Why tundra snow is upside down in models, and why it matters

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Northern Hemisphere seasonal snow cover

- area > $40 \times 10^6 \text{ km}^2$ and mass > $3 \times 10^{15} \text{ kg}$ at annual peak
- highly variable in space and time
- highly sensitive to weather and climate change

Data from National Snow and Ice Data Center
Snow models

- hydrology models
  - empirical modelling with limited data requirements

- weather / climate models
  - simple energy balance modelling

- snow physics models
  - radiative transfer models
  - high vertical resolution and many processes

Graphs showing discharge and snow depth over time, with statistical metrics provided.
Snow insulation

Walters et al. (2017), Geosci. Model Dev. Discuss.
Snow grain growth

Snow grain metamorphosis

- broken particles
- rounded particles
- rounded clusters
- melt-freeze crust

International Classification for Seasonal Snow on the Ground. UNESCO/IHP 2009
Snow stratigraphy

Sturm et al. (1995), J. Clim., 8
Seasonal snow cover classification
Tundra snow stratigraphy

Domine et al. (2016).
*The Cryosphere, 10*, 2573–2588

Barrere et al. (2017)
*Geosci. Model Dev., 10*, 3461–3479
MACSSIMIZE ground campaign, 14-22 March 2018

Trail Valley Creek field camp, NWT, Canada
January - March weather at Trail Valley Creek

- Flights
- Field days
Manual measurement of snow properties

Density
• weigh known volume of snow

Temperature
• stem thermometer

Wetness
• snowball test

Hardness
• penetration (fist / finger / pencil / knife)

Microstructure
• visual identification of grain type and size
Optical grain size
Snow microstructure

- $p_{ex}$ – exponential correlation length from fit to autocorrelation function
- $p_c$ – correlation length from derivative of autocorrelation function
- $D_o$ – radius of monodisperse spheres with same optical properties
- $D_q$ – radius of monodisperse spheres with same surface area–volume ratio
- $D_m$ – average of greatest extension of grains

$p_{ex} < p_c < D_o = D_q < D_m$
Thermal conductivity

Field data processed by Michael Lai (NERC Research Experience Placement)

heated needle

- Temperature (°C)
- Time (s)
- Conductivity (W m⁻¹ K⁻¹)
- Density (kg m⁻³)

- fresh snow
- wind slab
- depth hoar

Yen (1981)
Conclusions

Tundra snow has a characteristic structure of hard, small-grained wind slab over loose, large-grained depth hoar which:

- has important influences on microwave scattering (remote sensing) and thermal conduction (numerical weather prediction, climate modelling)
- is formed by processes not represented in snow models (although there may be compensating errors)
- can be characterised objectively in the field by instruments that are now becoming more widely available
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Thank you!

Photo: Branden Walker