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SVC dual-sphere spectro-albedometer

a new instrument for continuous measurements of snow spectral albedo

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Why continuous, high-temporal-resolution spectral albedo measurements?

- Snow metamorphism can be a **fast process**, and can modify the surface albedo by 10-20% (in case of near melting temperatures) to 80% (in case of thin, melting snow layer) in few hours.

- Other possibly **fast developing (hourly) processes** affecting snow albedo are snow precipitation, snow drift, snow roughness, changes in sky conditions (above all cloud cover).

- Robust validation of satellite-based albedo products requires continuous in-situ measurements of spectral albedo (sampled following the evolution of solar zenith angles, snow metamorphism, and surface geometrical features).

- Spectral albedo is used to derive **wavelength-dependent snow properties** that are relevant for climatological, hydrological, hazard-risk studies and forecasts (such as snow microstructure, impurity content, presence of liquid water).

Challenges

1. The spectroradiometers measuring the whole solar spectrum (350-2500nm) are **expensive** and have **high power consumption** (compared to broadband pyranometers) due to the need of thermal stabilization of the sensors.
2. The **measurements are complex**: for a single data collection, the exposure time of the sensors (integration time) needs to be optimized to prevent light saturation of the detectors and, at the same time, allow a sufficiently high signal-to-noise ratio in all the measured wavelength intervals.
3. The **temperature stabilization** and full **weatherproofing** of the optical sensors is not trivial in the harsh polar environment. The window of the fore optic need to be kept clean and free from frost.
4. The **angular response** of the light collector (fore optics) is wavelength dependent and need to be carefully determined.

Challenges

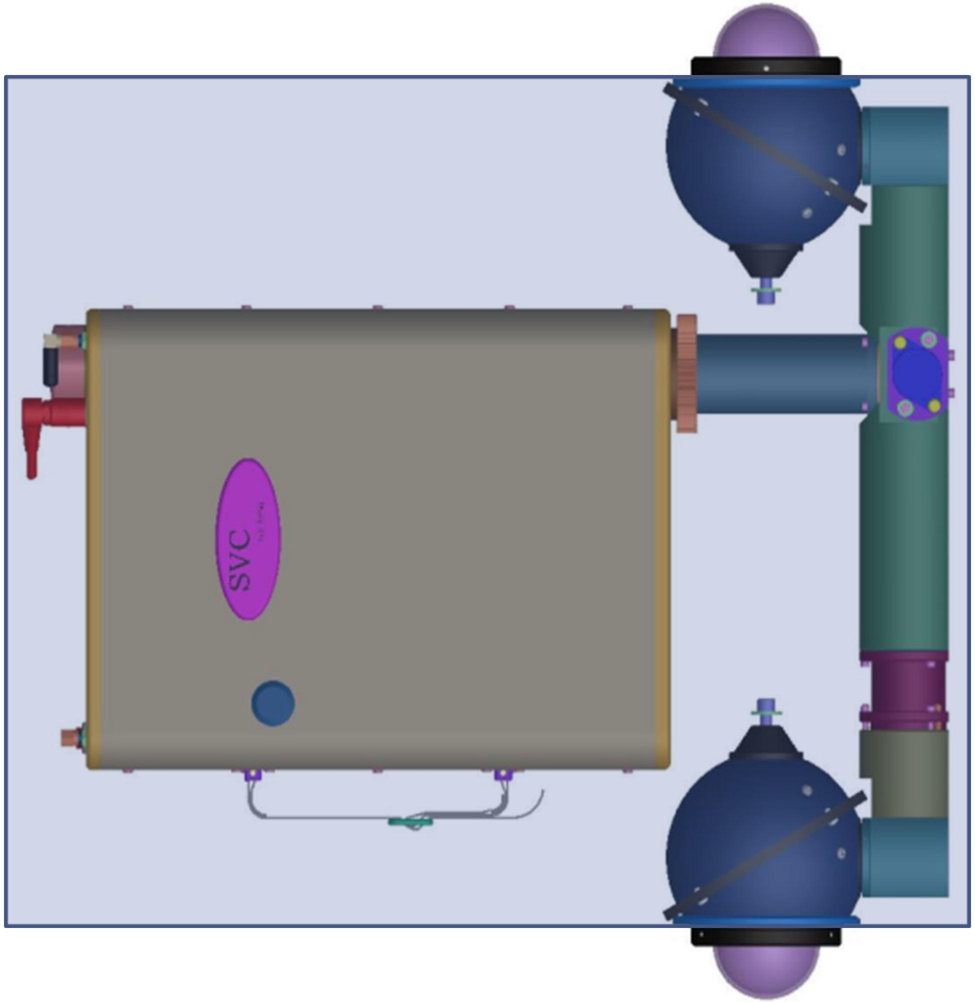
5. Spectral albedo measurements require **two spectroradiometers** measuring from about the same height (one facing the sky and the other facing the surface) or a **single spectroradiometer** that can alternatively point to the sky and to the surface (by turning its head, or by flipping optical guides, or by alternating the target surface with fully reflective materials that direct the sky light to the sensors).
6. Instruments with **narrow Field Of View (FOV)** need to make assumption on BRDF to obtain the bi-hemispherical albedo, while instruments with **hemispherical FOV** need to have proper characterization of the cosine response, and need to correct for the impact of the obstructions in the FOV (for instance, the operator and/or the supporting structure of the instrument).
7. The measurements need to be **fully automatized**, with possibility of remote control of the settings and remote data acquisition.

Key requirement

Good synergy and communication between the engeneers designing and building the instrument and the scientists who need to operate it!!

DUAL SPHERE SPECTRO-ALBEDOMETER

Built by **Spectra Vista Corporation (SVC)** in close cooperation with FMI.



Core instrument: SVC HR-1024i
(three optical sensors, 350-2500nm
Spectral resolution:3.5 nm @ 700 nm
9.5 nm @1500 nm
6.5 nm @2100 nm)

Light collectors: integrating spheres with glass domes

Light switcher: flipping mirror

Insulating box: aluminium case with ventilation units (to blow air over the domes), insulating foam, and (eventually) temperature stabilizer.

Integrating spheres

Built by LABSPHERE INC., US

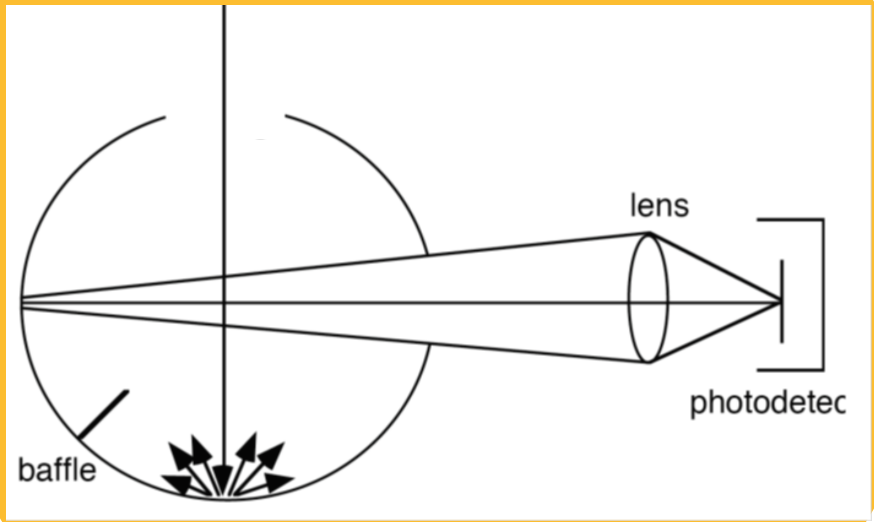
One year of attempts, different designs, and tests were needed to reach an accurate angular response.

Size of sphere and of opening:

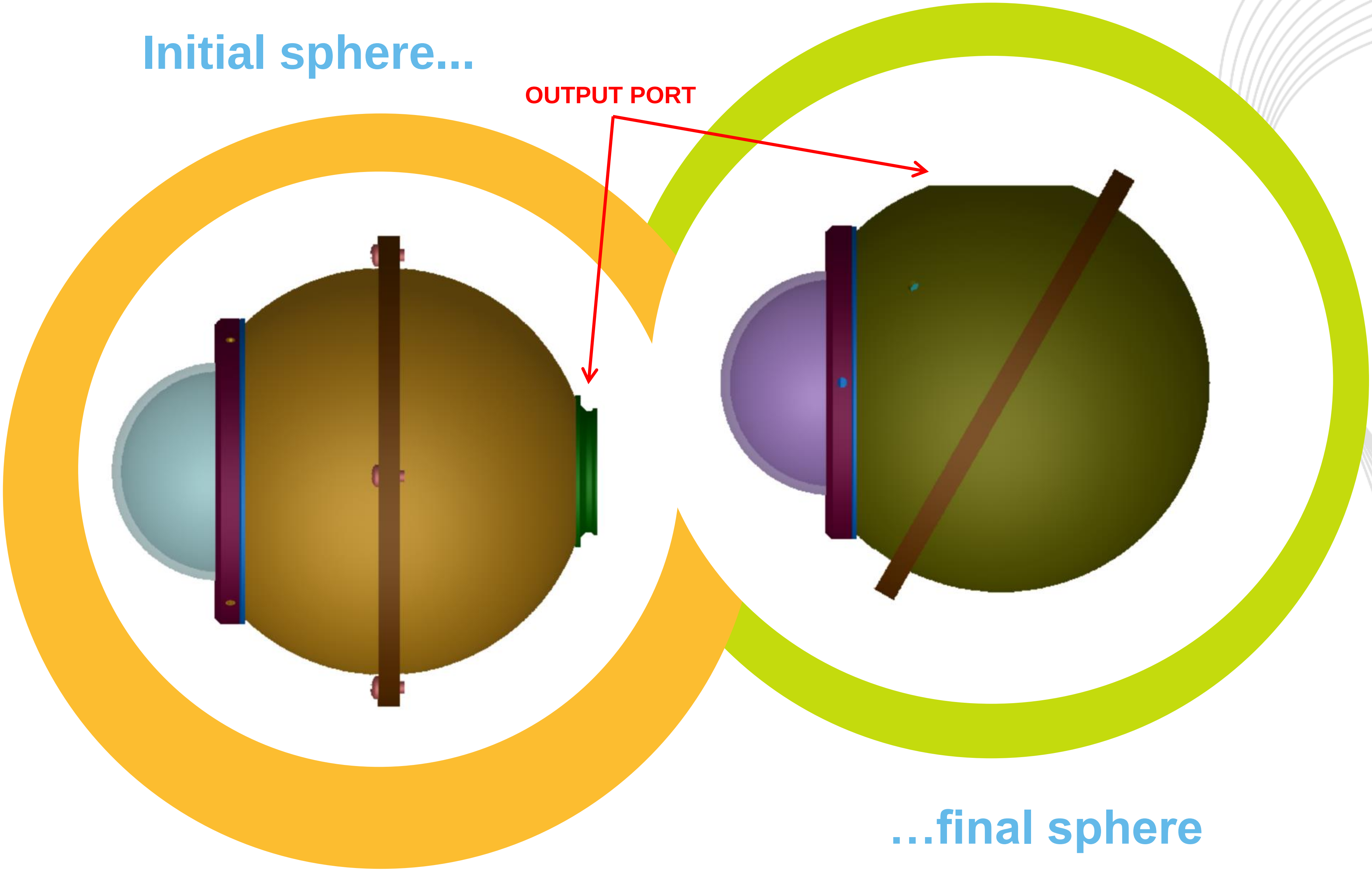
- amount of output radiance
- spatial performance

Location of output and shape of baffle:

- spatial performance

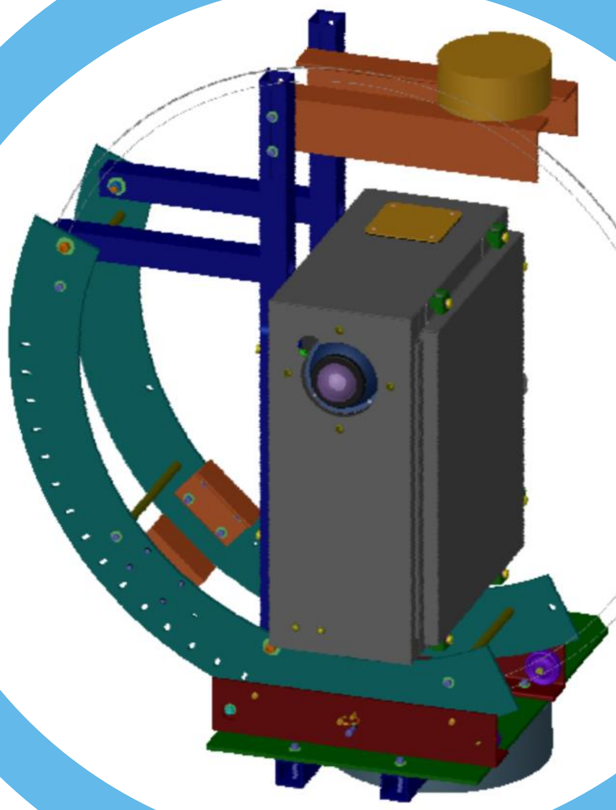


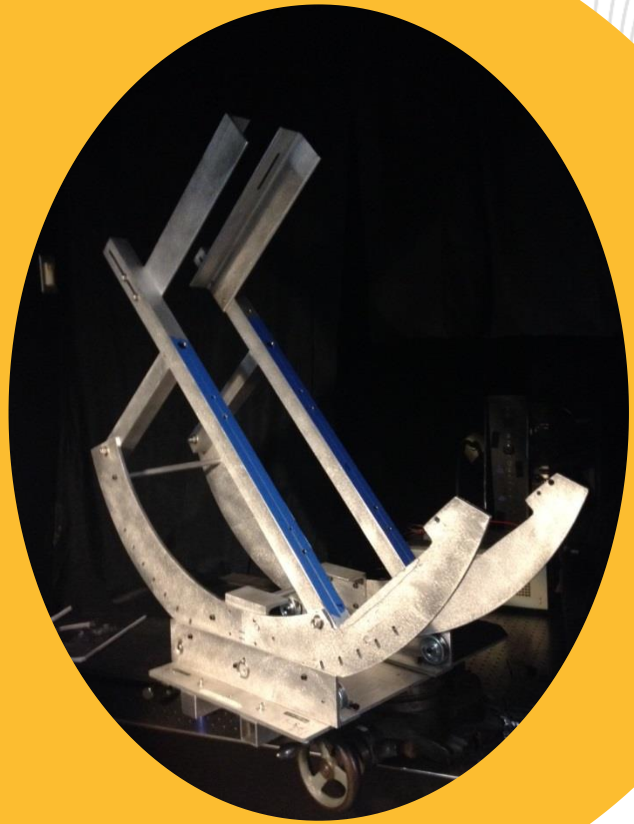
Initial sphere...



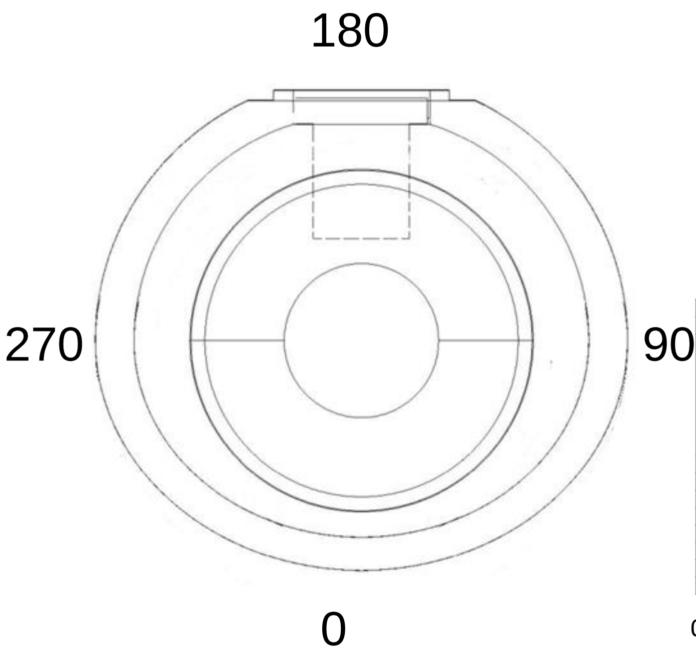
…final sphere

Fixture to measure cosine response



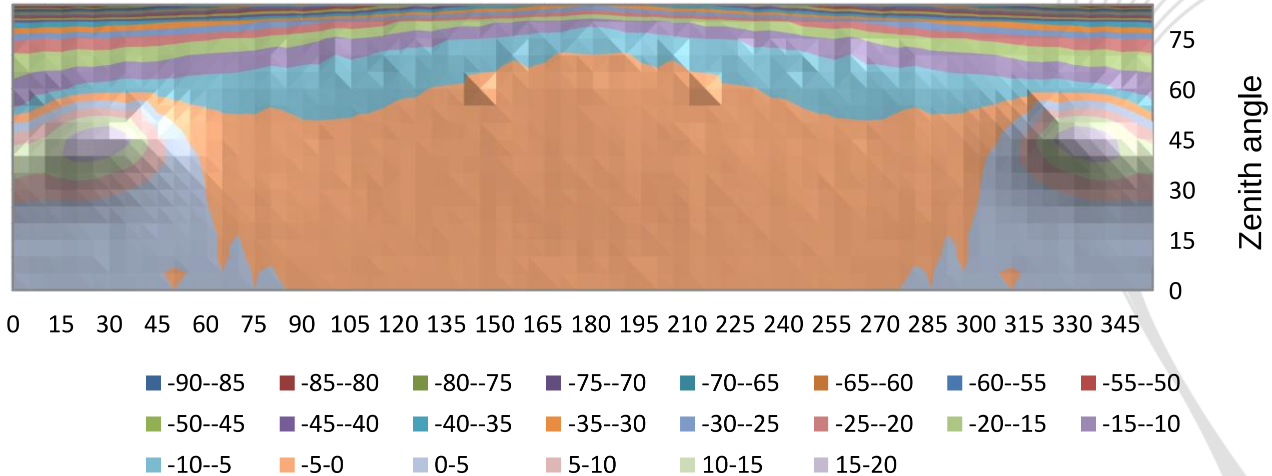


Cosine response

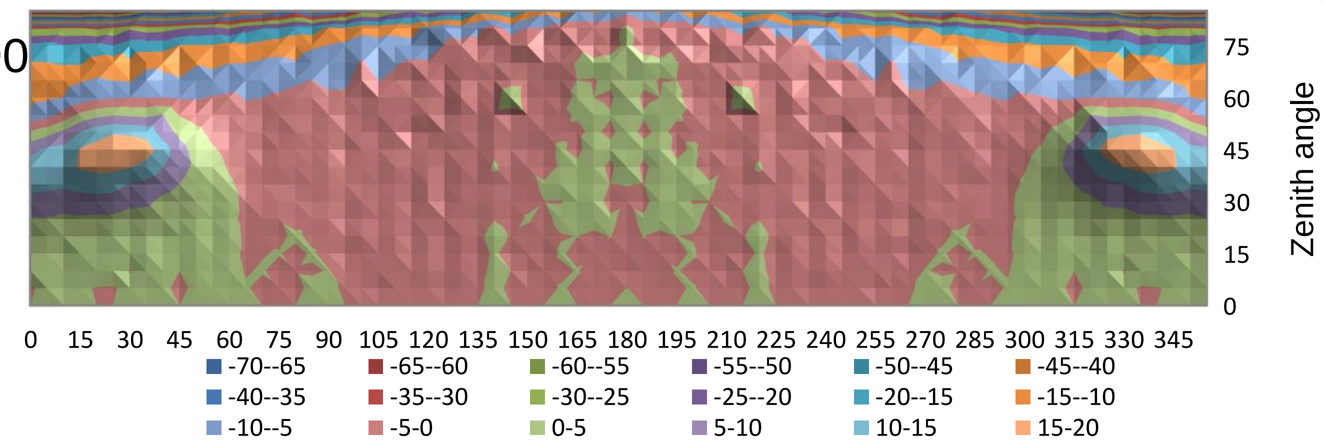


Percent deviation from perfect cosine response:

578.5 nm



885.6 nm



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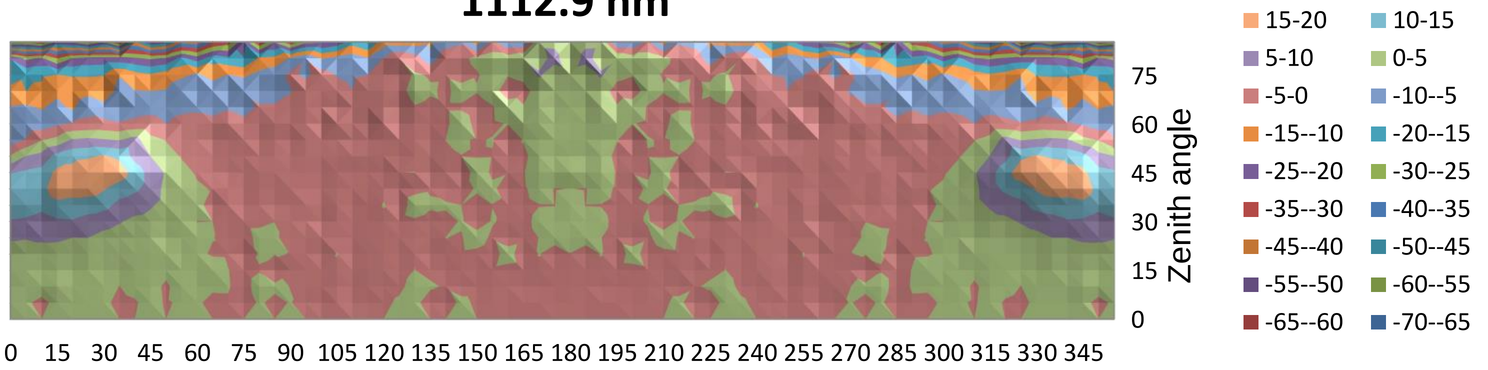
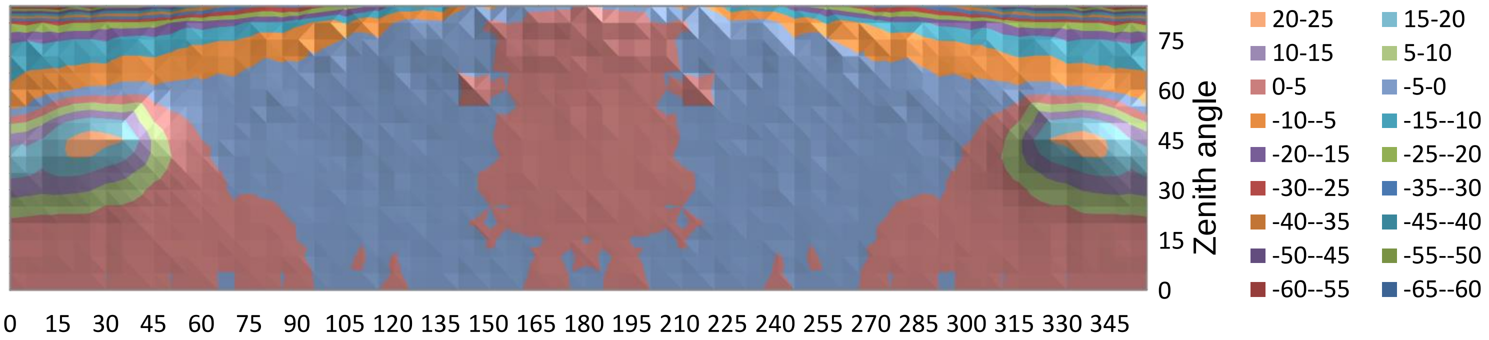
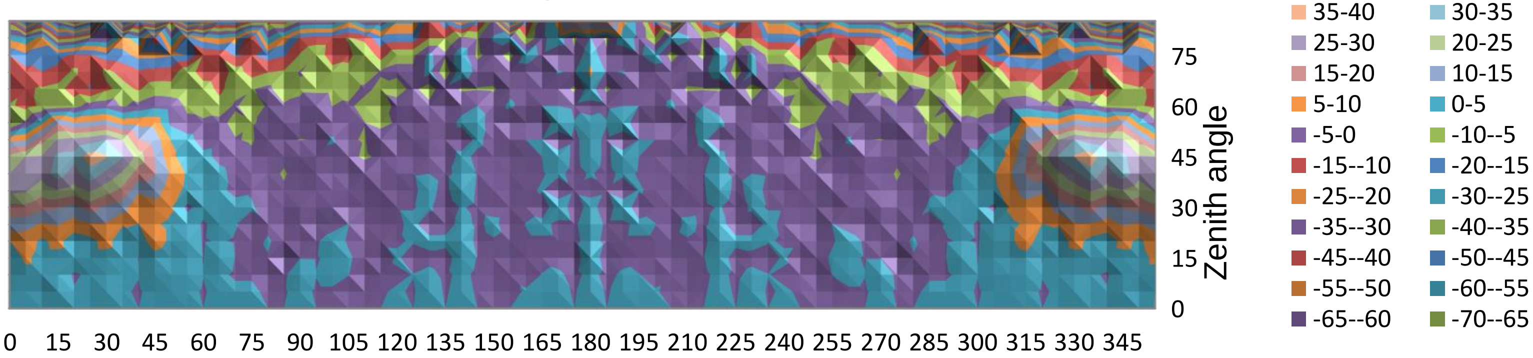
1112.9 nm



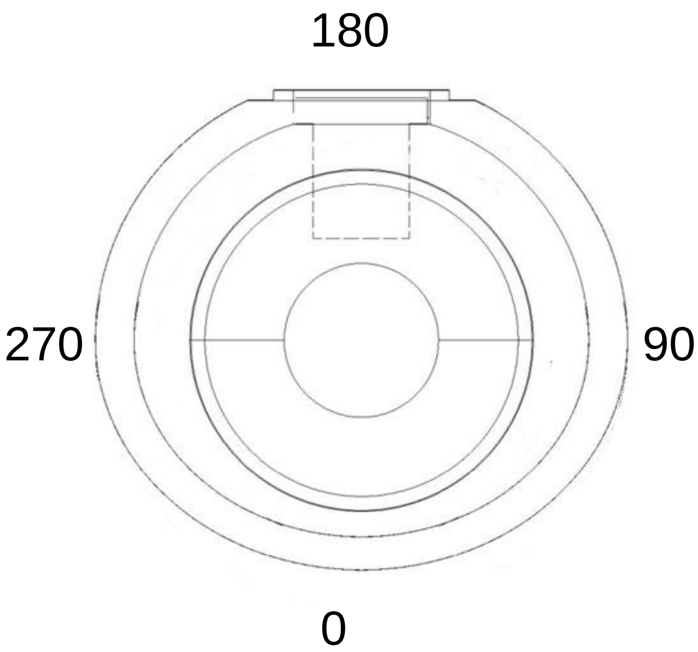
1698.3 nm



2202.2 nm



Cosine response



In the incident azimuth 90-270:

578.5 nm:	Err <5%	for θ ≤ 50°
	5 ≥ Err ≤10%	for 50 ≤ θ ≤ 70°
	10 ≥ Err ≤15%	for 70 ≤ θ ≤ 75°
885.6 nm:	Err <5%	for θ ≤ 60°
	5 ≥ Err ≤10%	for 60 ≤ θ ≤ 75°
1112.9 nm:	Err <5%	for θ ≤ 75°
1698.3 nm:	Err <5%	for θ ≤ 70°
	5 ≥ Err ≤10%	for 70 ≤ θ ≤ 80°
2202.2 nm:	Err <5%	for θ ≤ 60°
	5 ≥ Err ≤10%	for 60 ≤ θ ≤ 75°

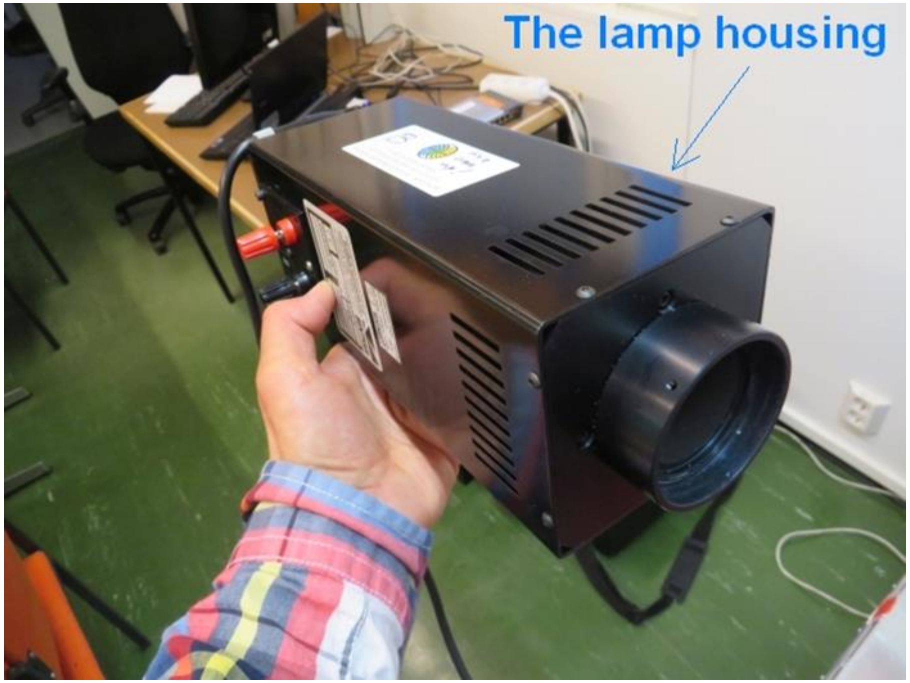
Plans for lab calibration

- Radiance/Irradiance calibration
- Wavelength calibration
- Cosine response characterization
- Temperature dependence of spectrometer's sensitivity (-30˚C ÷ +20˚)
- Temperature dependence of wavelength calibration (-30˚C ÷ +20˚)

The work to set up these calibration routines is in progress…

Plans for field calibration

- Is it enough to calibrate the radiometers in the lab, before and after the measurements campaigns?
- Could we build field calibrators similar to those in use for the Brewer?



50W portable calibrator for Brewer, FMI, Finland

1000W “portable” calibrator for Brewer in Aosta, Italy

Thank you!