Ice Crystals

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Atmos 3200/ Geog 3280
Mountain Weather and Climate
Saturation vapor pressure for ice is lower than that for water.
Air is near saturation for water, but is supersaturated for ice.
Ice crystals/snowflakes grow by vapor deposition.
Cloud droplets may lose mass to evaporation.
Ice crystal growth
**Habits** – types of ice crystal shapes created by vapor deposition

- Sector plate
- Stellar dendrite
- Dendritic sector plate
- Hollow column
- Needle
Ice crystal *habits*

- stellar dendrites
- plates
- sectored plates
- needles
- spatial dendrites
- rimed crystals
- hollow columns
- capped columns
- oddballs

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Unusual snow crystal forms

- 12-sided snowflakes
- Bullets
- Triangular snowflakes
- Arrowhead crystals
- Twin prisms
- Pyramidal crystals

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Magono and Lee’s classification of snow crystals

<table>
<thead>
<tr>
<th>N1a</th>
<th>Elementary needle</th>
<th>C1f</th>
<th>Hollow column</th>
<th>P2b</th>
<th>Stellar crystal with sectorlike ends</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1b</td>
<td>Bundle of elementary needles</td>
<td>C1g</td>
<td>Solid thick plate</td>
<td>P2c</td>
<td>Dendritic crystal with plates of ends</td>
</tr>
<tr>
<td>N1c</td>
<td>Elementary sheath</td>
<td>C1h</td>
<td>Thick plate of skeleton form</td>
<td>P2d</td>
<td>Dendritic crystal with sectorlike ends</td>
</tr>
<tr>
<td>N1d</td>
<td>Bundle of elementary sheaths</td>
<td>C1i</td>
<td>Scroll</td>
<td>P2e</td>
<td>Plate with simple extensions</td>
</tr>
<tr>
<td>N1e</td>
<td>Long solid needle</td>
<td>C2a</td>
<td>Combination of bullets</td>
<td>P2f</td>
<td>Plate with sectorlike extensions</td>
</tr>
<tr>
<td>N2a</td>
<td>Combination of needles</td>
<td>C2b</td>
<td>Combination of columns</td>
<td>P2g</td>
<td>Plate with dendritic extensions</td>
</tr>
<tr>
<td>N2b</td>
<td>Combination of sheaths</td>
<td>N2c</td>
<td>Combination of long solid columns</td>
<td>P3a</td>
<td>Two branched crystal</td>
</tr>
<tr>
<td>C1a</td>
<td>Pyramid</td>
<td>P1a</td>
<td>Hexagon plate</td>
<td>P3b</td>
<td>Three branched crystal</td>
</tr>
<tr>
<td>C1b</td>
<td>Cup</td>
<td>P1b</td>
<td>Crystal with sectorlike branches</td>
<td>P3c</td>
<td>Four-branched crystal</td>
</tr>
<tr>
<td>C1c</td>
<td>Solid bullet</td>
<td>P1c</td>
<td>Crystal with broad branches</td>
<td>P4a</td>
<td>Broad branch crystal with 12 branches</td>
</tr>
<tr>
<td>C1d</td>
<td>Hollow bullet</td>
<td>P1d</td>
<td>Stellar crystal</td>
<td>P4b</td>
<td>Dendritic crystal with 12 branches</td>
</tr>
<tr>
<td>C1e</td>
<td>Solid column</td>
<td>P1e</td>
<td>Ordinary dendritic crystal</td>
<td>P4c</td>
<td>Stellar crystal with needles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P1f</td>
<td>Facetlike crystal</td>
<td>P4d</td>
<td>Dendritic crystal with 12 branches</td>
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<td></td>
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<td>P1f</td>
<td>Facetlike crystal</td>
<td>P4e</td>
<td>Dendritic crystal with needles</td>
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<td></td>
<td></td>
<td>P2a</td>
<td>Stellar crystal with plates at ends</td>
<td>P4f</td>
<td>Dendritic crystal with 12 branches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2a</td>
<td>Stellar crystal with plates at ends</td>
<td>P4g</td>
<td>Dendritic crystal with needles</td>
</tr>
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<td></td>
<td></td>
<td>P2b</td>
<td>Stellar crystal with plates at ends</td>
<td>P4h</td>
<td>Dendritic crystal with 12 branches</td>
</tr>
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<td>P2b</td>
<td>Stellar crystal with plates at ends</td>
<td>P4i</td>
<td>Dendritic crystal with needles</td>
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<td>P2b</td>
<td>Stellar crystal with plates at ends</td>
<td>P4j</td>
<td>Dendritic crystal with 12 branches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2b</td>
<td>Stellar crystal with plates at ends</td>
<td>P4k</td>
<td>Dendritic crystal with needles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2b</td>
<td>Stellar crystal with plates at ends</td>
<td>P4l</td>
<td>Dendritic crystal with 12 branches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2b</td>
<td>Stellar crystal with plates at ends</td>
<td>P4m</td>
<td>Dendritic crystal with needles</td>
</tr>
<tr>
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<td></td>
<td>P2b</td>
<td>Stellar crystal with plates at ends</td>
<td>P4n</td>
<td>Dendritic crystal with 12 branches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2b</td>
<td>Stellar crystal with plates at ends</td>
<td>P4o</td>
<td>Dendritic crystal with needles</td>
</tr>
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<td>P2b</td>
<td>Stellar crystal with plates at ends</td>
<td>P4p</td>
<td>Dendritic crystal with 12 branches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P2b</td>
<td>Stellar crystal with plates at ends</td>
<td>P4q</td>
<td>Dendritic crystal with needles</td>
</tr>
</tbody>
</table>

- **N1a**: Elementary needle
- **N1b**: Bundle of elementary needles
- **N1c**: Elementary sheath
- **N1d**: Bundle of elementary sheaths
- **N1e**: Long solid needle
- **N2a**: Combination of needles
- **N2b**: Combination of sheaths
- **N2c**: Combination of long solid columns
- **C1a**: Pyramid
- **C1b**: Cup
- **C1c**: Solid bullet
- **C1d**: Hollow bullet
- **C1e**: Solid column
- **C1f**: Hollow column
- **C1g**: Solid thick plate
- **C1h**: Thick plate of skeleton form
- **C1i**: Scroll
- **C2a**: Combination of bullets
- **C2b**: Combination of columns
- **P1a**: Hexagon plate
- **P1b**: Crystal with sectorlike branches
- **P1c**: Crystal with broad branches
- **P1d**: Stellar crystal
- **P1e**: Ordinary dendritic crystal
- **P1f**: Facetlike crystal
- **P2a**: Stellar crystal with plates at ends
- **P2b**: Stellar crystal with plates at ends
- **P2c**: Dendritic crystal with plates of ends
- **P2d**: Dendritic crystal with sectorlike ends
- **P2e**: Plate with simple extensions
- **P2f**: Plate with sectorlike extensions
- **P2g**: Plate with dendritic extensions
- **P3a**: Two branched crystal
- **P3b**: Three branched crystal
- **P3c**: Four-branched crystal
- **P4a**: Broad branch crystal with 12 branches
- **P4b**: Dendritic crystal with 12 branches
- **P4c**: Stellar crystal with needles
- **P4d**: Dendritic crystal with 12 branches
- **P4e**: Dendritic crystal with needles
- **P4f**: Dendritic crystal with 12 branches
- **P4g**: Dendritic crystal with needles
- **P4h**: Dendritic crystal with 12 branches
- **P4i**: Dendritic crystal with needles
- **P4j**: Dendritic crystal with 12 branches
- **P4k**: Dendritic crystal with needles
- **P4l**: Dendritic crystal with 12 branches
- **P4m**: Dendritic crystal with needles
- **P4n**: Dendritic crystal with 12 branches
- **P4o**: Dendritic crystal with needles
- **P4p**: Dendritic crystal with 12 branches
- **P4q**: Dendritic crystal with needles
- **P4r**: Dendritic crystal with 12 branches
- **P4s**: Dendritic crystal with needles
- **P4t**: Dendritic crystal with 12 branches
- **P4u**: Dendritic crystal with needles
- **P4v**: Dendritic crystal with 12 branches
- **P4w**: Dendritic crystal with needles
- **P4x**: Dendritic crystal with 12 branches
- **P4y**: Dendritic crystal with needles
- **P4z**: Dendritic crystal with 12 branches
Crystal type vs temperature and supersaturation

Ken Libbrecht's Field Guide to Snowflakes (Voyager Press, 2006)
Are any two snow crystals alike?

**Snow Crystal Growth and “The No-Two-Alike Conjecture”**

- Nucleation around a dust particle

  Grows to hexagonal prism, since smooth facets grow most slowly

  Simple plate unstable as crystal grows larger ... corners sprout arms

  Crystal moves to different temperature ... plates grow on arms

  Crystal moves through many different temperatures ... each change causes new growth behavior on arms

  Complex history → Complex crystal shape
  Each arm experiences same history → Symmetry
  No two paths similar → No two alike
How can we make snow?

What do we need to make snow?
Source of liquid water, compressed air, ice nuclei, cold air temperatures.
Ice Crystal Optics
Sundogs = parhelia
Sub sun

Little Cottonwood Canyon

(c) Trace Carrillo
Sub-sun & sub-parhelion
Halos at the South Pole

http://www.atoptics.co.uk/halo/spole.htm
Molecular Structure of Ice Crystals

All crystals have identical interfacial angles!

Why: they are all **hexagonal prisms** of varying habit: ranging from long columns to thin plates.

Alignment: due to air resistance they are often aligned in a certain way.

http://www.atoptics.co.uk/halo/crhal.htm
Atmospheric Halos

- random alignment - 22° halo
- plate arcs or halos
- column arcs or halos

A 22° circular halo surrounds a low sun. To the left and right are colored sundogs. Above shines an upper tangent arc and beneath is a sun pillar. HaloSim simulation of a fairly common ice crystal halo display.

http://www.atoptics.co.uk
HaloSim

http://www.atoptics.co.uk/halo/downlId.htm
Hole in cloud
Links and Sources:

http://www.atoptics.co.uk/
http://www.its.caltech.edu/~atomic/snowcrystals/