Snow reflectance measurements

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With contributions from
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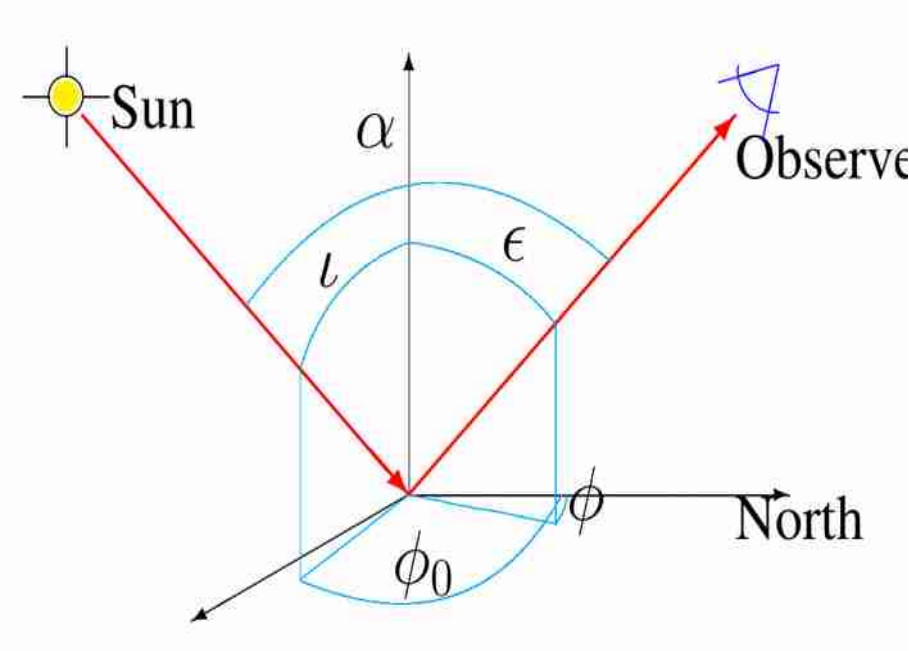
Background

- Remote sensing is based on observing some differences in target properties
  - Shapes
  - Brightness
  - Spectrum
  - Directional effects
  - Polarisation
- Remote sensing needs good model for the reflectance of snow
  - Physical
  - Invertible
  - Validatable
- Modelling needs lot of measurement data
  - Natural
  - Extremely processed

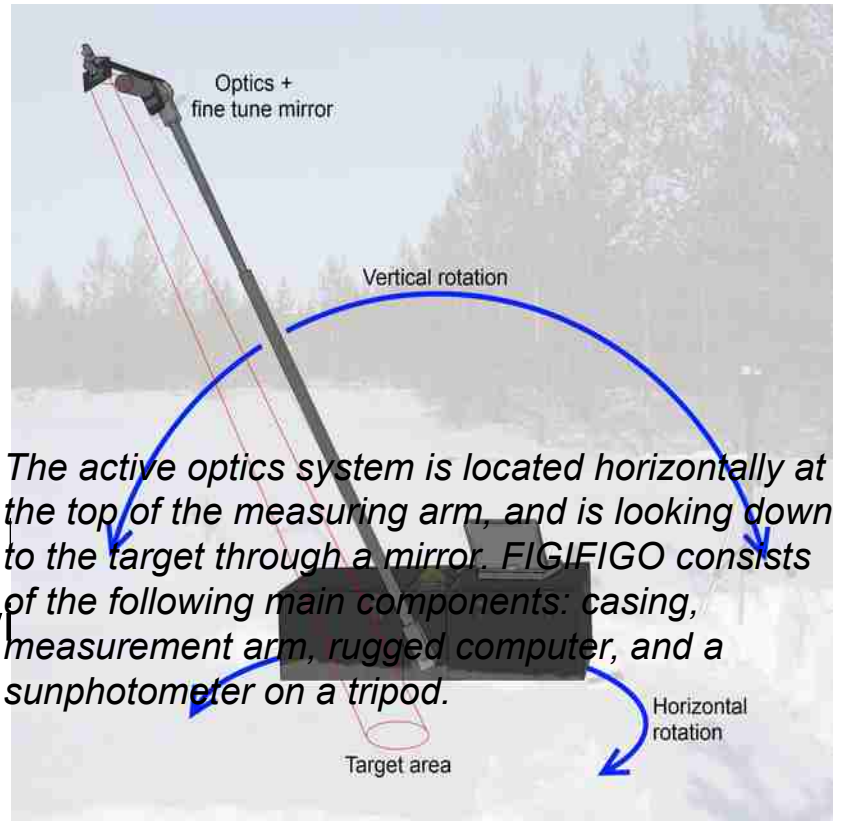
Basics

- Bidirectional reflectance factor (BRF)
  - Observed reflectance depends on 4 angles (3 with symmetric targets)
  - R=I/I_Lambert
  - $I(\varepsilon,\Phi)=\cos \imath/\pi\ R(\varepsilon,\Phi,\imath,\Phi_0)\ F0(\imath,\Phi_0)$
  - To model polarisation, **I**=[I,Q,U,V] and **R**= 4*4 matrix
  - Degree of linear polarisation P=-Q/I



FIGIFIGO

- FInnish Geodetic Institute's FIeld Goniospectrometer
- Measures BRF in full hemisphere
- Automated zenith turn, manual azimuth turn
- ASD FieldSpec Pro FR
  - 350-2500 nm
  - Changeable optics
  - Field of view 5-25 cm
- Includes computer turned linearly polarizing optics (broadband Glan-Thompson calcite wedge), Stokes I,Q,U
- Portable, mounting time 10 minutes, weight 40 kg
- Fast, 10 to 30 minutes for full BRF without or with polarisation



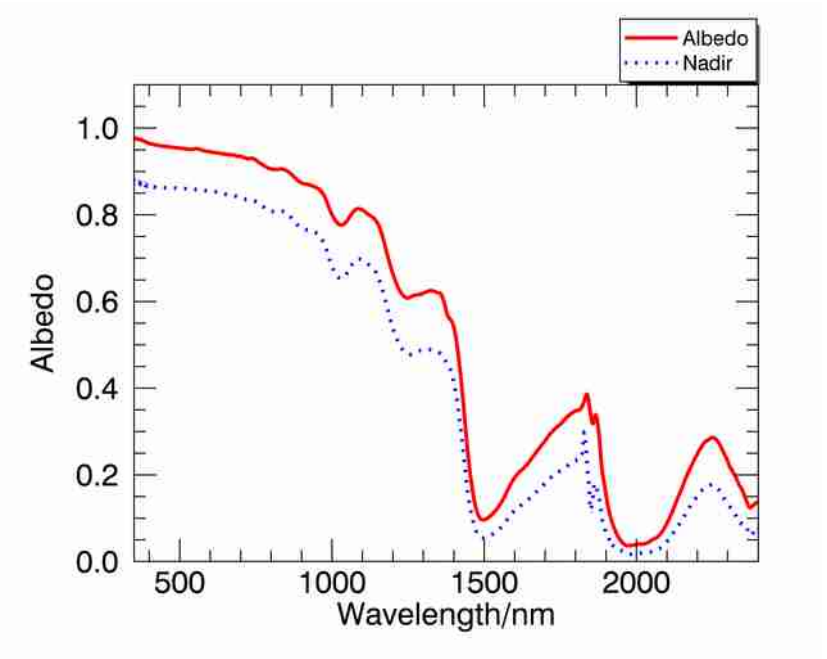
The active optics system is located horizontally at the top of the measuring arm, and is looking down to the target through a mirror. FIGIFIGO consists of the following main components: casing, measurement arm, rugged computer, and a sunphotometer on a tripod.

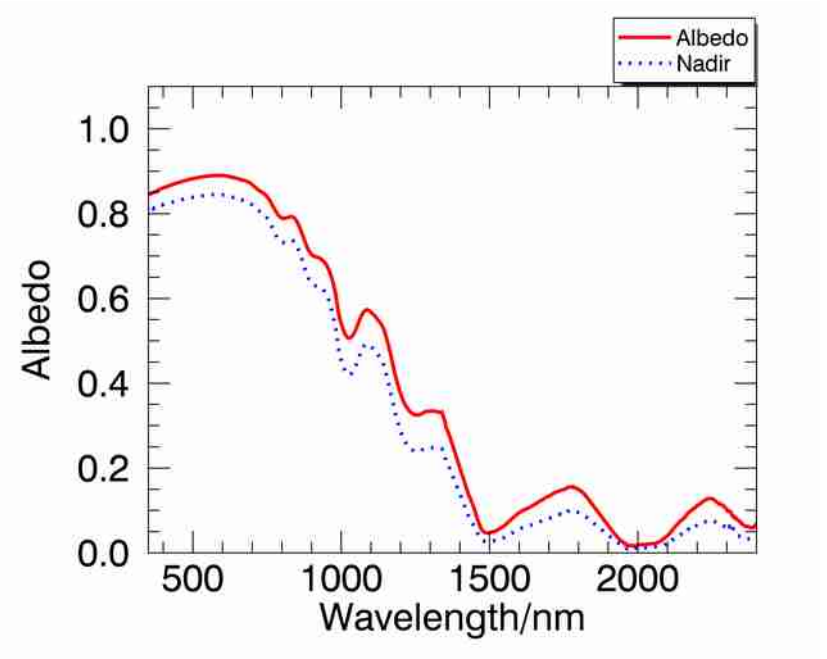
FINNISH GEODETIC INSTITUTE

FGI reflectance library

- webdav://webdisk.kotisivut.com/fgi/Reflectance_Library/
  - Username: BRFuser, password: BRFuseri
- All data are free for normal scientific use
- Currently the library contains BRF/HDRF measurements of over 150 samples
  - Snow – wet and dry, new and old, natural and contaminated
  - Gravel, Sand
  - Volcanic stuff
  - Vegetation
  - Asphalts, concrete
- Status still experimental, needs some efforts to use
- A pdf datasheet is produced from each library file
  - Shows contents of the file
  - Describes the reflectance properties of the sample

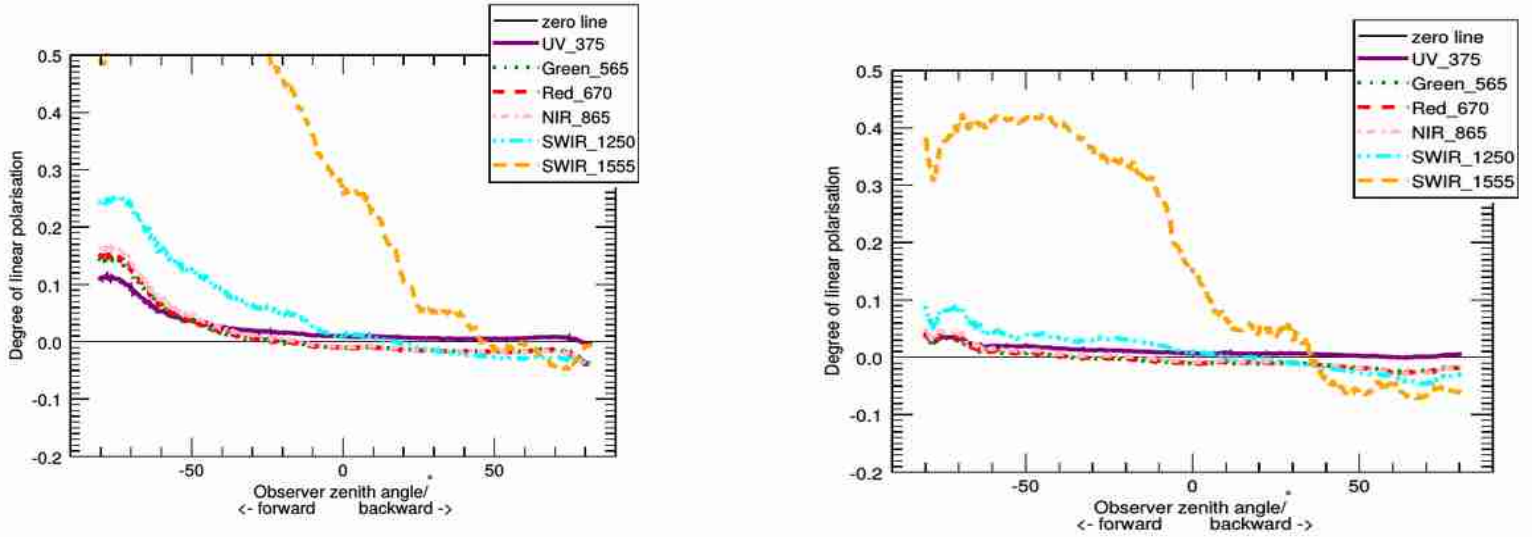
New – old, spectrum





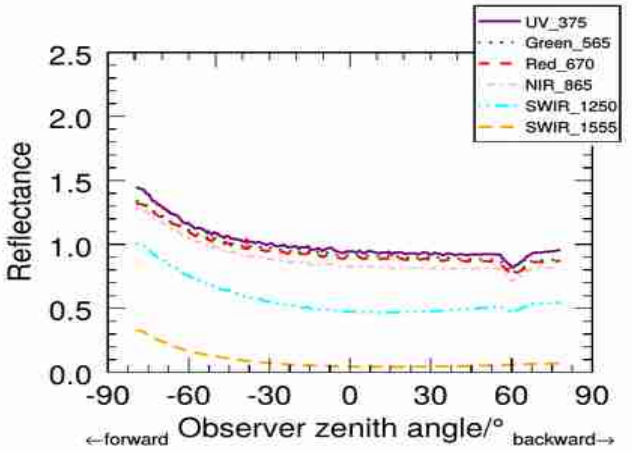
- New snow has much smaller grains, and less absorption
- Also small differences in anisotropy and polarisation

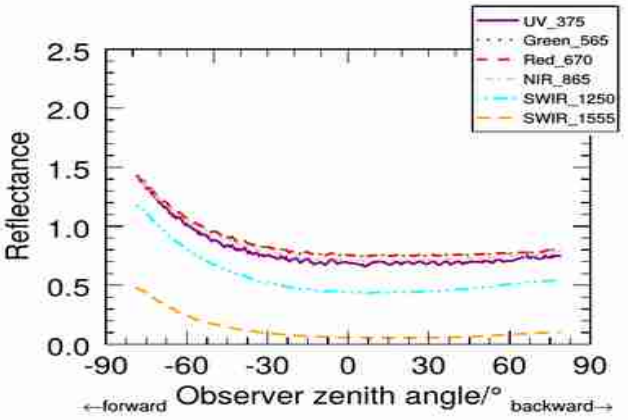
Dry – wet differences, polarisation



- Dry snow polarises more in the forward than wet snow
- Also small differences in the spectrum and aniotropy
- No signal alone sufficient

Natural-dirty, principal BRF





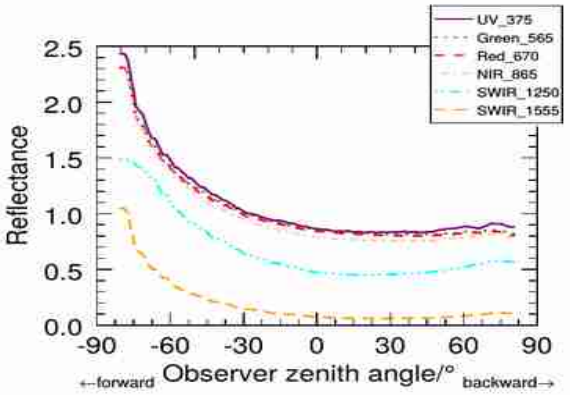
- All contaminants also darken snow in visual bands, but in NIR may be vice versa
- Sometimes backscattering can be even enhanced

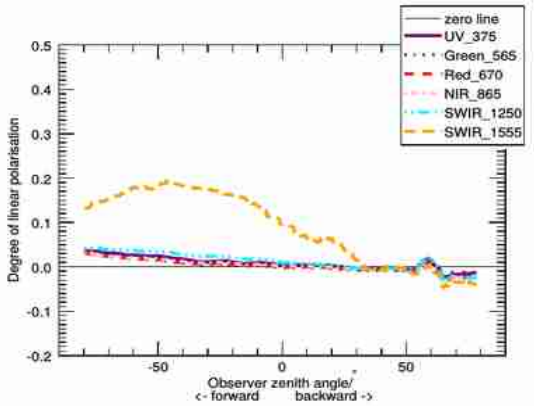
Radiative transfer modelling

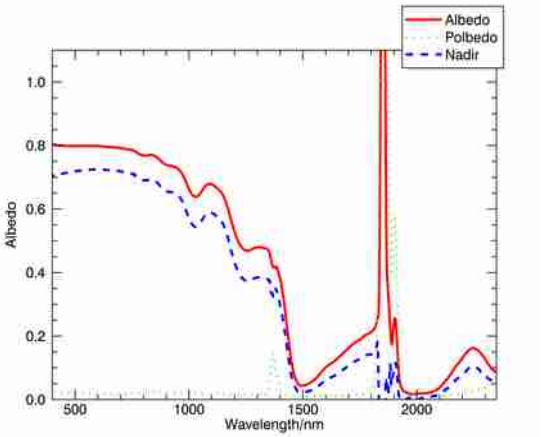
- Brand new model from 1987-1993 with small upgrades
- Initialize a thin layer using Monte Carlo ray–tracing, assuming large Gaussian densely packed snow grains
  - 1 hour each
- Combine a snow pack from different initialization layers using adding/doubling and interpolation
  - < minute
- Arbitrary size distribution using scaling
- Full polarisation
- Limited spectrum (some memory issues with compiler)

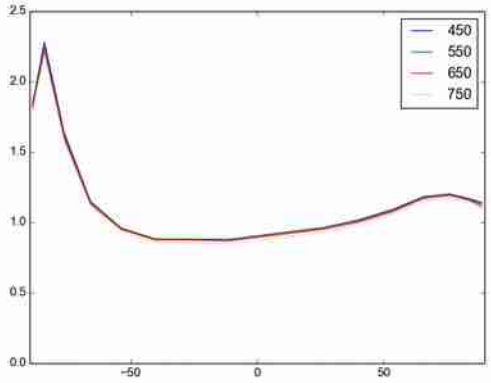
Top measurement, bottom model

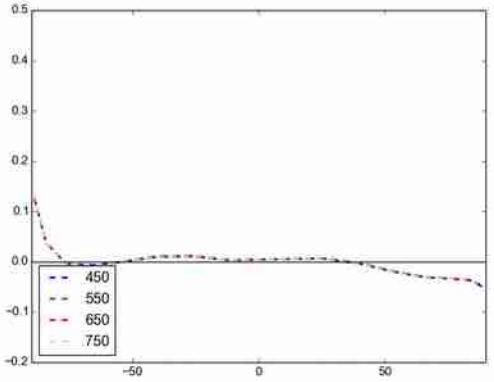
New snow principal BRF, oldsnow polarisation, dirty snow albedo

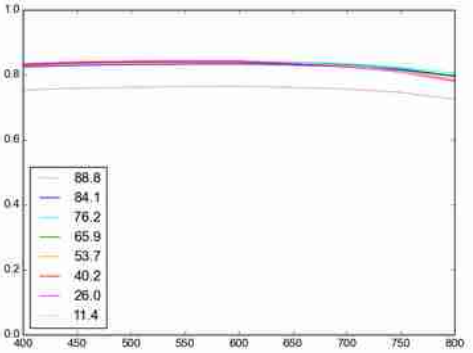












Conclusions

- We know a lot of snow reflectance
- Still open
  - Effects of small impurities
  - Quantitative roughness
  - Grain shapes
  - Cause of enlargened forward polarisation
- Todo with models
  - Roughness and 3D structures
  - Crystal forms
  - Wave effects
- Todo with measurements
  - Presice polarisation, including circular (V) and illumination control
  - Backscattering
  - Natural and processed roughness
  - Mixtures, smaller and larger contamination ratios
  - Time series of metamorphism
  - Better characterization of snow from wavelength scales to topographic scales