FINNISH METEOROLOGICAL INSTITUTE

Report on the

WORKSHOP ON IN-SITU SNOW ALBEDO MEASUREMENTS: TOWARD A SNOW ALBEDO INTERCOMPARISON EXPERIMENT

(HELSINKI, 24-25.08.2016)

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Outlook

1. Summary on measurement accuracy: presently achieved vs desired
2. Best practices for calibration/characterization of instruments
3. Protocol to minimize and quantify measurement uncertainties due to measurement setup and environmental conditions
4. Recommendations concerning the use of auxiliary tools to measure/monitor ancillary snow properties
5. Upcoming activities

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Summary on measurement accuracy: presently achieved vs desired

WISHES FROM THE DATA USERS

1) Remote sensing community

Representativeness of the data:

- Many point measurements (broadband and spectral albedo) without need of high accuracy
  - Sledge-based albedo station with Trios/pyranometers+camera+snow pit observations+roughness+impurity
  - UAV equipped with broadband and spectral sensors
- Single point measurement with high accuracy (located close to long term monitoring AWS)

Summary on measurement accuracy: presently achieved vs desired

WISHES FROM THE DATA USERS

1) Remote sensing community

Data format:

- common standardized format
- Standardized metadata (detailed, with well explained definitions, explanation of corrections/calibrations/quality checks, traceable data processing)

2) Modelling community

For SMB estimations:

Time series covering the critical albedo changes and the seasonal cycle (temporal resolution is equally important as data accuracy)

For Snow grain size (SSA) estimation:

Spectral Albedo accuracy should be **0.01** or better (to give an error in snow grain size in the order of 10%).

For BC estimation and organic impurities:

Spectral Albedo accuracy should be **0.01** or better (to give an error in BC estimation larger than 50 % error in the retrieval of BC (if BC is 100pp and grain size is 0.1 mm).

Summary on measurement accuracy: presently achieved vs desired

ACCURACY IN MEASUREMENTS

Spectral albedo:

- With white reference standard (narrow FOV):
  10-17% (without angular and shadow corrections), <5% (with corrections)
- transparent diffuser (cosine collector), 350 < λ < 2500 nm:
  10-17% (without angular and shadow corrections), <10% (with correction)
- transparent diffuser (cosine collector), 350 < λ < 1100 nm:
  10-15% (without corrections), <5% (with correction)
- integrating sphere: <5% (with corrections)

- Spectral BRDF: 5-10%
- Narrowband albedo: 5-10%
- Broadband albedo: 5%

Best practices for calibration/characterization of instruments

VARIOUS INSTRUMENTS, NUMEROUS DESIGNS, …

Need to group them for their application and hence a definition of Albedo:

Spectral Global Albedo

Spectral Direct Albedo (FOV=XX deg)

Weighted Global Albedo (ERY, UVB, UVA, UVG, SW, IR…)

Effective Albedo

➔ ALBEDO, never has been proved

Need for homogenization of the measurement

Best practices for calibration/characterization of instruments

CALIBRATION AND CHARACTERIZATION OF THE INSTRUMENTATION

What:

- Cosine Response followed by the calculation of cosine correction function
- BB: Spectral Responsivitiy
- Absolute vs. Relative Responsivity → Remark: Full System (Optics, Fiber, Detector)
- Temperature Dependency for low Temperatures (Sensor,Input Optic – diffuser material)
- Stability ➔ Frequency of recalibration, Accepted procedure

“**Where**”

- Ring comparison of one selected instrument
- Ring comparison using a “Albedo travel standard” (White Box thing WBT” or Roving Instrument)
- Accredited Calibration Facility FMI, NPL, WRC (money)

Best practices for calibration/characterization of instruments

UNCERTAINTY DOCUMENT

Measurement uncertainty **u=sqrt(a^2 + b^2 + c^2 + d^2 + …)**
Expanded Uncertainty **U=2u (k=2)**
Define a,b,c,d,…
Estimate (calculate if possible, sensitivity studies): Absolute or relative calibration,

Cosine Error , Diffuse, Clear Sky, Sun & Clouds, Wavelength scale
Stability: Before / After measurement period, between?

Measurement Errors: Orientation, Shadow, Operator

INTERCOMPARISON CONSIDERATIONS
Appel vs. Appel
Albedo vs. Albedo
Independ on the instrument: U=sqrt(UinstA^2 + UinstrB^2)
Reduce variabilities: Homogeneous, stable weather and ground conditions
Facility for instrument characterization, Location, date and timeframe (**few days**)

Protocol to minimize and quantify measurement uncertainties due to measurement setup and environmental conditions

MEASUREMENT SETUP:

- Tilt / leveling
- Sensor orientation w/r sun
- stability of the platform (on ice / sea-ice / ground)
- footprint size / installation height
- shadows
- reliability (power, electronics, …)
- Signal/noise ratio (infra-red)

ENVIRONMENTAL CONDITIONS:

- slope
- high SZA, low SZA
- Hoar / riming / precipitation on the sensor (liquid and solid), dirt
- Snowfall -> height variations
- Temperature
- Sastrugi formation and melting due to the station and poles
- Rapid illumination variations

Protocol to minimize and quantify measurement uncertainties due to measurement setup and environmental conditions

RECOMMENDATIONS

- Instrument setup:
- Recommendation of the installation height (2 m if no accumulation issues)
- Distance of the sensors from the main pole (at least 1.5 m, 2 recommended), compromise between distance and vibration issues due to wind
- Ventilation + heating system (e.g. CNR4) : energy issue
- Sensors orientation/azimuth and position of the solar panels
- Separate pole for data logger and sola panel to avoid shadow
- Possibly bury the electronic and data logger (in snow or ice)
- (Ideally obtain the raw data to reprocess (spectral albedo)
- Sensitivity/Interpolation/Transition between the photo sensors (VIS-NIR-SWIR))
- High and low SZA: characterize the SZA dependency of the cosine collector and correct both incoming and reflected spectrum

Protocol to minimize and quantify measurement uncertainties due to measurement setup and environmental conditions

MITIGATION

- Ad Hoc corrections:
- Tilt corrections (several recent studies)
- Basic shadow correction (manual measurements)
- Develop and distribute a code to calculate the shadow effect of any simple setup.

Recommendations concerning the use of auxiliary tools to measure/monitor ancillary snow properties

AUXILIARY OBS. TO CORRECT ALBEDO

- Tilt of radiometers, slope of surface, height above surface, GPS time and pos.
- For spectral irradiance: diffuse to total radiation
- Temperature (and other relevant parameters) of sensor
- Pics of sensor and surroundings (ground and sky, cloud conditions)
- Coincident weather observations and radiative fluxes

Recommendations concerning the use of auxiliary tools to measure/monitor ancillary snow properties

AUXILIARY SNOW OBS TO UNDERSTAND ALBEDO (ANCILLARY SNOW PROPERTIES)

- Surface roughness (scale: ‘multiscale’): laser scanning, stereophotogrammetry, plate & camera
- Longwave flux → surface melting vs. not melting
- Light penetration with depth, and T profile
- Spectral goniometer observations, or at least broadband or narrowband
- SSA, BC, dust, microbiology: if among objectives, need manual in situ independent from optical properties, incl. during snow melt and vertical profiles below the snow surface of: density, crystal shape, water content, -record site visit metadata, including picture, show snow conditions

Upcoming activities

1. **Document** (white paper/ report) that summarize the results of the workshop.
2. **Laboratory characterization/intercomparison:**
   - We need to write the calibration/characterization protocols:
     - Irradiance/radiance calibration
     - Wavelength calibration
     - Angular response characterization
     - Characterization of thermal dependence of sensitivity
   - Calibration should be done before the field experiment, characterization can be done at any time.
   - Table to be filled, for the selection of the instruments and arrangement of the setups.
   - We need to select the lab (FMI-Helsinki is one option. Davos? NPL? Grenoble?).
   - Time (it depends on the selected lab…)
3. **Field intercomparison**:
   - Spectral radiometers only?
   - Manual instruments only?
   - Possible sites (should be flat, free from obstacles in a wide area, with a guaranty of receiving enough snow, with good supporting facilities): airport field in Sodankylä, …

Table for the lab characterization

Contact Scientist	Roberta Pirazzini (FMI)
Instrument	
Name	SVC spectro-albedometer
Size	42x50x15cm
Weight	10 kg
Power requirement	24 V
Wavelength range	350-2500nm
Wavelength resolution	≤ 3.5 nm (700nm), ≤ 9.5 nm (700nm), ≤ 6.5 nm (700nm)
Field of view (foreoptics)	178.x deg
Fiber optic connection (Yes/No)	No
Calibration and characterization	
Irradiance/Radiance calibration	x
Wavelenght calibration	x
Angular response characterization	x
Characterization of thermal dependence of sensitivity	x