



Dendrite Generator

More snow with less energy

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

Team:

Michael Bacher, Meinhard Breiling, Fred Best, Sergey Sokratov, Dieter Draxler



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



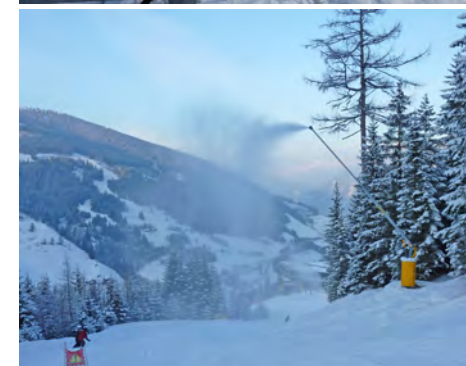
Dendrite Generator

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





Dendrite Generator

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

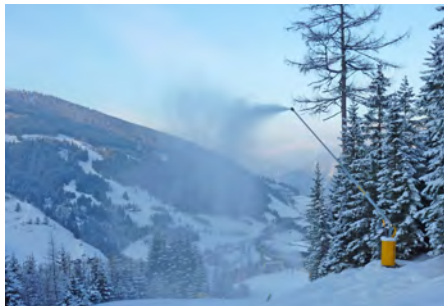




Transformation of water into snow

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
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	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
-8		-12	-11	-11	-11	-11	-11	-11	-10	-10	-10	-10	-9	-9	-9	-9	-9	-9	-8	-8
-7		-10	-10	-10	-9	-9	-9	-9	-9	-9	-8	-8	-8	-8	-8	-7	-7	-7	-7	-7
-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	-6	-5
-4		-8	-8	-8	-8	-8	-7	-7	-7	-7	-7	-6	-6	-6	-6	-6	-5	-5	-5	-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	-2	-1	-1	-1
0		-5	-5	-4	-4	-4	-4	-3	-3	-3	-3	-2	-2	-2	-2	-1	-1	-1	-1	0
1		-5	-4	-4	-4	-3	-3	-3	-3	-2	-2	-2	-2	-1	-1	-1	-1	0	0	1
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

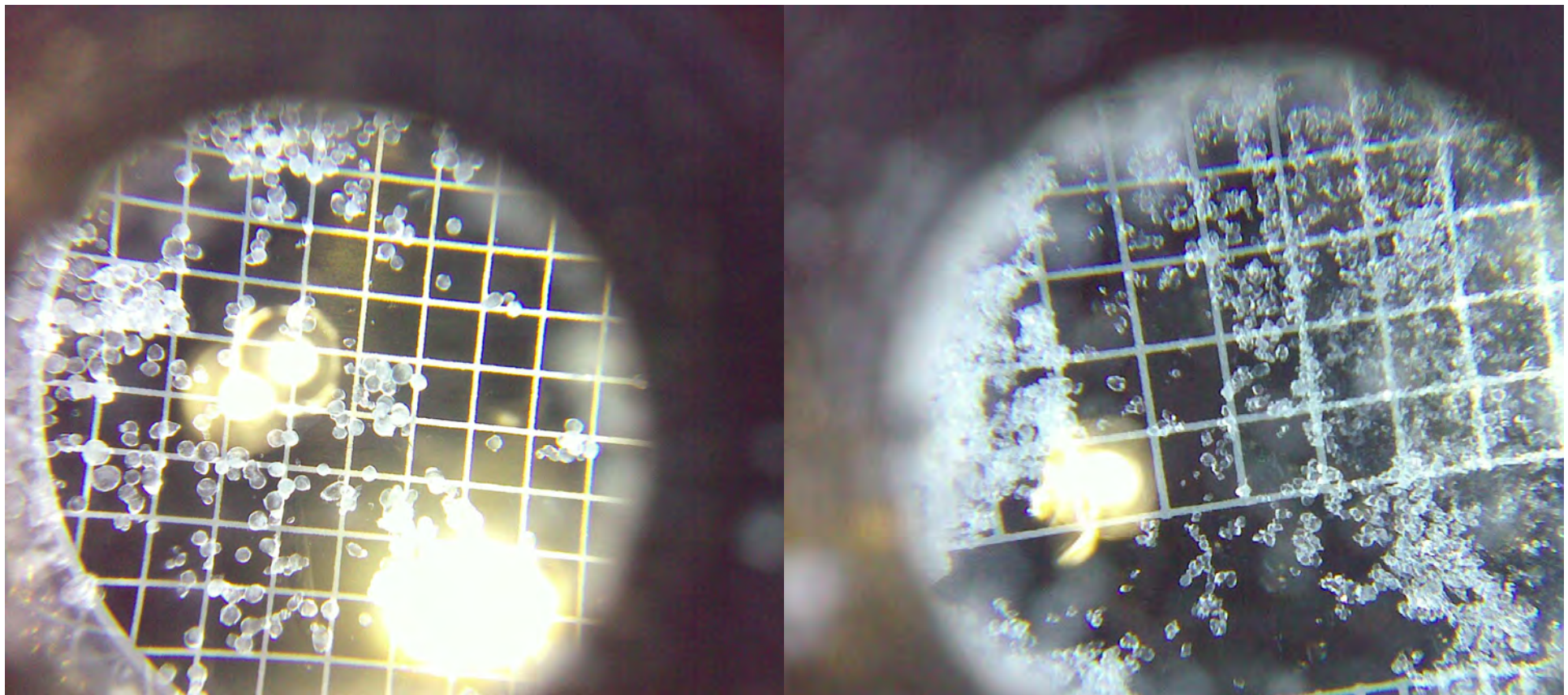
Wet bulb temperature is the lowest temperature that can be obtained by evaporating water into the air at a constant pressure. The term comes from the technique of wrapping a wet cloth around a mercury bulb thermometer and blowing air over the cloth until the water evaporates. The wet bulb temperature 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?

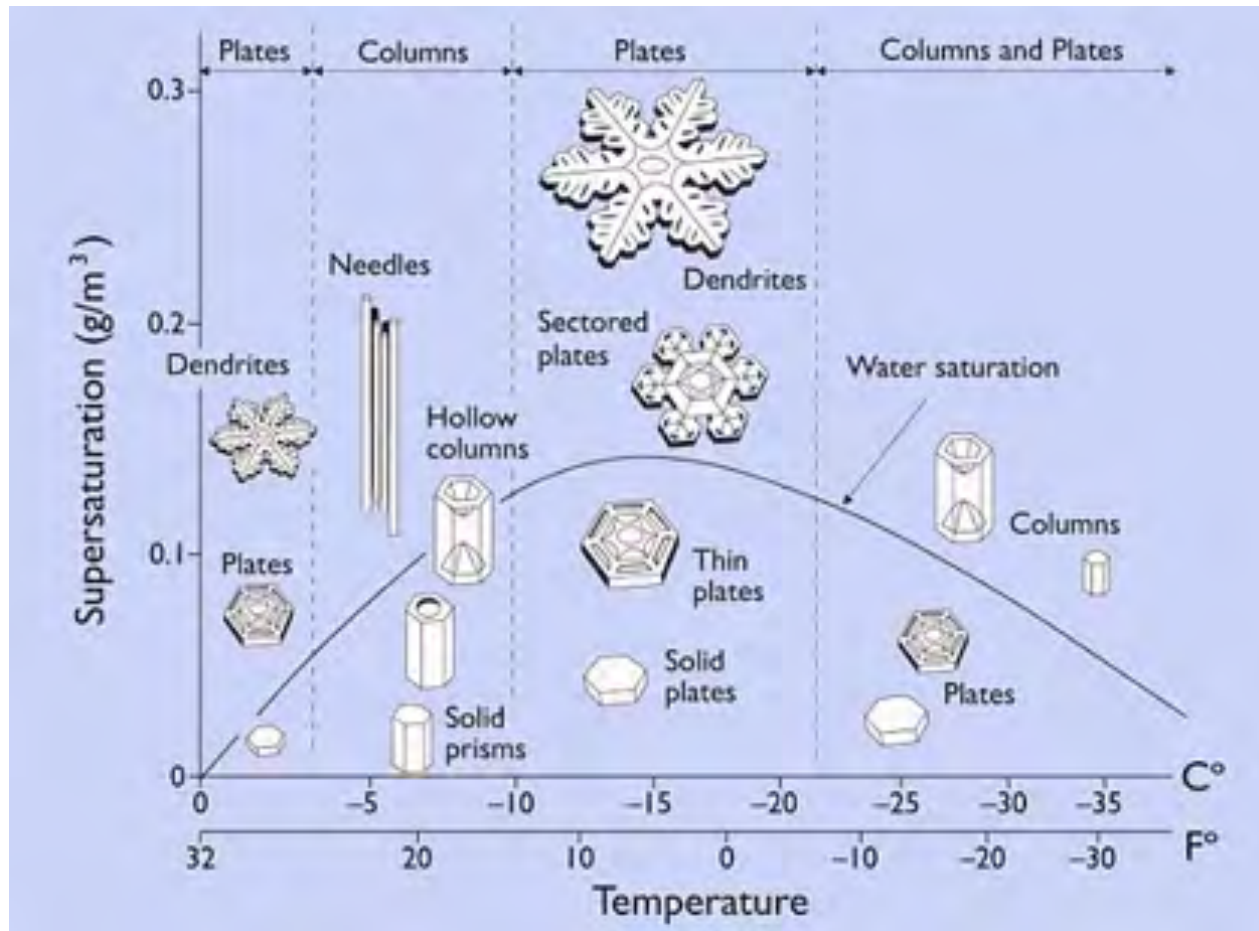


2mm grid; (r) lances, (l) propeller

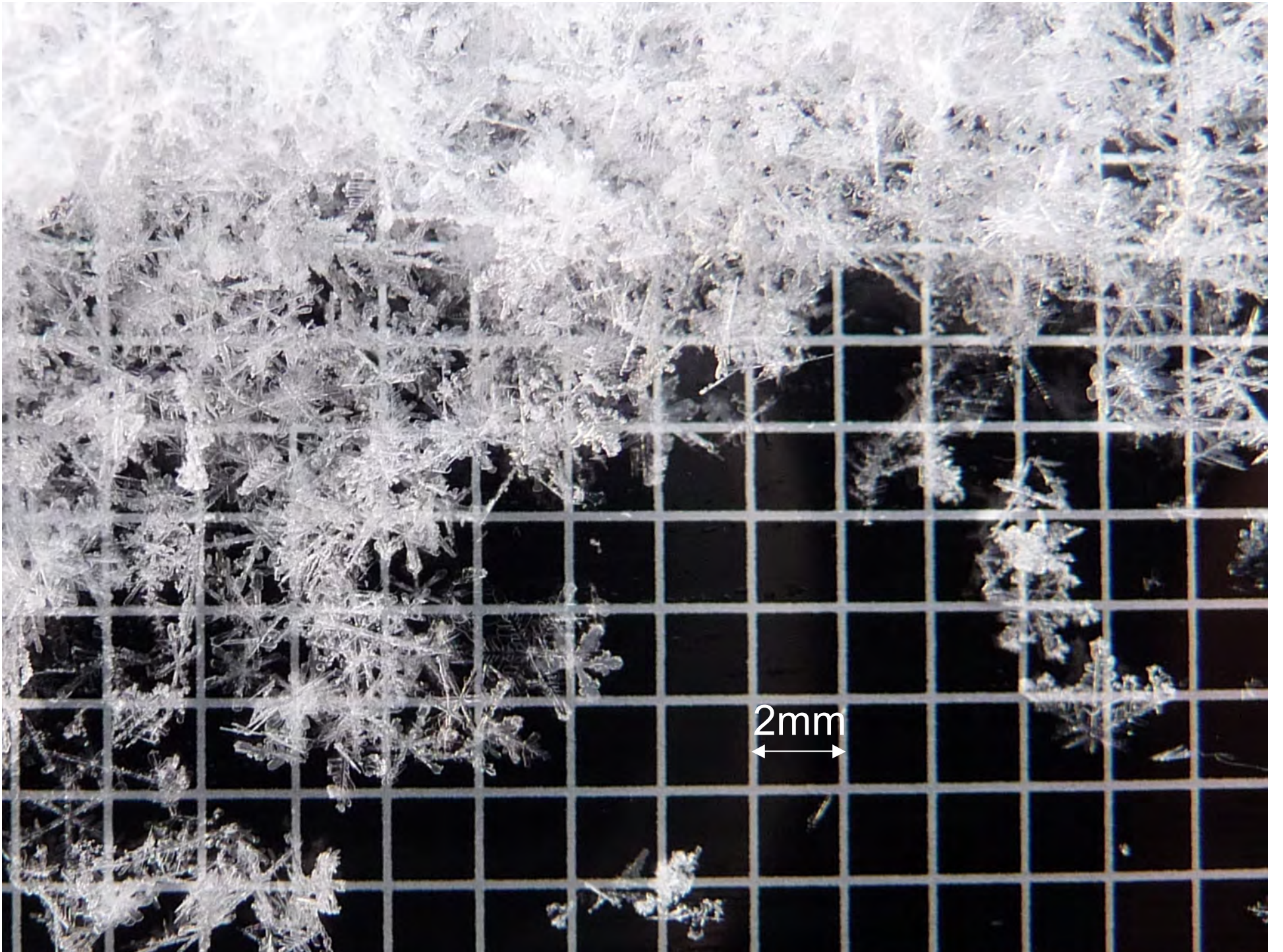


Dendrite Generator

A new device to produce machine made snow?



Picture: from Libbrecht 2005. Physics of snow crystals



A photograph of two skiers ascending a steep, snow-covered mountain slope. The skiers are in silhouette against the bright snow. The slope is covered in snow with some rocky patches visible. The text 'Dendrite Generator' is overlaid on the left side of the image in a white, sans-serif font.

Dendrite Generator

Requirements?

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

Adjustable snow density.

Adaptation to increasing temperature. (IPCC report)

...



Dendrite Generator

natural snow production

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

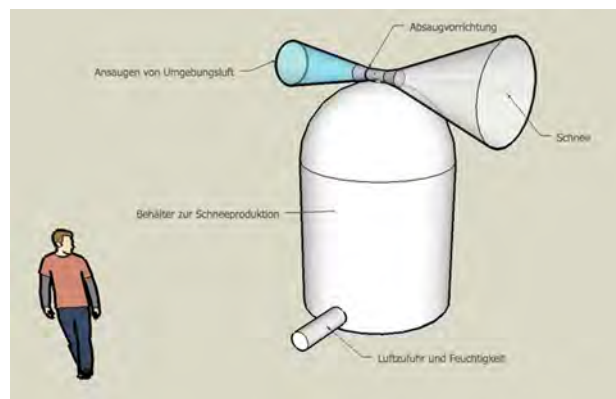
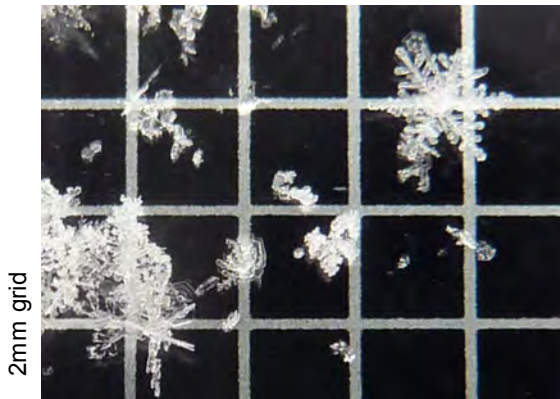
max. 200-250kg/m³

ratio ca. 1:5

reduction 40-90%

smooth, „fresh“ slopes

e.g. higher porosity



A wide-angle photograph of two skiers ascending a steep, snow-covered mountain slope. The skiers are positioned in the middle ground, moving from left to right. They are wearing dark winter gear and carrying large backpacks. The snow is bright white, and the background shows more of the mountain's ridges and valleys under a clear sky. The text 'Dendrite Generator' is overlaid on the left side of the image in a white, sans-serif font.

Dendrite Generator

Outlook

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



**... to be
continued**