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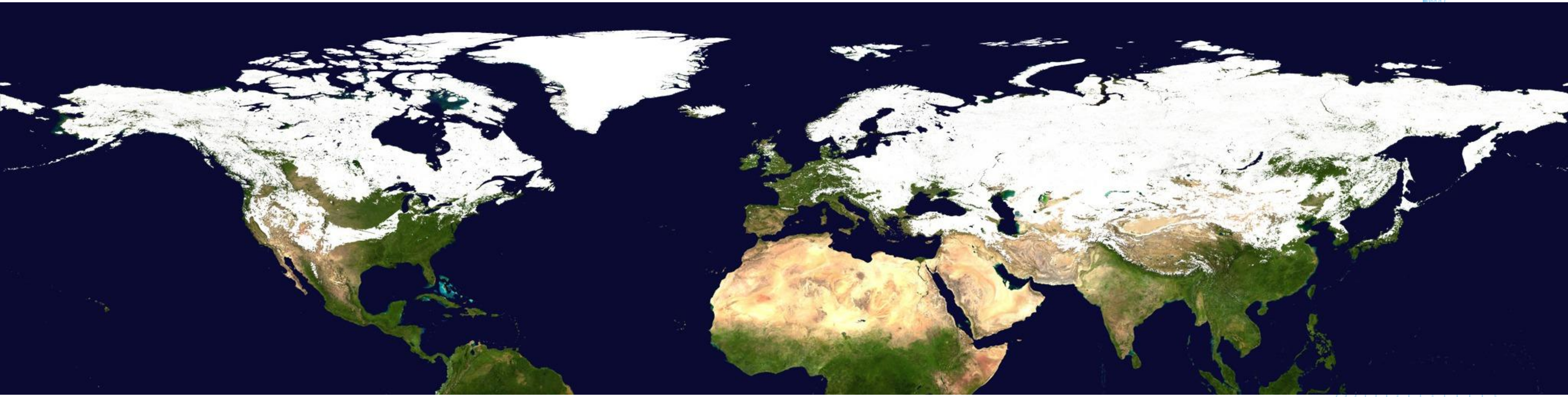
# OVERVIEW OF THE IN SITU SNOW ALBEDO MEASUREMENTS

Roberta Pirazzini (FMI)

# Why to measure snow albedo?

Surface albedo is an Essential Climate Variable that controls the Earth radiative energy budget



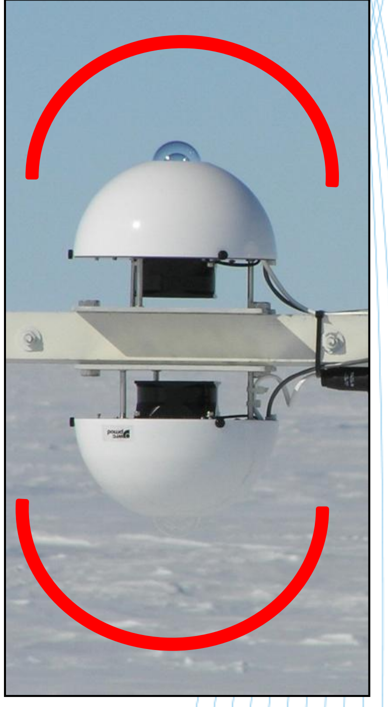
## The in situ measurements of snow albedo are used for:

- ✓ Validation of optical remote sensing observations (albedo, land classification, snow cover extent, snow microstructure, snow impurity)
- ✓ Climate studies (surface heat budget, snow albedo feedback on temperature)
- ✓ Validation of/input to snow, hydrological and atmospheric models

# Complex measurements:

**BROADBAND ALBEDO. Pyranometer properties to be evaluated and characterized:**
Sensitivity, stability, response time, cosine response, azimuth response, thermal offset, zero irradiance signal, and spectral response.

**SPECTRAL ALBEDO. Spectro-radiometer properties to be evaluated and characterized:**
In addition to the above, integration time and temperature drift.



**Installation requirements:**

- The sensor surfaces need to be horizontally leveled
- The domes need to be clean and free from ice/water
- The target surface need to be horizontal
- The site should be free from obstacles
- The holding structure should not shadow the pyranometers nor the probed surface
- The site should not be in the vicinity of vertical or tilted surfaces that may reflect solar energy.

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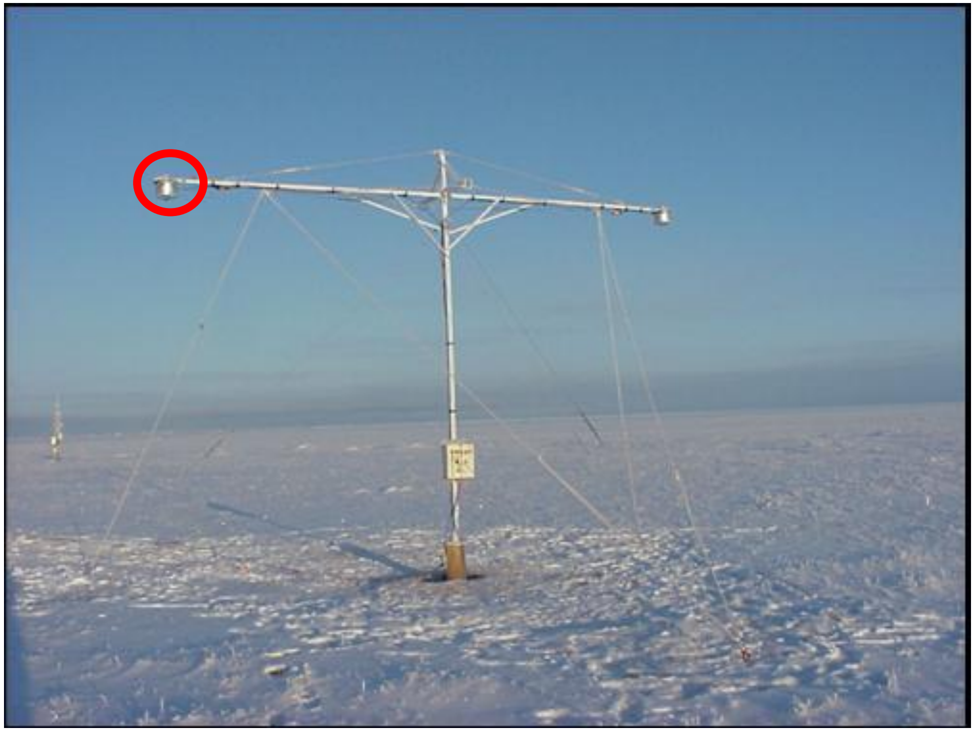
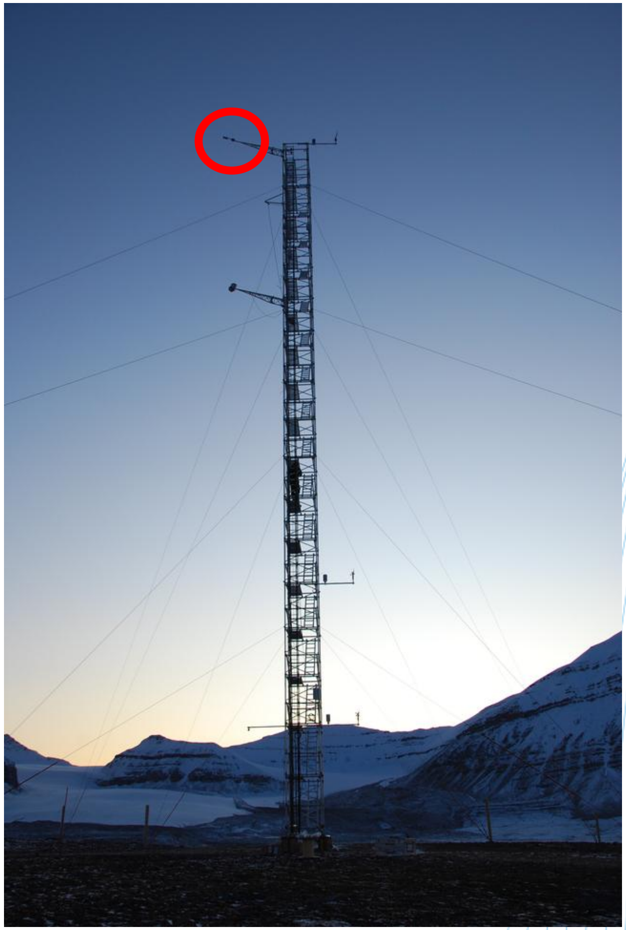
"No obstruction within the azimuth range of sunshine and sunset over the year should have an elevation exceeding 5°" (WMO, 2014)

"The minimum height of the downward looking pyranometer above the surface is 30 m" (McArthur, 2005)



BSRN at Barrow, Alaska (NOAA)



Amundsen-Nobile Climate Change Tower, Ny Ålesund (CNR, Italy)

# BSRN at Ny Ålesund (AWIPEV, German-French Station)

Not a BSRN site:

- It would require certified calibration once a year
- Daily cleaning and check of levelling

Sodankylä, peatland site (FMI)

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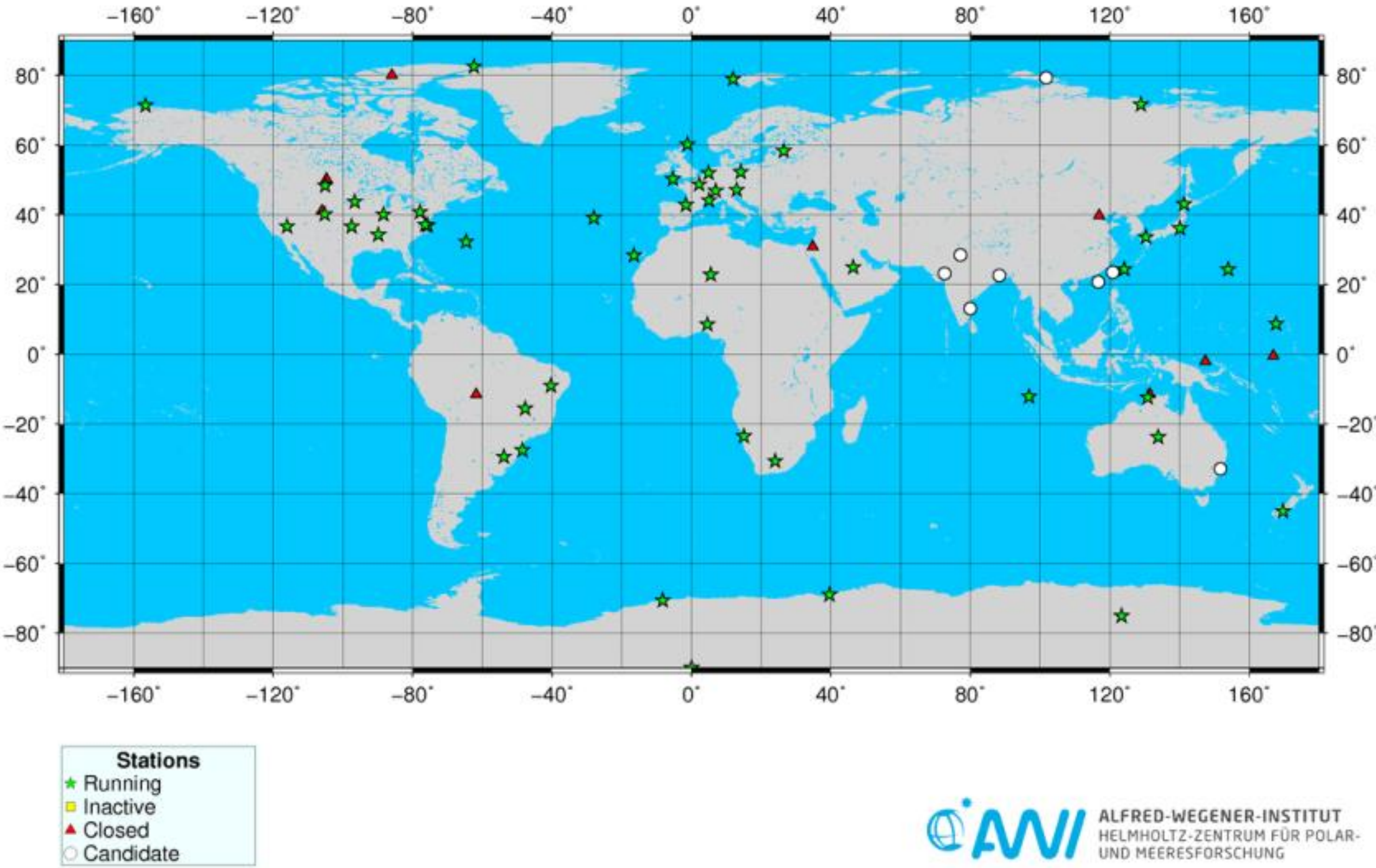
## Running, planned, and closed BSRN Stations, May 2017

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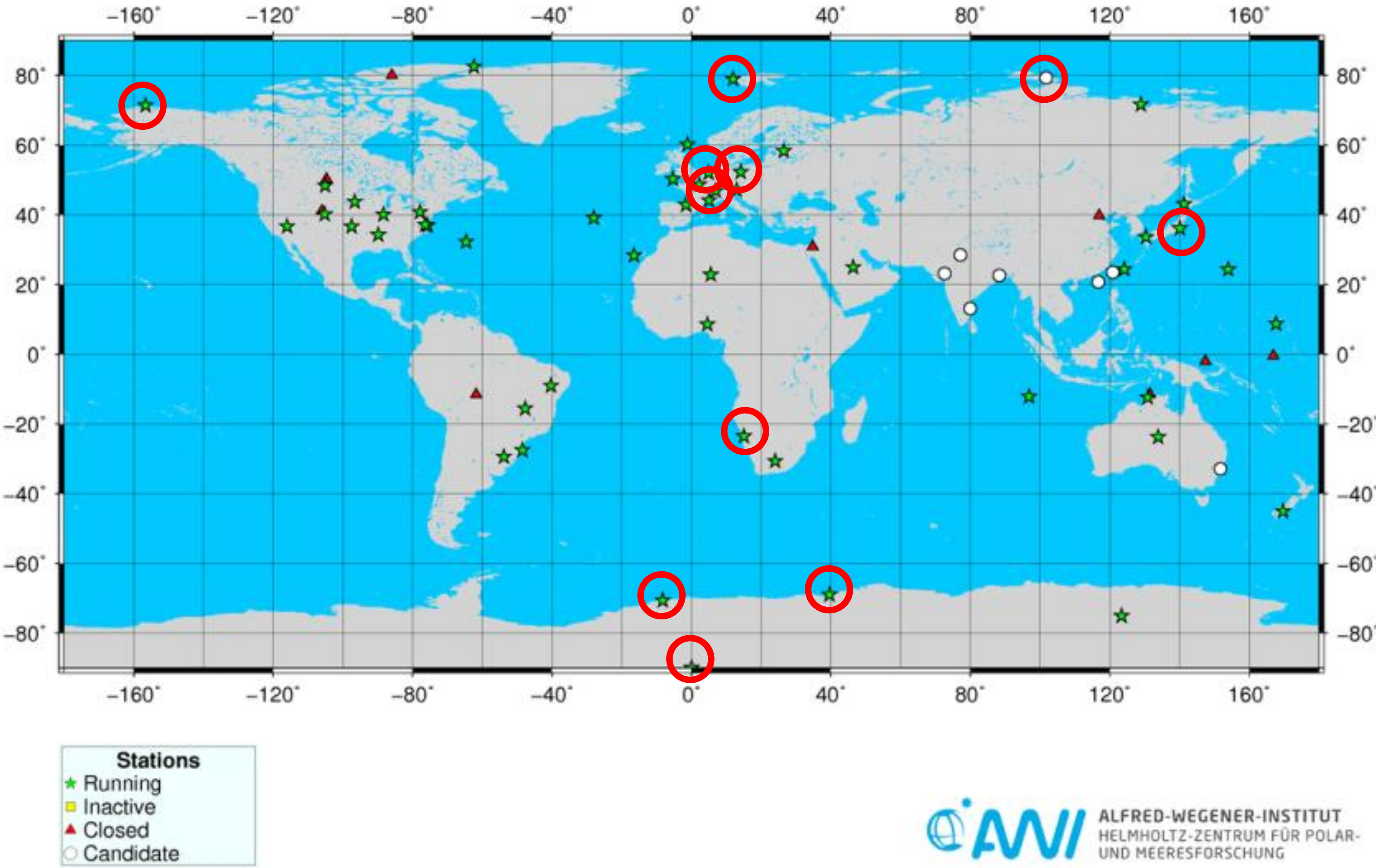
# Running, planned, and closed BSRN Stations, May 2017

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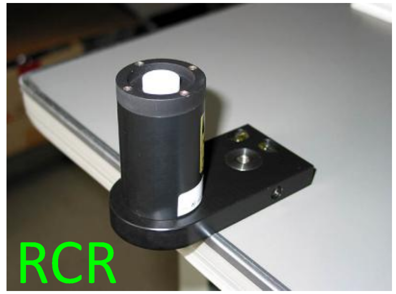
# Lack of standardized spectral measurements

Spectro-radiometers do not have common measurement protocol, apply a large variety of viewing conic angles (ranging from 1˚ to 180˚), have different spectral coverages (e.g. 350-900, 350-1100, 350-1600, 350-2500nm), and their calibration and characterization is not fully resolved.




Photos from Teruo Aoki

# Uncertainty issue

Insufficient characterizations of the spectro-radiometer (e.g. cosine response, temperature drift) and of the measurement setup (e.g. shadows, tilting) cause

Undetermined uncertainty ➡ Measurements can include biases, they are not comparable.

# Complexity issue

The spectro-radiometer technical complexity implies that:

| | | |
|---|---|---|
| The sampling of a spectrum takes time (several seconds) | → | Measurements cannot be taken under changing sky conditions |
| Instruments are not weather proof | → | Not-continuous measurements<br>Modifications need to be made to enable continuous measurements |
| Instruments are expensive | → | Only few groups applies them, mostly for research purposes |

# Measurement accuracy: requirements from data users

## Remote sensing community

Representativeness of the data:

- Many point measurements without need of high accuracy
  - Sledge-based albedo station
  - UAV equipped with broadband and spectral sensors
- Single point measurement with high accuracy (located close to long term monitoring AWS)




# Measurement accuracy: requirements from data users

## Remote sensing community

Data format:

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

## 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).

# Measurement accuracy: achievements in the field

- ✓ Spectral albedo:
  - With white reference standard (narrow FOV):

    10-17% (without angular and shadow corrections), **<5%** (with corrections)
  - transparent diffuser (cosine collector), $350 < \lambda < 2500$ nm:

    10-17% (without angular and shadow corrections), **<10%** (with correction)
  - transparent diffuser (cosine collector), $350 < \lambda < 1100$ nm:

    10-15% (without corrections), **<5%** (with correction)
  - integrating sphere: <5% (with corrections)
- ✓ Spectral BRDF: **5-10%**
- ✓ Narrowband albedo: 5-10%
- ✓ Broadband albedo: **5%**

**Target uncertainty for BSRN sites: 3%**

# Results of the workshop on "in situ snow albedo measurements: toward a snow albedo inter-comparison experiment"

Helsinki, 24-25.08.2016

- Calibration/characterization protocol, following best practices in UV/Metrology
- Measurement protocol
- Recommendation on the needed auxiliary measurements

# Best practices for calibration/characterization of instruments

**What:**

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

**Where:**

- Inter-comparison of one selected instrument
- Inter-comparison using an “Albedo travel standard”
- Accredited Calibration Facility

# Best practices for calibration/characterization of instruments

**Uncertainty document:**

Measurement uncertainty **u=sqrt(a^2 + b^2 + c^2 + d^2 + …)**

Define a,b,c,d,…

Estimate (calculate, if possible, sensitivity studies): Absolute or relative calibration, Cosine Error, in diffuse illumination and clear sky

Stability: Before / After measurement period, between?

Measurement Errors: Orientation, Shadow, Operator

# Protocol to minimize and quantify measurement uncertainties

***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

***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

***MITIGATION***

- Tilt corrections
- Shadow correction
- 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

***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

***TO INTERPRET THE ALBEDO***

- 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

# Rules to make good snow albedo measurements (by Don Perovich)

1. Know your instrument.
2. Know your footprint.
3. Measure towards the sun.
4. Keep the measurement site pristine.
5. Keep irradiance detectors level.
6. Characterize the sky.
7. Characterize the medium.

**8. Adapt your instrument**
**9. Be one with your instrument**

**Thank you for your attention!**