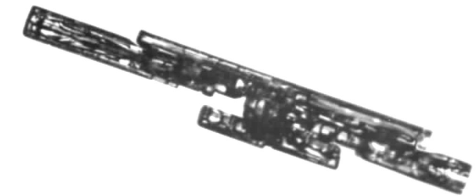
The Basics of Snow Formation

Jon Nelson

Snow School Training, Jan. 5 2017
Bellingham, WA

What is snow?

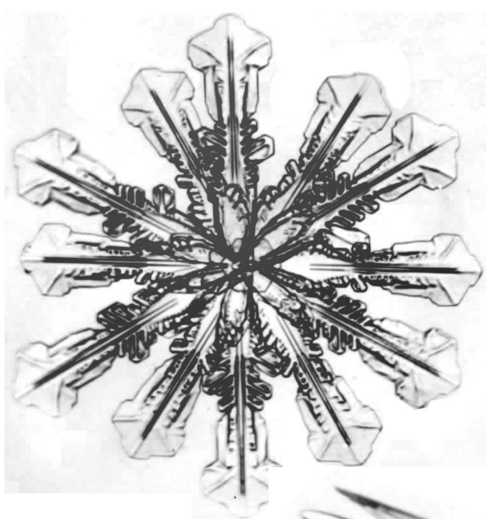


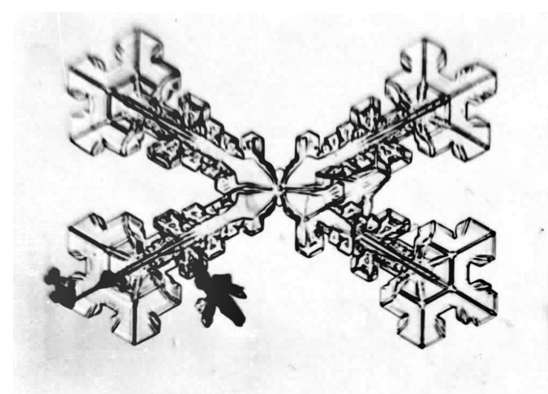
<u>Crystals</u>

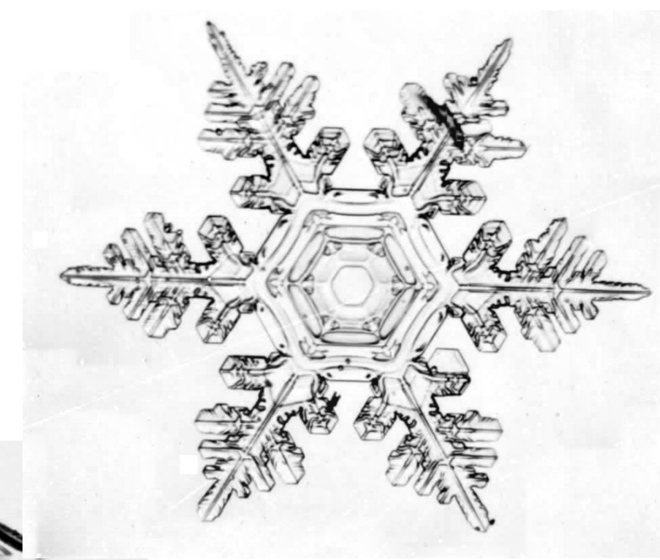
1) of regular hexagonal ice

2) of mass mostly from vapor deposition in air

3) that formed in a free-fall, usually in a cloud.



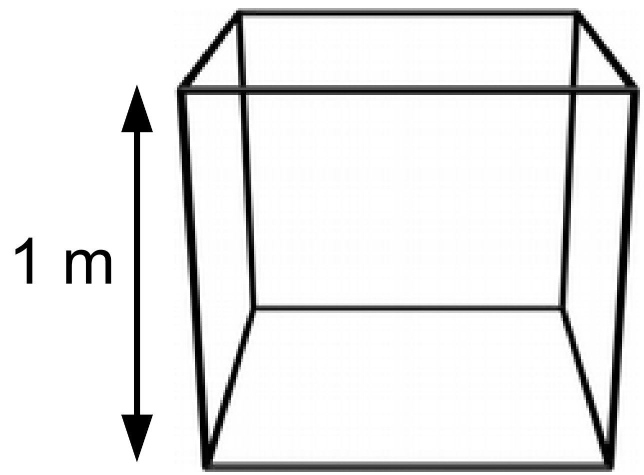




Notes: Not all ice that falls is snow. The above forms are all snow crystals. Hail, graupel, and "artificial snow" (at ski areas) gain their mass largely, or entirely, from freezing of liquid. Frost looks like snow, and grows like snow, but did not free-fall from above. Some snow might fall from a clear sky, but nearly all comes from a cloud.

What's in a snow cloud?

One cubic meter of cloudy air has



1) Air = about _______ grams (g)

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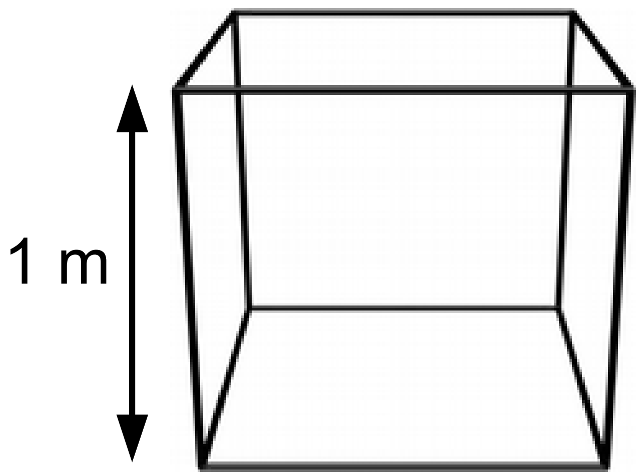

1) Air = about 1000 grams (g)

2) Water (drops) = about ______ g

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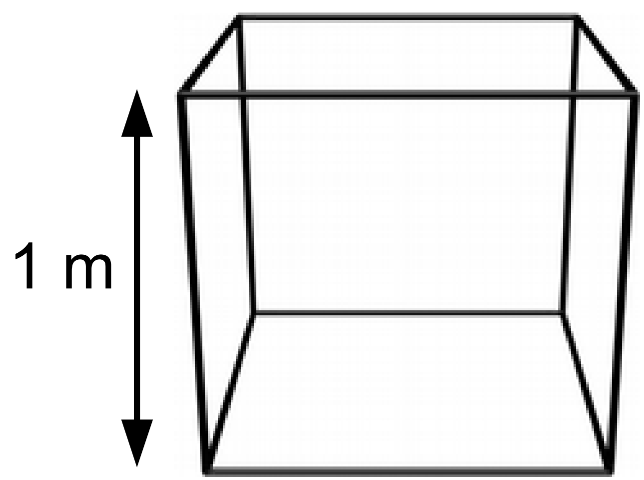

1) Air = about 1000 grams (g)

2) Water (drops) = about 1 g

3) Ice = about _____ g

What's in a snow cloud?

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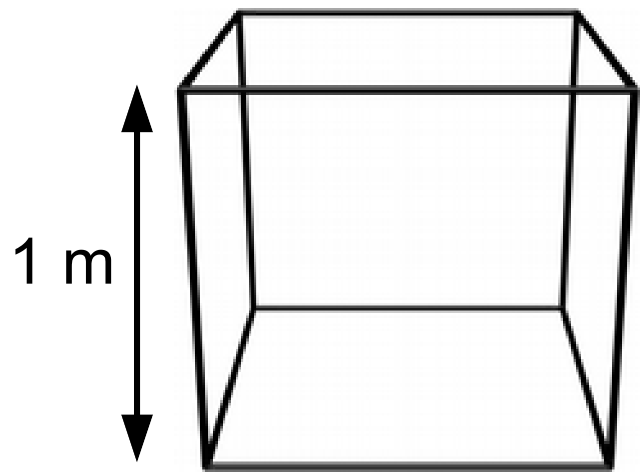


1) Air = about 1000 grams (g)

2) Water (drops) = about 1 g

3) Ice = about 0.01 g

How does the ice get started?

1) Dust rises in updraft.

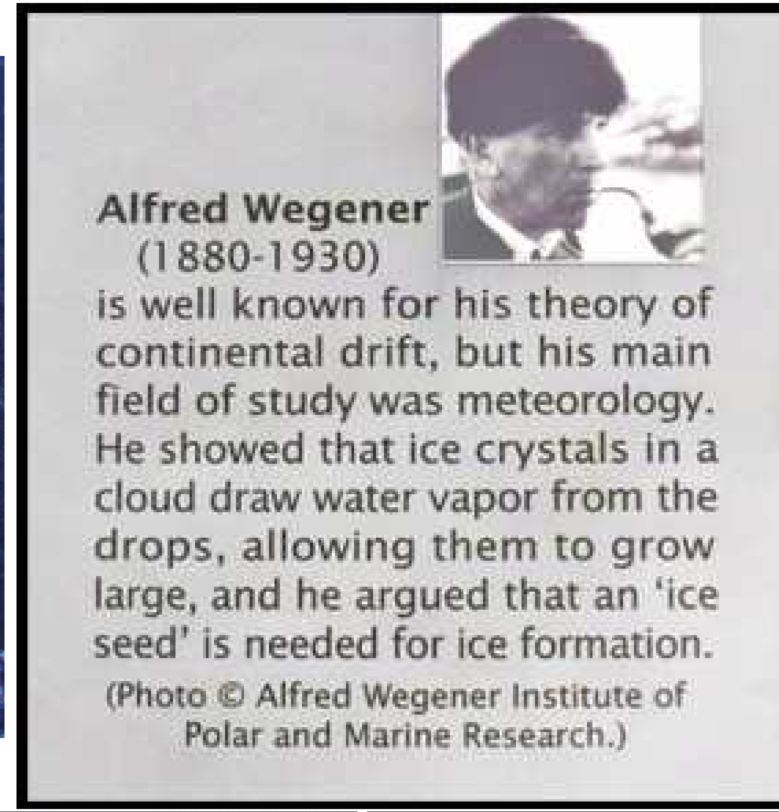
2) Droplet forms around dust (dew).

3) Droplet grows and freezes (below 0 C).

Ice always starts from melt-freezing. (Ostwald's "rule")

Notes: Water below 0 C is called "supercooled". Do not think of 0 C (32 F) as the freezing point. Instead, it is the melting point. Small amounts of water, such as drops, rarely freeze above -5 C. In clouds, most of the water is usually liquid down to at least -25 C. But at -40 C (-40 F) all liquid must freeze. The reason that ice forms first by melt freezing has to do with the surface energy. Even hoar frost must start on a frozen film of melt. The film is really thin, but it is there.

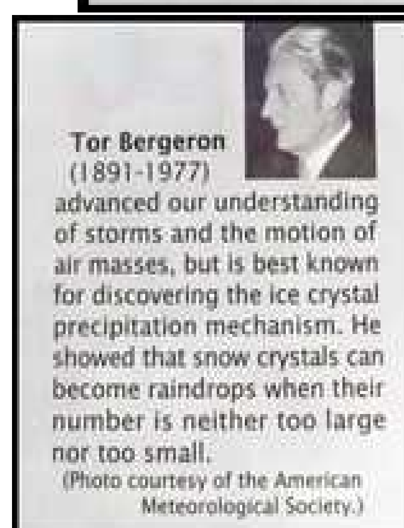
Why does the ice grow?



Alfred Wegener (1880-1930) is well known for his theory of continental drift, but his main field of study was meteorology. He showed that ice crystals in a cloud draw water vapor from the drops, allowing them to grow large, and he argued that an 'ice seed' is needed for ice formation.

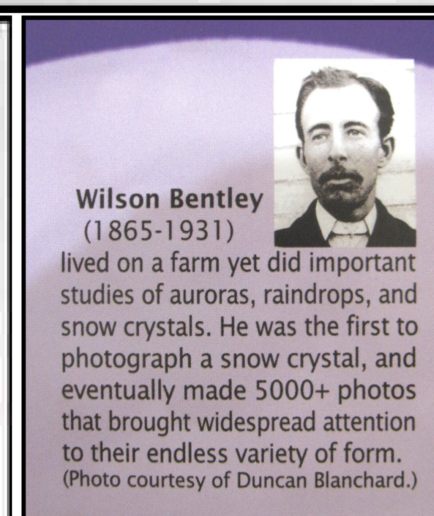
(Photo © Alfred Wegener Institute of Polar and Marine Research.)

Notes: The discovery about how ice can grow in clouds originates from an observation of frost, like the above. This shows a clear area around the large ice crystals. What happened was this: first, the surface was covered with tiny droplets of dew. Then, after it got cold enough, the four big ice pieces that are sticking up mark positions where a droplet froze. The nearby vapor density was high enough to keep the droplets from evaporating. Neaby vapor molecules stuck to the ice, drying out the nearby air. The droplets nearby vanished into the dry air. The four ice pieces grew large this way. Further away, droplets remained for awhile as the air got even colder, but later froze. Wegener said this happened in clouds. Bentley observed it too and said it happened in clouds, but did not understand the physical mechanism. Bergeron applied it to rain formation.



Tor Bergeron (1891-1977) advanced our understanding of storms and the motion of air masses, but is best known for discovering the ice crystal precipitation mechanism. He showed that snow crystals can become raindrops when their number is neither too large nor too small.

(Photo courtesy of the American Meteorological Society.)



Wilson Bentley (1865-1931) lived on a farm yet did important studies of auroras, raindrops, and snow crystals. He was the first to photograph a snow crystal, and eventually made 5000+ photos that brought widespread attention to their endless variety of form.

(Photo courtesy of Duncan Blanchard.)

How does it work (I)?

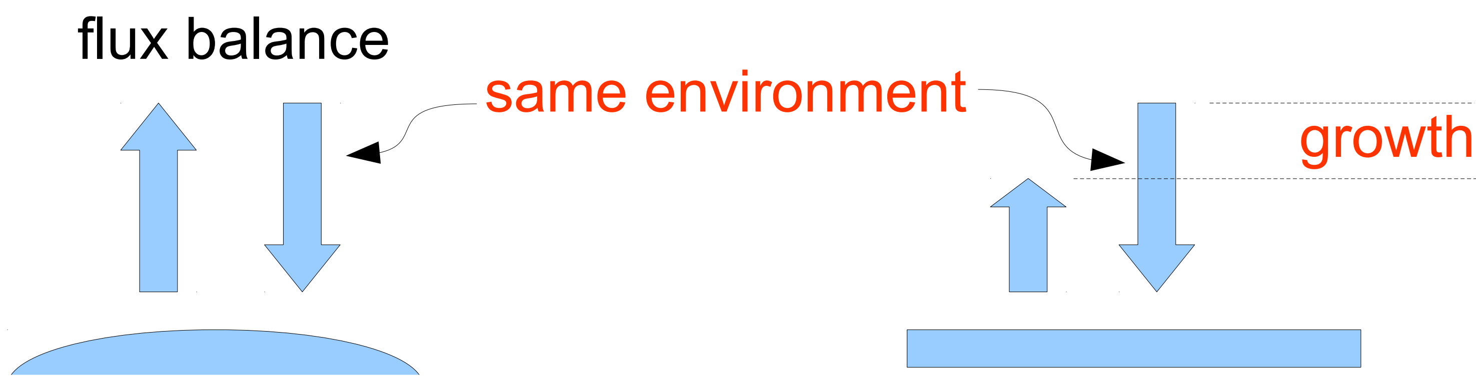
flux leaving

	drop surface	ice surface
-10 C	1.2 x 10^17 (#/mm^2-sec)	1.1 x 10^17
-30 C	2.2 x 10^16	1.6 x 10^16

Notes: The key idea is the flux of water that leave the droplet surface (AKA melt) and ice surfaces. For both surfaces, a very large number of molecules leave every square millimeter every second. Look at these numbers: nearly a million million millions. But the key thing is that, at any given temperature, ice has a stronger pull on its molecules, so fewer molecules leave than from the drop surface. Also, fewer leave at lower temperatures.

This flux leaving is also known as the evaporation flux (droplet) or sublimation flux (ice) into a vacuum. Think of it as evaporation.

How does it work (II)?



	drop surface	ice surface
-10 C	1.2 x 10^17 (#/mm^2-sec)	1.1 x 10^17
-30 C	2.2 x 10^16	1.6 x 10^16

Notes: There are so many water molecules evaporating off the droplets, that the air is "full" of water molecules (about 1 water molecule per 100 or more air molecules). These molecules are coming down and striking the surface. They reach a near balance, with about the same number arriving as there are leaving. This same number are also arriving on the ice. But fewer are leaving the ice. Therefore, the ice is collecting more molecules than ejecting. That is, the ice grows.

Do NOT think about "vapor pressure". People just get confused and start mistakingly thinking that there is a pressure difference pushing water molecules from the drops to the ice. Sounds neat and tidy, but wrong. Molecules are NOT pushed from the drop surface to the ice. The flow of molecules is not a pressure-driven wind. The actual process is called diffusion.

Think just the above: the ice is holding its water molecules harder than the droplets, and because there are so many droplets, the air has plenty of excess water molecules that stick to the ice. This idea is not just simpler, it is correct.