Ice particle habits observed at the ground during the passage of synoptic-scale weather systems over the Cascades.

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Outline

- Snow crystal habit variability and particle growth regions
- Riming and the influence of low-level easterly winds
- "Irregular" ice particle habits
Ground-based observations of snow crystals during IMPROVE-2
## Habit Types

<table>
<thead>
<tr>
<th>CRYSTAL SYMBOL</th>
<th>EXPLANATION</th>
<th>CONDITIONS UNDER WHICH PARTICLES GROW</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>Lump graupel</td>
<td>-4 to -8 °C, above water saturation</td>
</tr>
<tr>
<td>GS</td>
<td>Graupel-like snow of hexagonal/lump type</td>
<td>-4 to -8 °C, above water saturation</td>
</tr>
<tr>
<td>⋄</td>
<td>Frozen drops</td>
<td>-13 to -17 °C, above water saturation</td>
</tr>
<tr>
<td>⋄</td>
<td>Separate, bundles and combinations of needles and sheaths</td>
<td>-13 to -17 °C, above water saturation</td>
</tr>
<tr>
<td>⋄</td>
<td>Dendrites</td>
<td>-13 to -17 °C, above water saturation</td>
</tr>
<tr>
<td>⋄</td>
<td>Stellars</td>
<td>-13 to -17 °C, above water saturation</td>
</tr>
<tr>
<td>⋄</td>
<td>Broad branched</td>
<td>-13 to -17 °C, below water saturation</td>
</tr>
<tr>
<td>⋄</td>
<td>Radiating assemblages of dendrites</td>
<td>-15 to -22 °C, above water saturation</td>
</tr>
<tr>
<td>⋄</td>
<td>Assemblages of plates</td>
<td>-18 to -22 °C, above water saturation</td>
</tr>
<tr>
<td>⋄</td>
<td>Assemblages of sectors</td>
<td>-18 to -22 °C, above water saturation</td>
</tr>
<tr>
<td>⋄</td>
<td>Sideplanes</td>
<td>-20 to -25 °C, above and below water saturation</td>
</tr>
<tr>
<td>⋄</td>
<td>Bullets (radiating assemblages and single)</td>
<td>≤ -40 °C, &gt; 20% ice supersaturation</td>
</tr>
<tr>
<td>⋄</td>
<td>Columns</td>
<td>Several temperature ranges and saturations</td>
</tr>
<tr>
<td>⋄</td>
<td>Plates</td>
<td>Several temperature ranges and saturations</td>
</tr>
<tr>
<td>⋄</td>
<td>Crystal with sector-like branches</td>
<td>Several temperature ranges and saturations</td>
</tr>
<tr>
<td>⋄</td>
<td>Plates with sector-like extensions</td>
<td>Several temperature ranges and saturations</td>
</tr>
<tr>
<td>⋄</td>
<td>Plates with dendritic extensions</td>
<td>Varied temperature ranges and saturations</td>
</tr>
<tr>
<td>⋄</td>
<td>Columns capped with plates</td>
<td>Varied temperature ranges and saturations</td>
</tr>
<tr>
<td>⋄</td>
<td>Columns capped with stellars</td>
<td>Varied temperature ranges and saturations</td>
</tr>
<tr>
<td>⋄</td>
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<td>Bullets capped with dendrites</td>
<td>Varied temperature ranges and saturations</td>
</tr>
</tbody>
</table>
19-20 December 2001

Ray Benson Sno Park

Height Above Sea Level (km)

20 December 2001 (UTC)

19 December 2001

[Graph and chart details]
Findings

- During frontal precipitation bands over the Oregon Cascades, particles representing a broad range of temperature growth zones are seen, with a large number of cold-type crystals identifiable at the surface.
- Post-frontal flows were characterized by a distinct shift to warm-type crystals.
- Flow was predominantly westerly at all stages of frontal passage in Oregon, and thus riming was significant at all stages as well.
Riming and low-level easterly winds

Stampede Pass

Hoodoo Ski Area, Santiam Pass

Case 1 Case 2 Case 3 Case 4

(a)

(b)
Gap profiles

Profile along the crest of the Oregon Cascades
Profile along the crest of the Washington Cascades

Distance (km)
Elevation (km)

Snoqualmie Pass
Santiam Pass
Stampede Pass
Hoodoo Ski Area
Wind Observation

Snoqualmie Pass
Wind Observation

Stampede Pass
Wind Observation

Hoodoo Ski Area
Wind Observation
Role of storm tracks and pressure gradients

Surface low pressure center tracks, 27 Nov - 25 Dec 2001
Wind vectors as a function of pressure gradient

South-North Pressure Gradient (mb/km)

West-East Pressure Gradient (mb/km)
Wind vectors as a function of pressure gradient

Pure geostrophic winds
Wind vectors as a function of pressure gradient

Pure down-gradient winds

West-East Pressure Gradient (mb/km)

South-North Pressure Gradient (mb/km)
Wind vectors as a function of pressure gradient

Hourly winds at Stampeded Pass, 27 Nov - 25 Dec 2001

West-East Pressure Gradient (mb/km)

South-North Pressure Gradient (mb/km)

10 m s^{-1}
Wind vectors as a function of pressure gradient

Hourly winds at Stampeded Pass, 27 Nov - 25 Dec 2001

West-East Pressure Gradient (mb/km)
South-North Pressure Gradient (mb/km)
Findings

- Low-level winds during IMPROVE-2 (and perhaps more generally) were typically westerly both before and after frontal passage in Oregon, whereas there was often a prefrontal easterly regime in Washington.
- The difference appears to result, at least partly, from storm tracks that bring lows closer to, and more directly west of, the Washington Cascades.
- The different regimes result in more upslope and riming on the west slopes during prefrontal/frontal precipitation regimes in Oregon.
"Irregular" ice particle habits

- Korolev et al. (2000) and Korolev and Isaac (2003) find that 70% - 80% of snow particles in stratiform clouds are "irregular"

- They define "irregular" as particles that "cannot be covered by any of the existing classifications of cloud ice particles (e.g., Magono and Lee 1966)

- This contradicts our experience with ground-based observations of snow crystals, in which we find that the vast majority (probably 80% - 90%) of snow particles reaching the ground (as long as they are not melting or too heavily rimed) are of identifiable habit
Example of independent ground observations

<table>
<thead>
<tr>
<th>Time</th>
<th>0300</th>
<th>0200</th>
<th>0100</th>
<th>0000</th>
<th>2300</th>
<th>2200</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Dec</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4 Dec</td>
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</tr>
</tbody>
</table>
Aircraft 2-D imagery from Korolev (2000)
Cold-type crystals from Magono and Lee (1966)
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Cold-type crystals from Magono and Lee (1966)
Findings

- Snow particles are much more readily identifiable according to known habits than recent studies imply.
- The term "irregular" is misused, and automated identification algorithms based on aircraft 2-D imagery should adopt the term "unknown" or "indeterminate" rather than "irregular".