Snow modelling – challenges and opportunities for polar prediction

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Snow properties

high (but spectrally, spatially and temporally variable) albedo
– impacts on surface energy balance in spring

low (but spatially and temporally variable) thermal conductivity
– impacts on soil temperatures in winter

(spatially and temporally variable) granular structure on mm scales
– Mie scattering of μm-scale shortwave radiation
– Rayleigh scattering of cm-scale microwave radiation
    – signal of snow cover in atmospheric window channels
    – noise in lower-troposphere sounding channels
(actually a dense medium of sintered, non-spherical grains)

instantaneous (albedo) and delayed (hydrological) coupling between snow anomalies and the atmosphere → sources of predictability

Snow model complexity

- Lagrangian snow physics models

  were developed for avalanche risk forecasting but are beginning to inform parametrizations in

- Eulerian multi-layer snow models for Earth System modelling

  which are becoming available as alternatives to

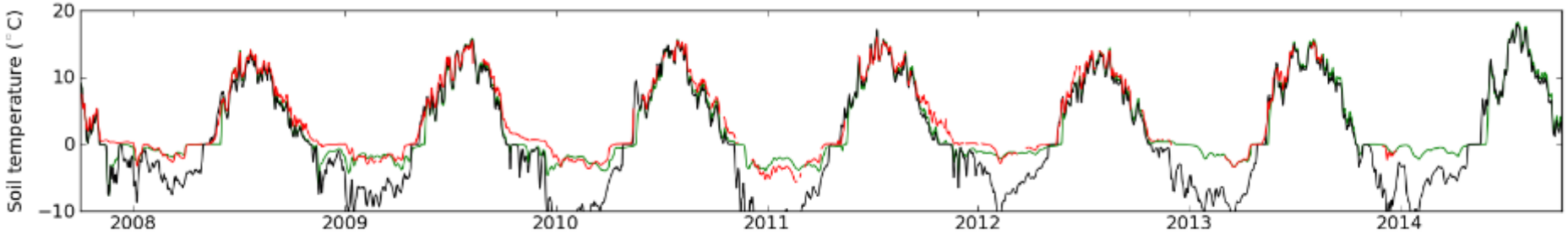
- simple snow models in NWP

  but are not yet displacing

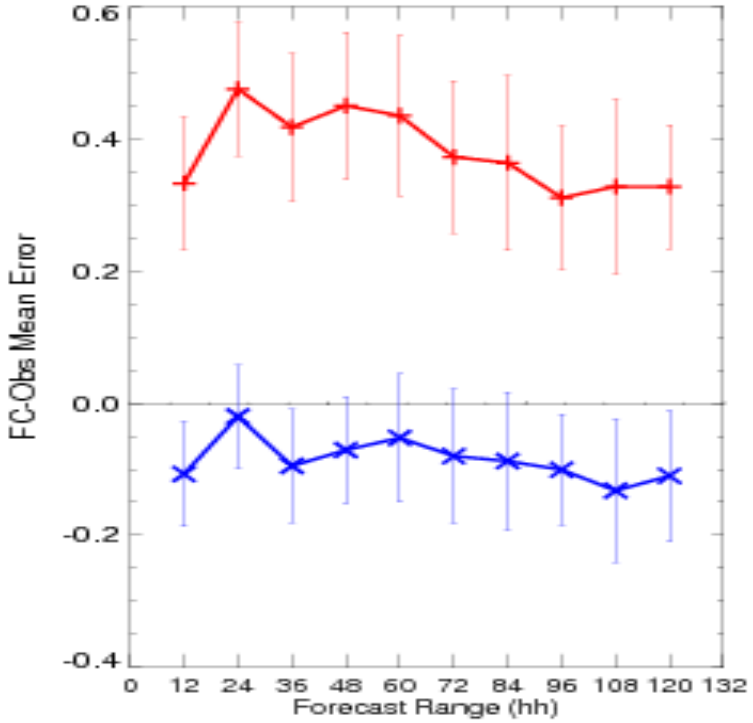
- empirical snow models for operational hydrology and impact studies

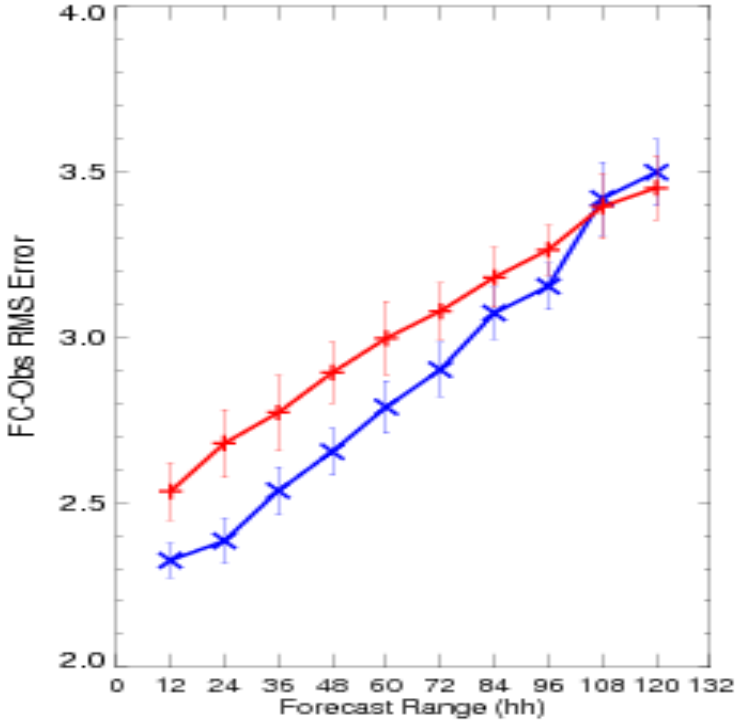
JULES multi-layer snow scheme

Soil temperature climate impacts

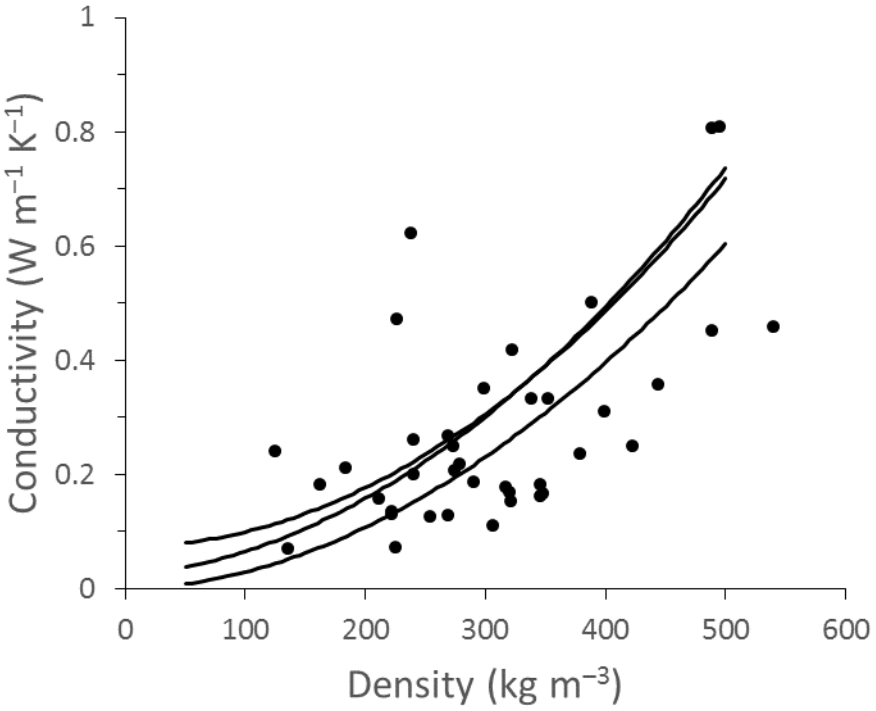


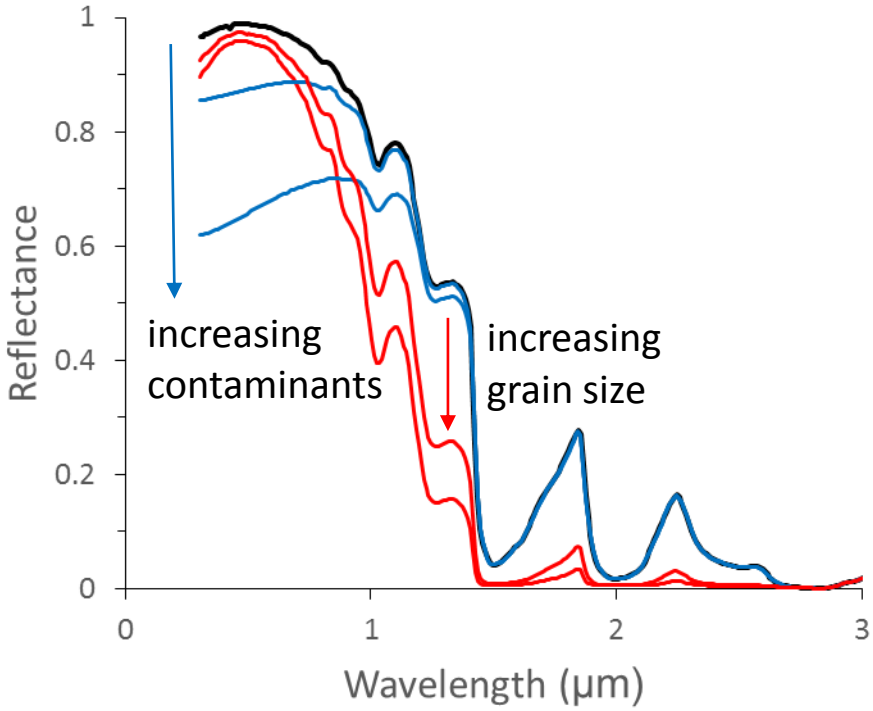
Air temperature forecast impacts





Parametrization of snow properties

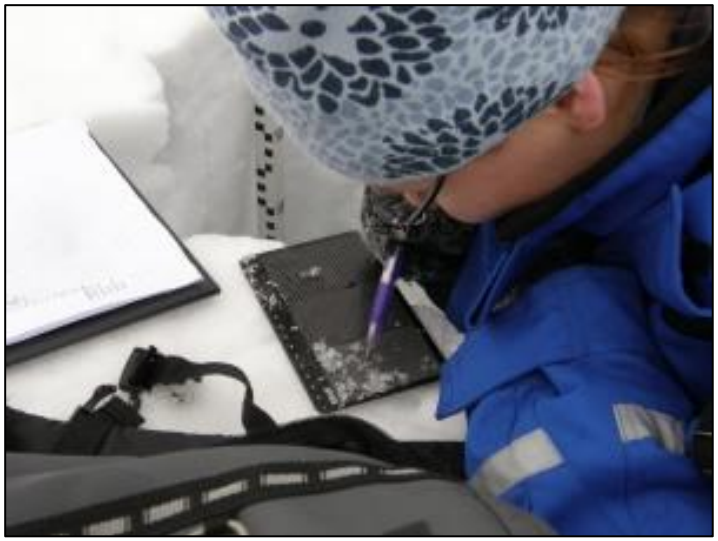


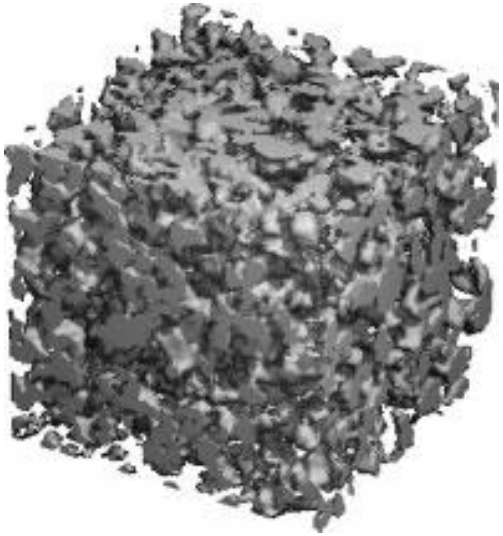


Thermal conductivity is generally parametrized as a function of snow density but is actually determined by microstructure

Albedo is generally parametrized as a function of snow age but is actually determined by microstructure and deposition of aerosols

Field measurements of snow microstructure





Snow observations for assimilation

Improvements in ECMWF forecasts from snow model and snow data assimilation improvements
– de Rosnay et al. (2015), ECMWF Newsletter no. 143

Estimates of snow extent f are available from remote sensing and are adequate for nudging hourly to daily forecasts

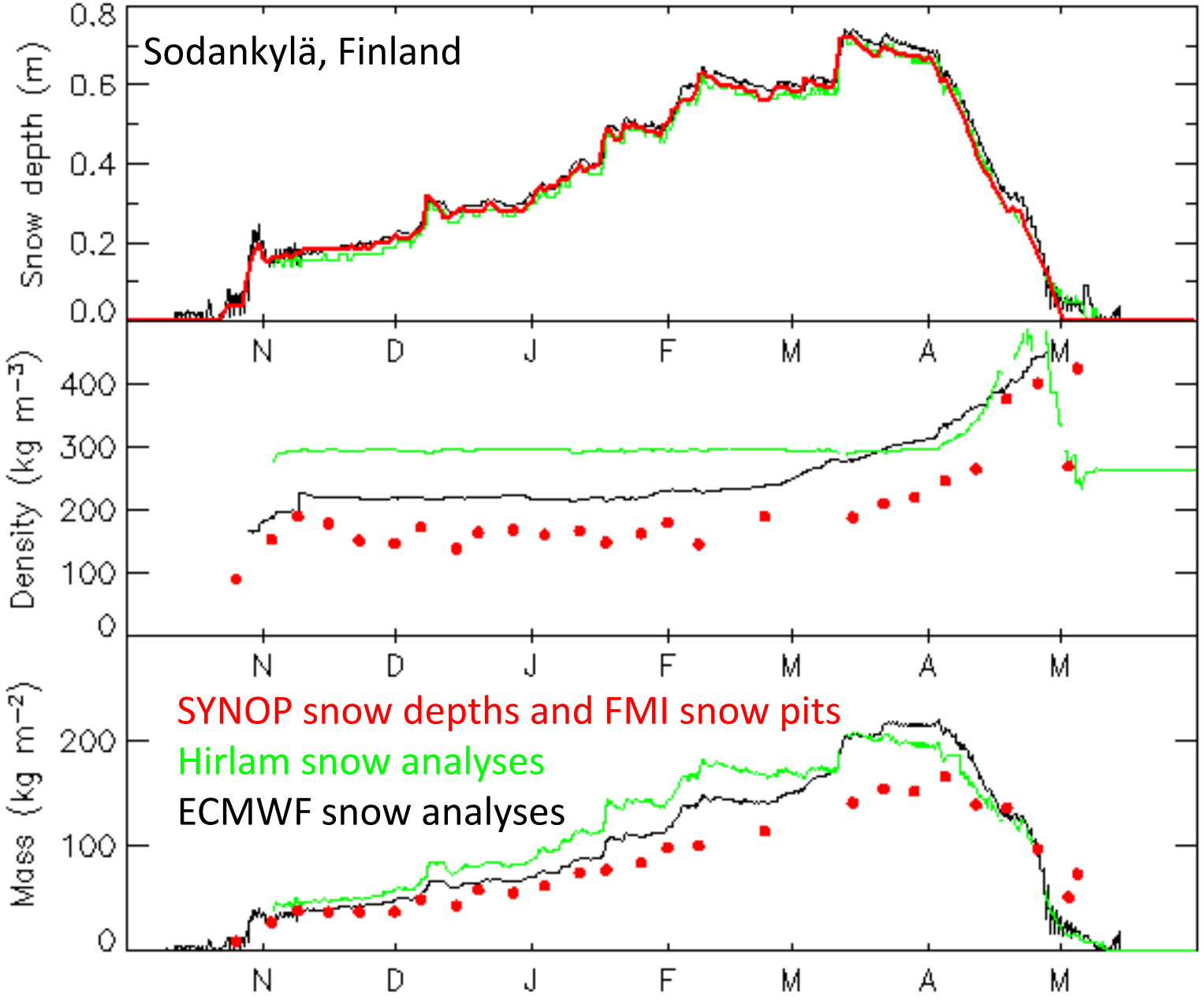
Estimates of snow mass S are required for initialization of seasonal forecasts

Measurements of snow depth d are available from synoptic stations

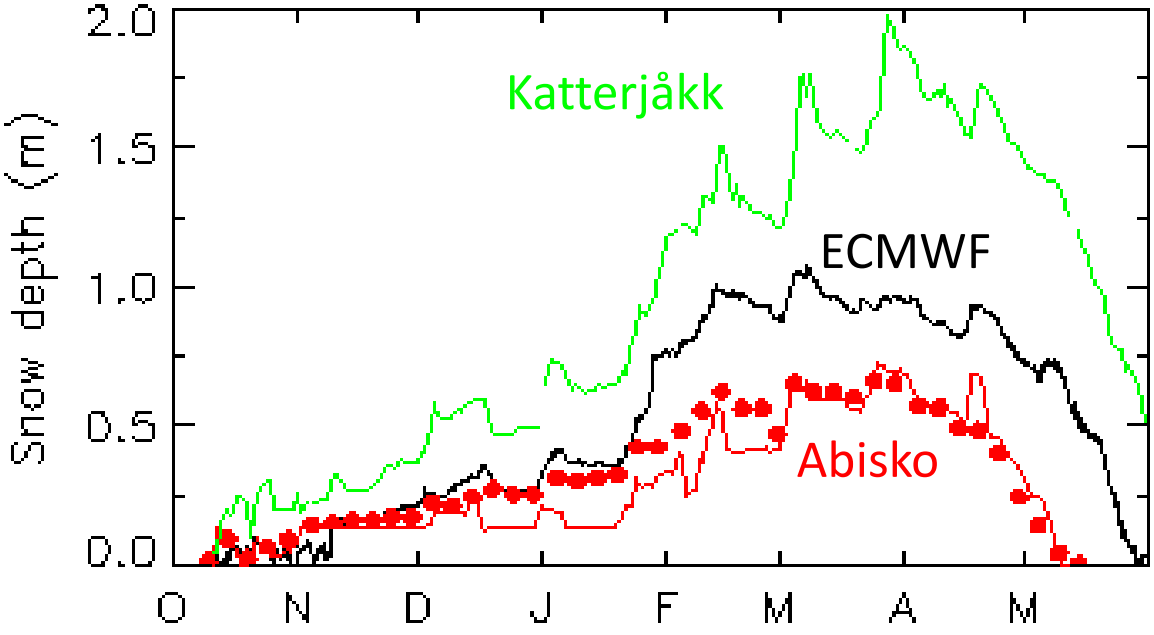
→ require observation operators e.g. $f(S)$, $d = S/\rho$

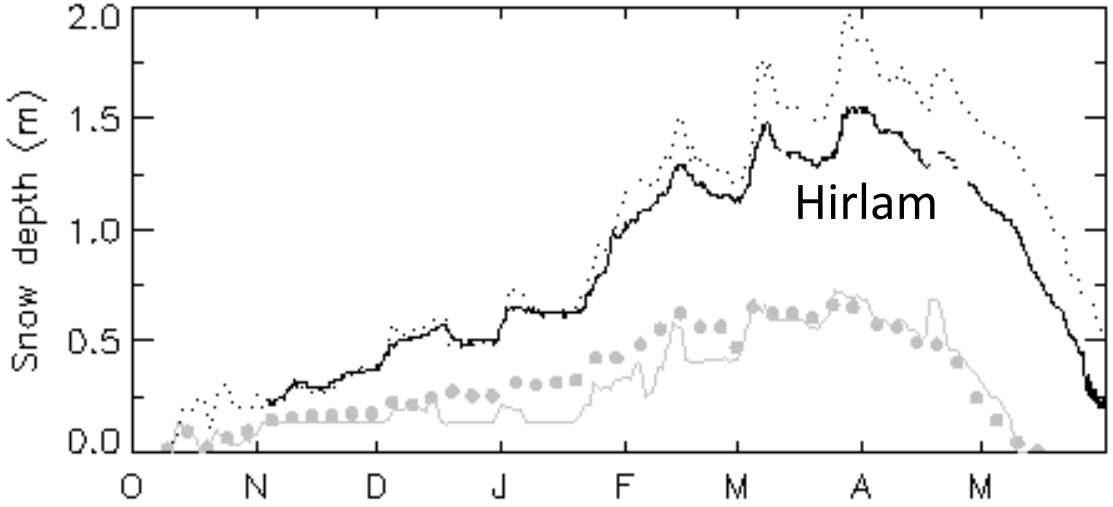
Passive microwave snow mass products using a model $T_b(S, r, T_s, \lambda)$ are available but are not yet trusted for assimilation

Operational snow analyses



Operational snow analyses





Opportunities

- seasonal snow on land and sea ice are potential sources of predictability through local feedbacks and interactions with circulation http://www.ecmwf.int/sites/default/files/Subseasonal-WS-Dutra.pdf
- better snow thermodynamics models are becoming available for NWP (Met Office and ECMWF trials)
- (relatively) fast and inexpensive objective methods of measuring snow structure are becoming available for use in the field
- understanding of microwave scattering by snow and the controlling microstructural properties is improving (IACS MicroSnow working group, legacy of the ESA CoReH_2O mission assessment, proposed WCOM mission)
- improved microwave forward modelling will allow improved retrievals of snow properties and sounding over snow
- YOPP will provide a unique opportunity for coordinated surface, airborne, remote sensing and modelling campaigns