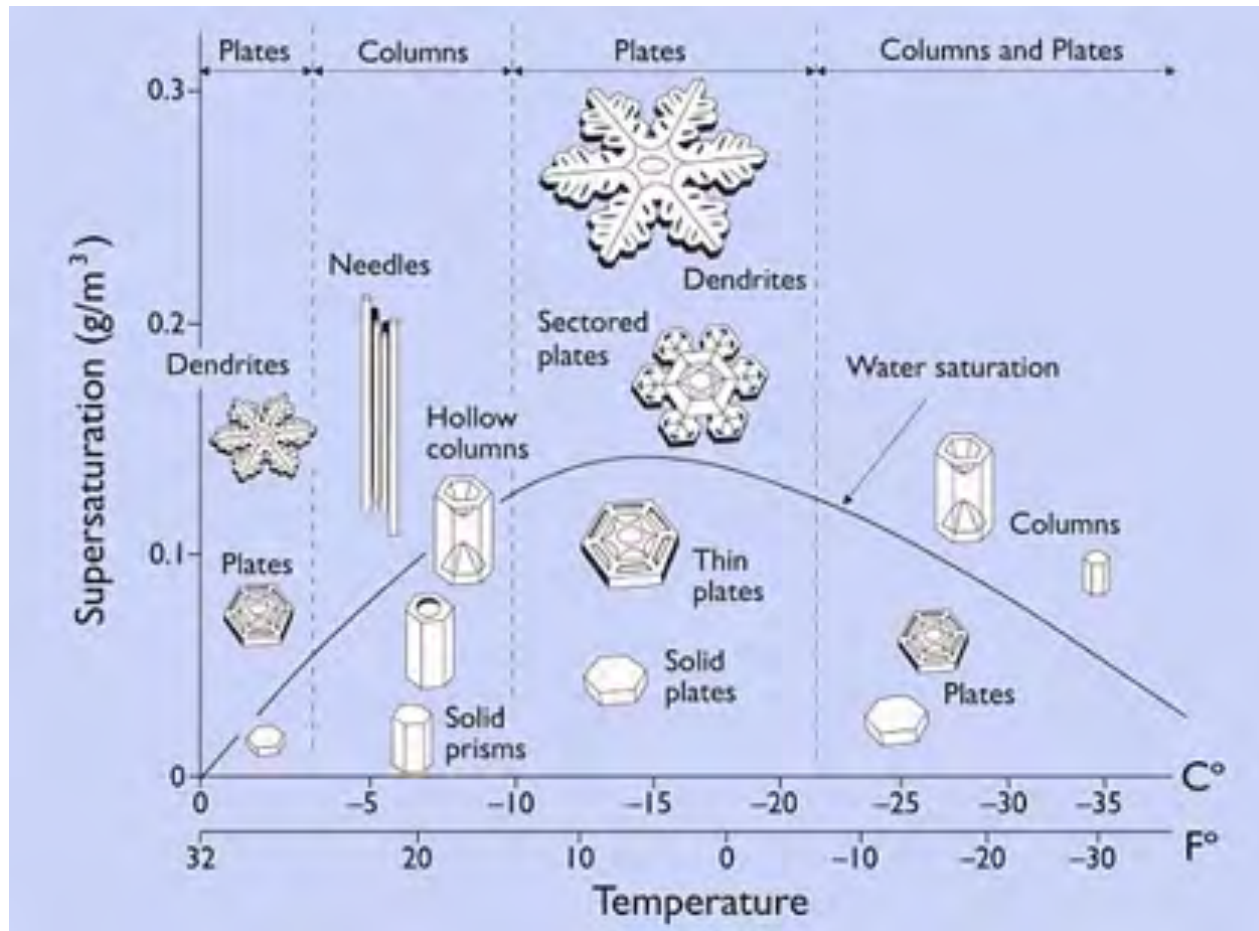


2mm grid; (r) lances, (l) propeller

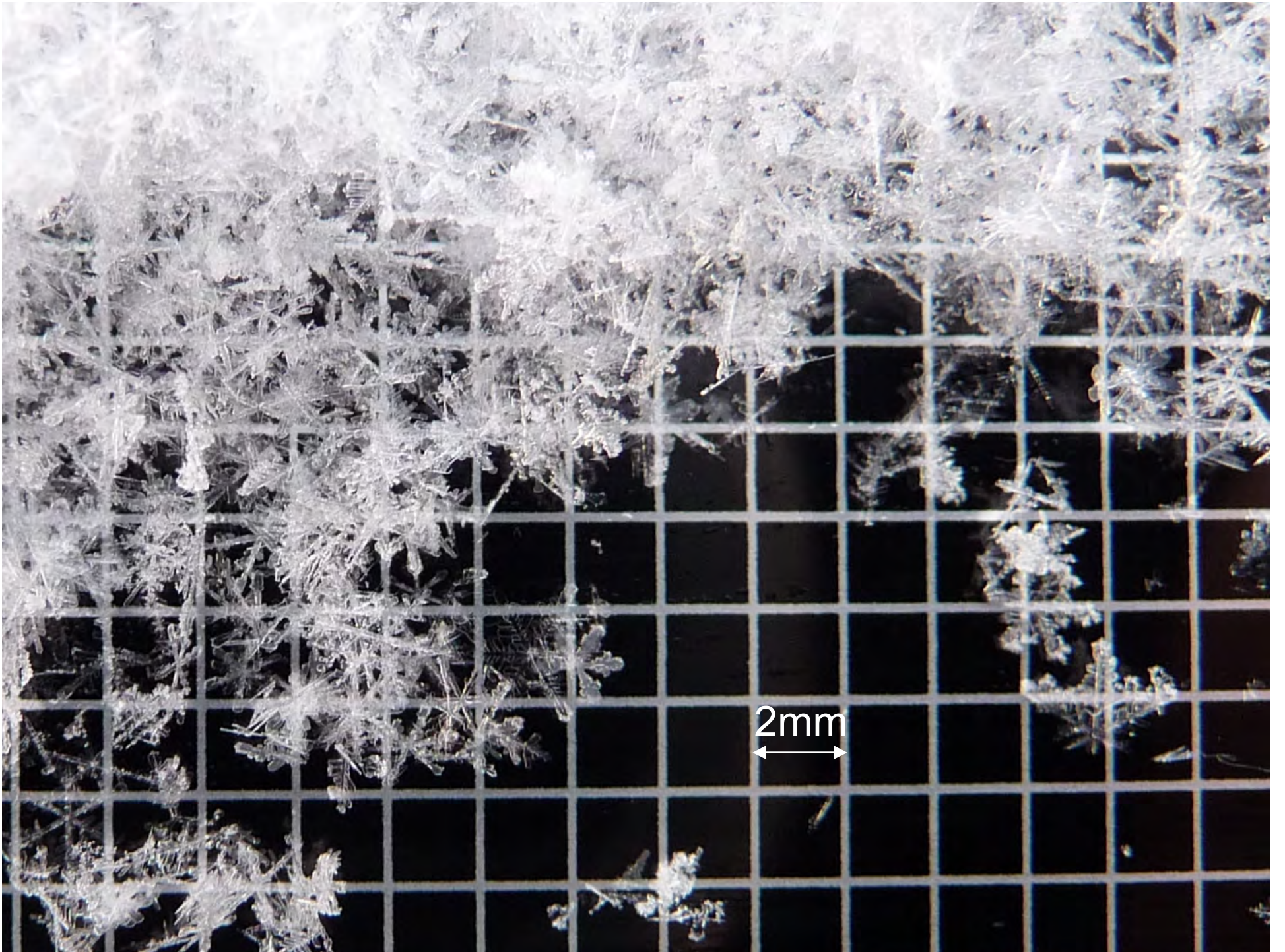


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A new device to produce machine made snow?



Picture: from Libbrecht 2005. Physics of snow crystals



A wide-angle photograph of a snowy mountain slope. Two skiers are visible in the middle ground, moving up the slope. The snow is bright white with some shadows and tracks. The sky is a pale, overcast blue.

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Requirements?

Lower energy demand. (e.g. < 7.5 MW for 90ha)

Adjustable snow density.

Adaptation to increasing temperature. (IPCC report)

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natural snow production

- * snow with low density
- * more snow / m³ water
- * low energy consumption
- * higher acceptance of ski tourists
- * environmentally friendly

max. 200-250kg/m³

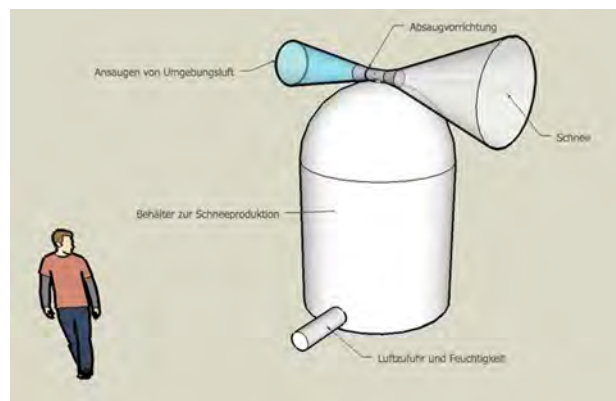
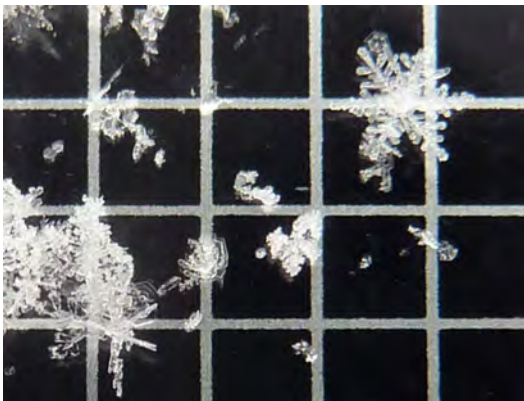
ratio ca. 1:5

reduction 40-90%

smooth, „fresh“ slopes

e.g. higher porosity

2mm grid



A wide-angle photograph of two skiers ascending a steep, snow-covered mountain slope. The skiers are silhouetted against the bright white snow. The terrain is rugged with some rocky patches visible. The sky is a pale, overcast blue.

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Outlook

- * proof of concept
- * developing new applications
- * field trials
- * scientific co-operations



**... to be
continued**