Snow avalanches: The forest aspect

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Rockfall, debris flow, landslides, vegetation characteristics
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Report QC: Frode Sandersen, Ulrik Domaas, Dieter Issler ,++
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Crown cover

- Relative area of crown cover
- Microclimate, less wind, less temperature variation
- Less total ground snow accumulation, interception
- Snow properties and layers

- Spruce/pine well defined
- Birch, deciduous forests?
- 50 % evergreen forests
- 80 % alpine birch, i.e from 2500 trees /ha

- Difficult to register separate effects of the crown and anchoring from the stem
Crowncover spruce (~pine)

Crown radius ~ function DBH

Figur 26 Tynnings-slips for grønbestander etter prinsippfigur fra (SKL, 2006). De to stipede kurvene viser beregnet kronetetthet for henholdsvis 70 % (grønn) og 50 % (rød) kronetetthet.
Anchoring effect, alpine birch, small diameters

Theoretical approaches for calculating needed number of trees:
- Salm (1978), Snow forces on plants
- Margreth (2007), Snow impacts on masts
- Valid only for larger diameters, assuming hard slab conditions i.e. snow and stem strength not critical, and no sliding (=less mobilization of forces against the stems)

Number of stems per ha for stabilizing snow cover, the lines represent different stem diameters

2500 alpine birch/ha ~80 % crown cover
Independent of formulas: Existing trees have some resistance against moving snow!

- Slab thickness?
- Birch forests do not hinder smaller slides
Spatial variability snow properties, long snow pit 23/2/13
Effects of undershrub and branches

- Open space along branches
  - Convection of air
  - 1) fine cave hoar
  - 2) later ice formation

- Branches restrict compaction
  - Favor open structures: faster diffusion and convection, dry metamorphism
- Inclined layers against the stem
- Ice armouring between stem/branches and snow
- Layer thickness increase outwards from stem
- Inclined layers against the stem
- Ice armouring between stem/branches and snow
- Layer thickness increase outwards from stem
- Inclined layers against the stem
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- Layer thickness increase outwards from stem
Forest:
- Small slabs
- Small or none propagation
- Only upper part of recently wind drifted snow, no weak layer observed
Same day, different exposure

Open areas:

- Avalanches!
- Larger avalanches (propagation)
- Thick slab, persistent weak layer
- Majority of shoot in this area, in forest and close to the tree line

Figur 15 Trekanter markerer posisjon til snøprofiler Profil A lengst til venstre, Profil B i midten og Profil C til høyre i skogen. Skuddpunkt for dette skredet lå omtrent der stjerne er plassert.
Why is this an avalanche danger area compared with other steep areas?

- Wind
- Snowdrift
- Convex shape, tension
- At tree line: Climatic margin for forest
- Cold wind critical for young leaves in springtime
- Low air temperature and root temperature/snow cover reduce growth season
- Water content – soil cover
- Harsh environment for birch
Weak layers - open / forest

Open:
- Thin layers of faceted crystals
- Weak layers
- Fast crack propagation
- Even cracking planes

Forest:
- Thick layers of faceted crystals (~0.5-1 m)
- No crack propagation
- Damping of energy
- No effectively weak layer
Fracture propagation and trees

- Fractures around groups of trees
- Fractures from one tree to another
- Ice around stems, larger effective diameter
- Stems ➔ less continuous weak layer
Is this test representative?

Continental climate versus maritime climate?

Only further tests and snow pits will show
## Snow stability and forest/vegetation

<table>
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<tr>
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<th>Alpine birch</th>
<th>Evergreen forests</th>
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<td>Larger, less snow to ground, effect on microclimate</td>
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<td>Small diameters, Strength ?</td>
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<td>Fracturing</td>
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<tr>
<td>Wet slide</td>
<td>Possible</td>
<td>Possible, less snow</td>
</tr>
</tbody>
</table>
Open areas / forest

Open:

- Thick, hard layers from wind drifted snow: Higher hardness → Larger slabs
  - Potential larger avalanches (+)
  - Less easy to trigger (-)
- Several thin layers of faceted crystals = weak layer, potential for fracturing
  - Fracture propagation → larger avalanches, remote release possible (+)
- Soft slab and wet avalanches
- Around smaller tress, also ice

Forest:

- “hard layer” less hard than in open areas
- No thin persistent weak layers
- Layers with less homogeneity, broken, bent at trees
- Ice around trees
- Larger part of the snow profile consists of faceted crystals
  - Low propagation
- Soft slab and wet avalanches
Avalanche at clearcuts = open area

Figur 1 Snøskred på hogstflate i Hof i Vestfold 22. februar 1977, 3 skiløpere omkom (foto NGI).
Figur 25 Skisse av hogstfelt med reduert lengde i fallretningen Tabell for største lengde i fallretning er for snøskred.
How should we take forests into account?

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Forest effects

- More irregular snow cover around trees and in forests and decrease of snow depth
- Reduction of wind speeds in the forest compared to open areas and large gaps
- Interception of falling snow by branches of trees
- Reduced incoming solar radiation beneath tree cover. Reduced outgoing long-wave radiation at night. Surface hoar is less pronounced in forests
- Direct support of the snow pack by tree stems
Direct support of the snow pack by tree stems

Simple snowpack stability aspects:

Performance functions $G$

$$G_{nd} = -1 + \left( \frac{C}{g \rho HS \cos \phi \sin \phi} + \frac{\mu_s \cot \phi}{O \approx 0.3-1} \right) + \frac{1}{2 \times 10^4} \frac{N_{ha} d_t HS \eta_f KN_g}{\cos \phi \sin \phi}$$

where $G < 0$ implies failure

parameter describing stand structure

mechanical stabilization due to tree support

snowpack stability
Dynamic influence of forest: Simple mass block

\[
\frac{dU^2}{2ds} = g \sin \phi - a_{\text{ret}} - d_t N_A C_D(U) \frac{U^2}{2}
\]

Parameter describing stand structure

\(C_D(U)\) drag factor
\(N_A\) number of trees per m\(^2\)
\(d_t\) diameter of tree trunk
Use of SAT-SKOG Data

To quantify effectiveness of forest stands:

- VUPRHA: total timber volume per hectare
- AGE: average age of the stand
- BONITET: appraisement classes of the prevailing tree species
- TRESLAG: prevailing species
Example of forest stand parameters derived from SAT-SKOG

Volume per ha (given)

BHD (cm)

Number per ha
dN (m⁻¹)

Question: Is dN sufficient??
Direct support of the snow pack by tree stems

Simple snowpack stability aspects:

Performance functions $G$

$$G_{nd} = -1 + \left( \frac{C}{g \rho HS \cos \phi \sin \phi} + \frac{\mu_s \cot \phi}{\phi = 0.3 - 1} \right) + \frac{1}{2 \cdot 10^4} \frac{N_{ha} d_i HS n_f K N_g}{\cos \phi \sin \phi}$$

Required safety

$$p_{rf} = P(G_{nd}(R_S, R_{FS}) < 0) \approx 10^{-3}$$

Required contribution of the forest cover

$$O(\mu_{RFS}) \approx 0.1 - 0.21$$
Proposed criteria for $dN$ versus $N_{ha}$ depending on HS and slope angles typically between $30^\circ$ and $55^\circ$. Work in progress.
Example
Adaptation of VS-Model type models

\[ \xi = \frac{2g}{d_t N_A C_D h_a} \]

and possibly \( \mu \)

\( C_D(U) \) drag factor
\( N_A \) number of trees per \( m^2 \)
\( d_t \) diameter of tree trunk
\( h_a \) flow height

Work in progress
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