Continuous spectral albedo measurements in Antarctica and in the Alps: instrument design, data post-processing and accuracy

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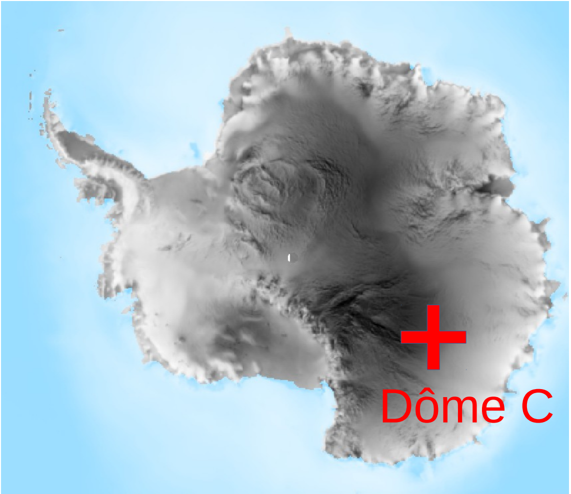
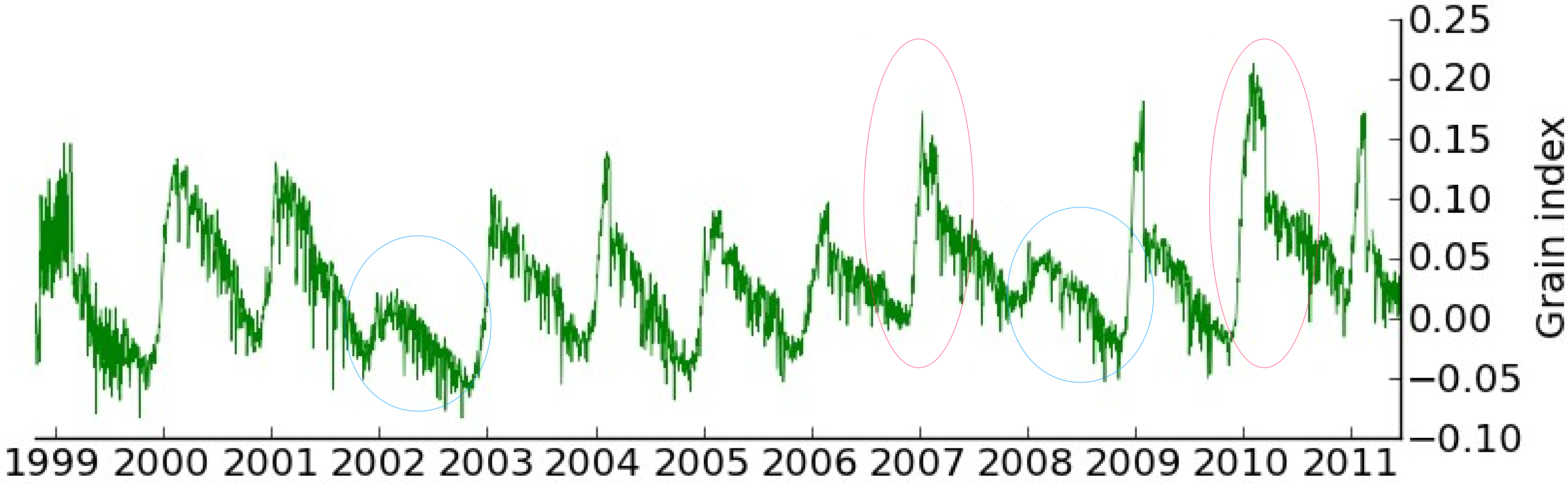
Context

Microwave satellite observations of the « grain index » at Dome C revealed (Picard et al. 2012):

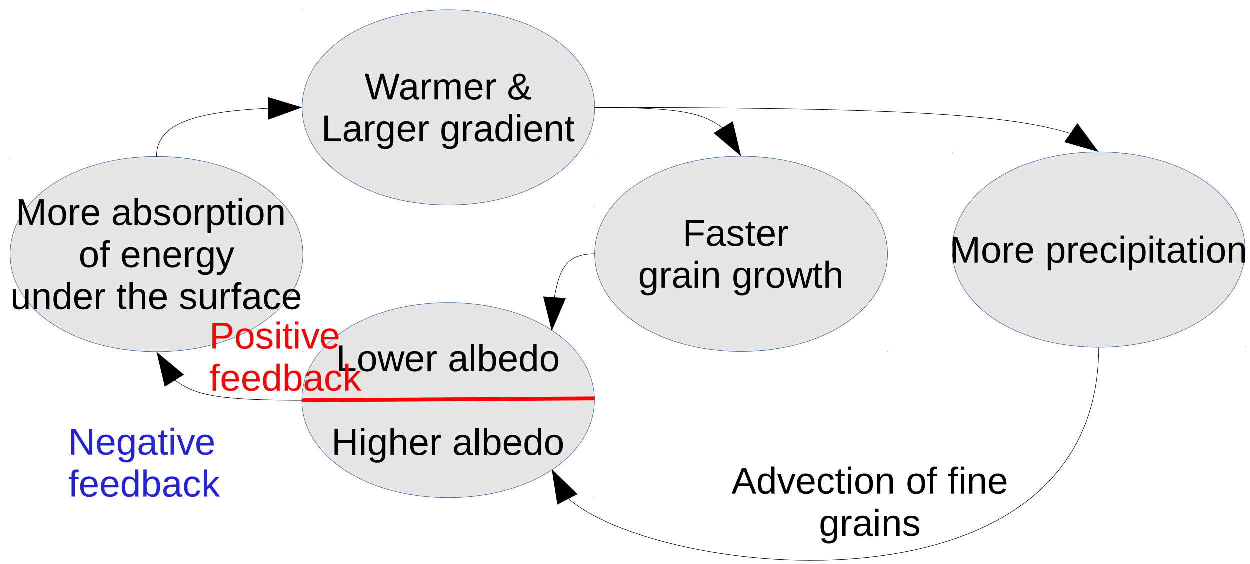
- a seasonal cycle of grain size
- correlation between the inter-annual variability and precipitation





Context

Our hypothesis/conviction: This cycle is largely driven the **positive snow-albedo-grain size feedback** + negative feedback involving precipitation



Our goal: measure in-situ albedo and deduce grain size

→ **developed a spectral albedometer for Dome C.**

Outline

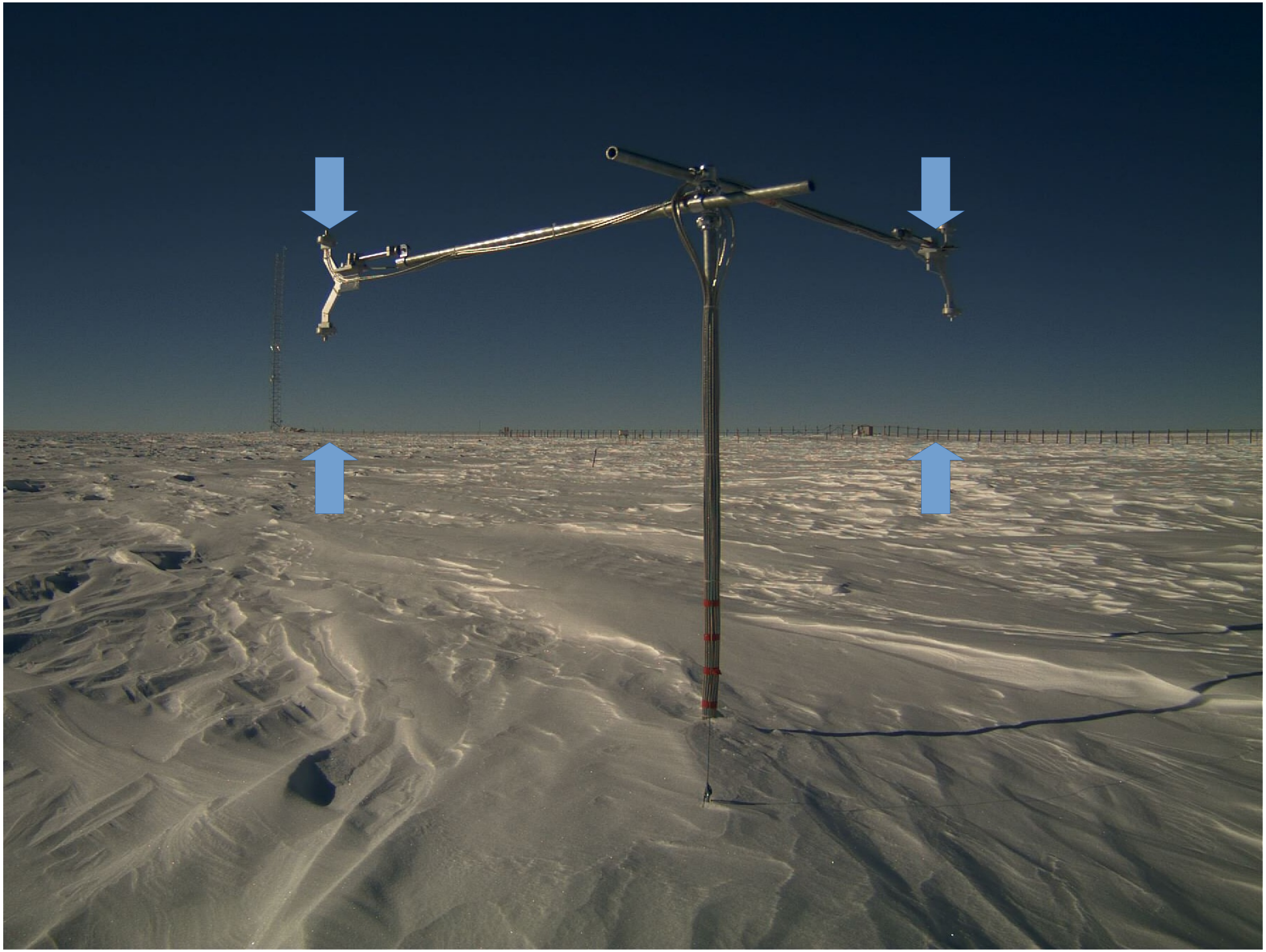
1 - description of the instrument

2 - description of the data processing

3 - conclusion

The instrument "Autosolexs"

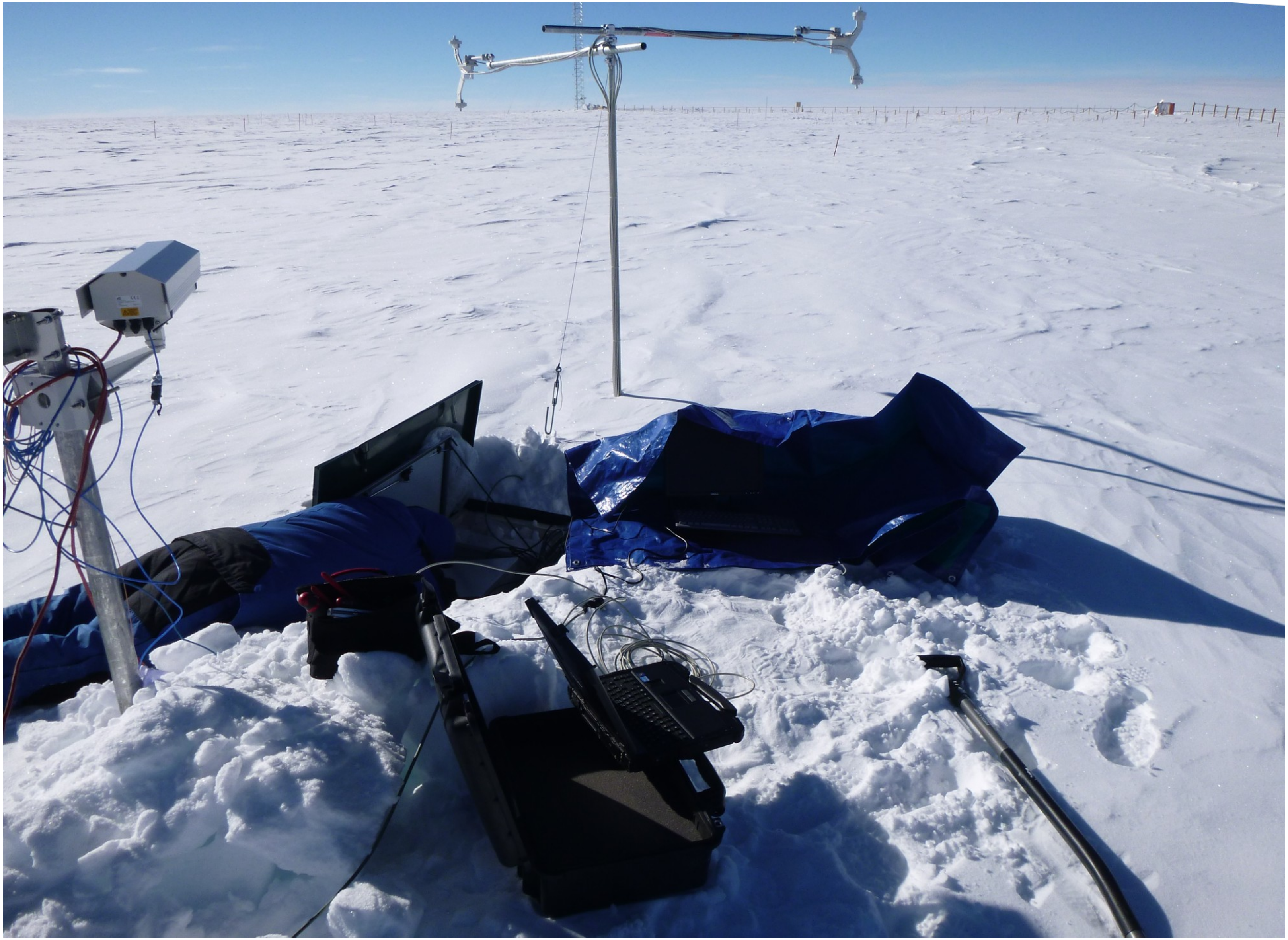
The minimum is above-ground: no electronics, no spectrometer



Only the light collectors and **fiber optics**

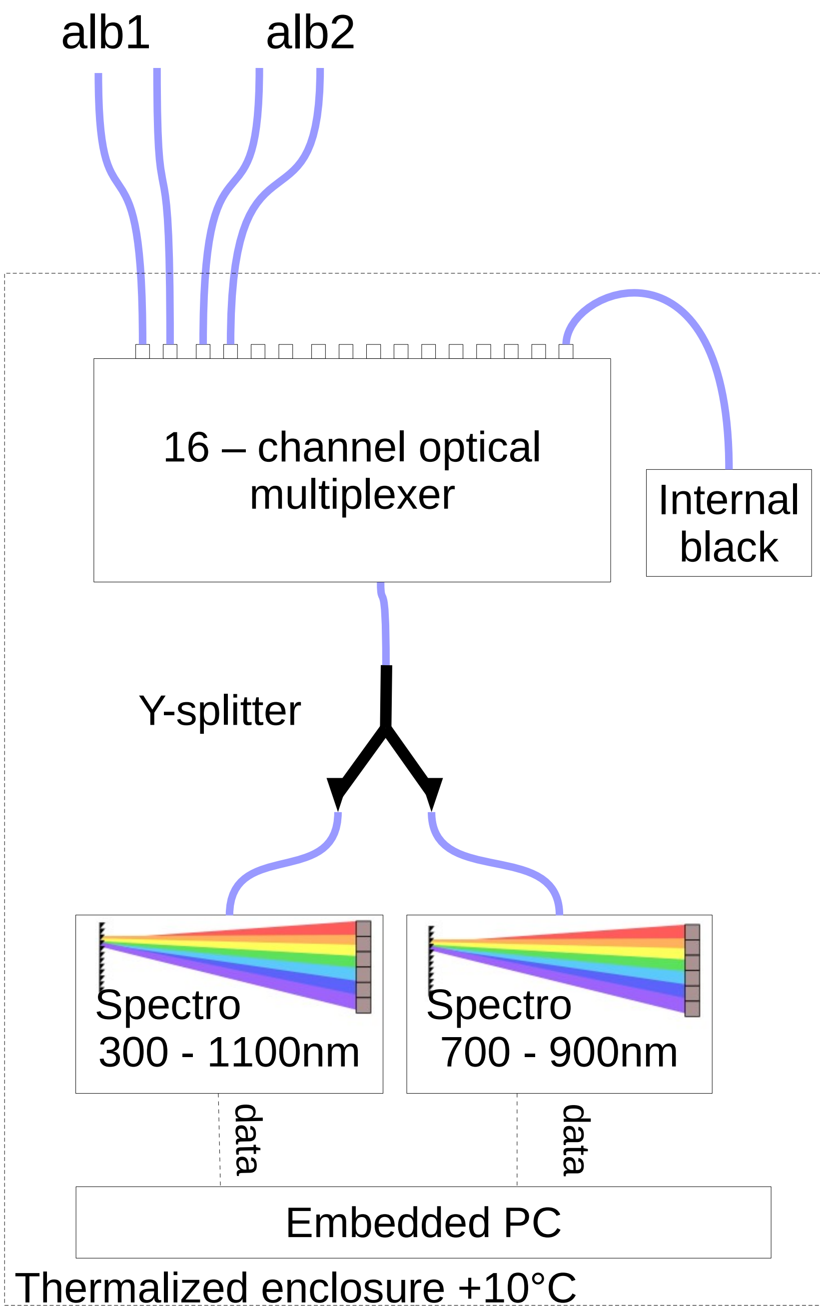
The instrument "Autosolexs"

Under-ground: a box



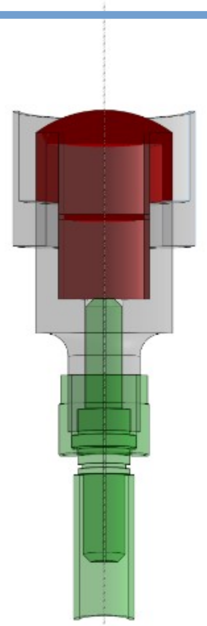
The instrument "Autosolexs"

Another box in the outer box:



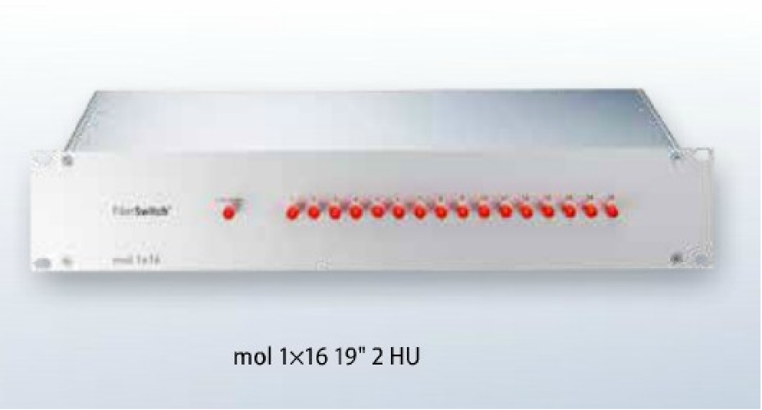
The instrument "Autosolexs"

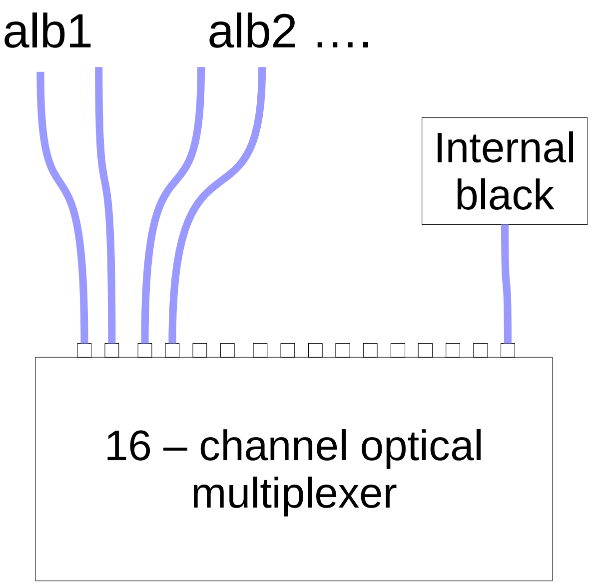
1- Home-made light collector: the most critical part.
See later



2- Ocean Optics fibers: 4-6 m. Negligible attenuation, good radiometric performance, very robust. Choice between UV/Vis or Vis/NIR.

3- Leoni Optical Multiplexer 16 channels to 1 channel





Pros: one spectrometer measures all the channels, many channels for a ~constant cost.
Cons: delay between different channels. Switching reproducibility error (~1%), light attenuation

The instrument "Autosolexs"

4- Ocean Optics spectrometers: MayaPRO with different gratings (300-1100nm and 700-900nm)

Pros: no mechanical parts (CCD sensor+electronics), robust, cheap, open source library

Cons: high dark current and low signal/ratio, sensitivity to the temperature, straight light, ...
Learning curve to achieve accurate measurements.

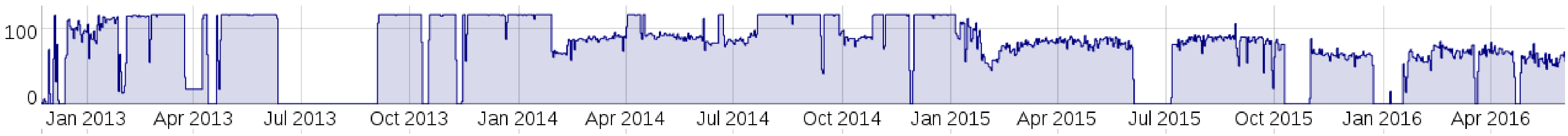
MayaPRO is in the high-end of the Ocean Optics visible spectrometer range. It is more sensitive and the sensitivity extends up to 1050 nm in the near-infrared.

The instrument "Autosolexs"

5- Industrial embedded PC, wide range temperature -40°C

Manage the optical multiplexer and the spectrometers. Perform a sequence of acquisitions every 12 min: incident head 1, reflected head 1, incident head 2, reflected head 2, dark current, ..., take a picture with the webcam.

Robustness: operating since December 2012 day/night summer/winter.



Number of acquisitions per day (received at LGGE)

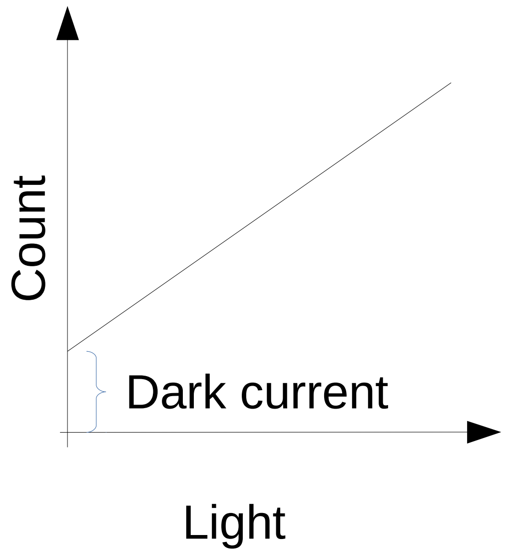
Total : 104929 acquisitions , 2.4M spectra

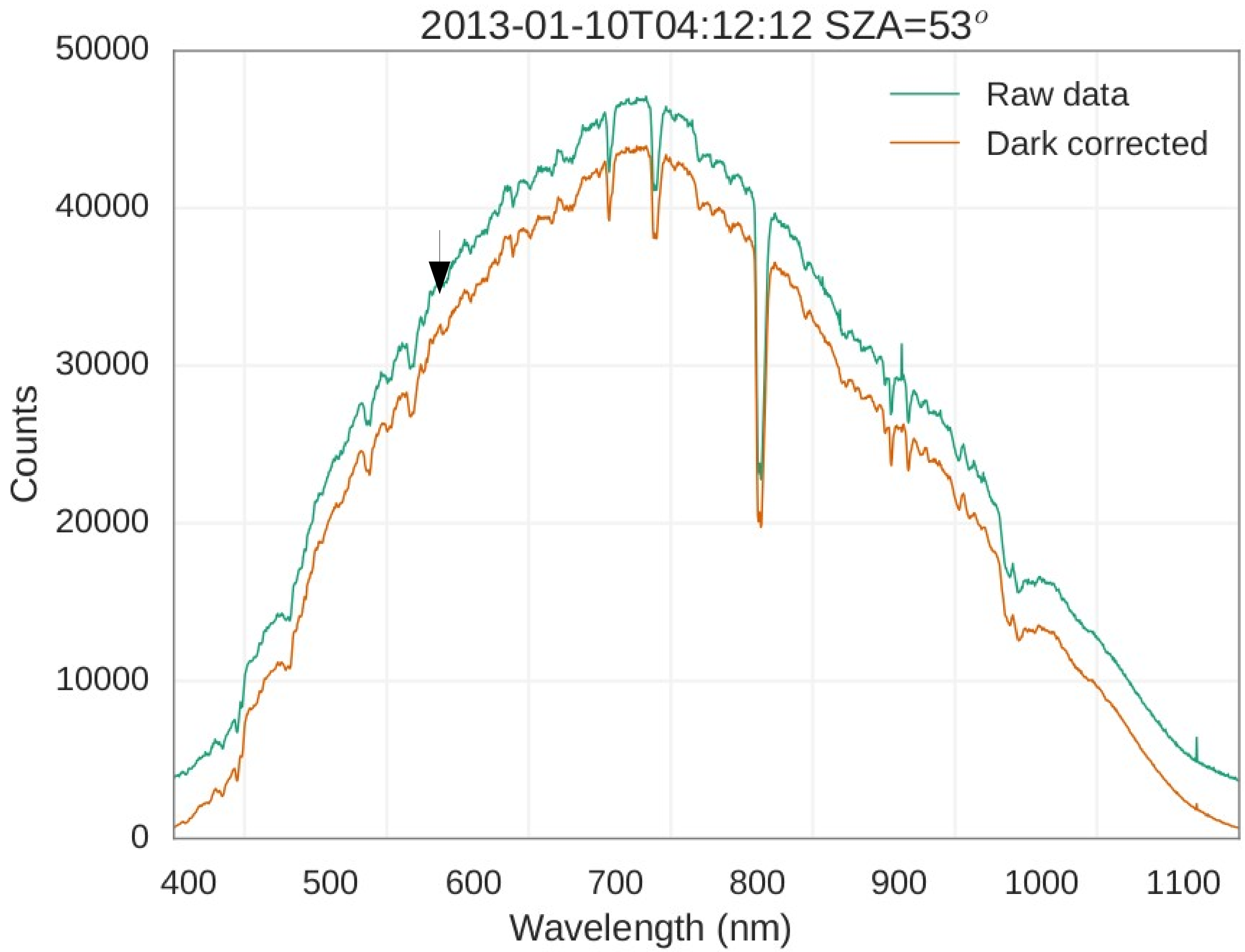
Data processing

- Dark current & straight light correction
- Calibration
- Angular response correction of the light collector
- Estimation of SSA
- Filtering albedo spectra based on the solar zenith angle, cloudiness and quality of the fit in the visible

Data processing

- Dark current & straight light correction





2-step correction:

- use "dark" pixels (around 200nm)

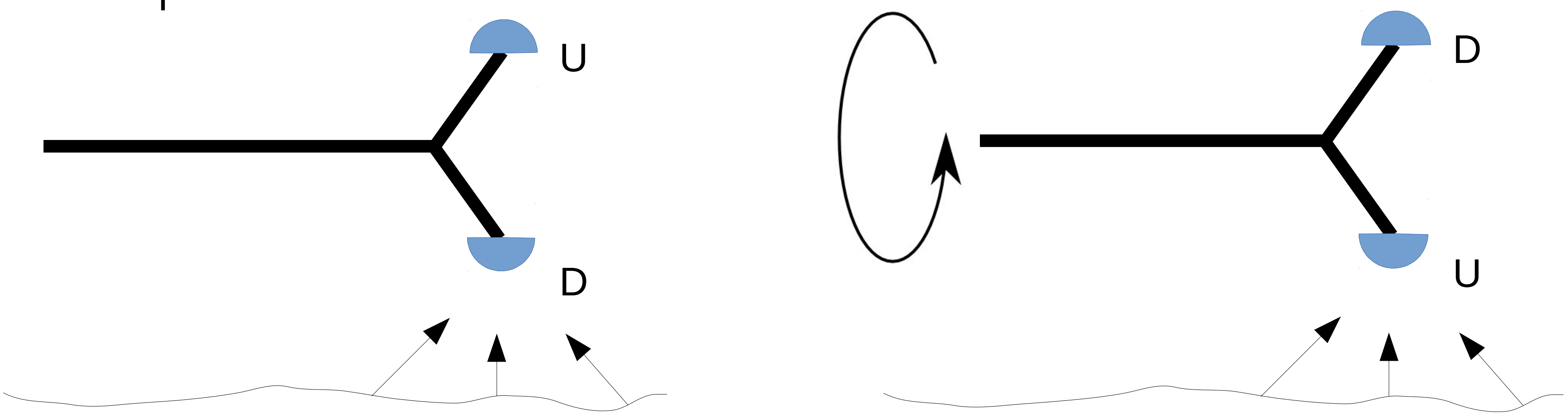
- use a "dark" spectrum taken on an unconnected/obstructed channel

Data processing

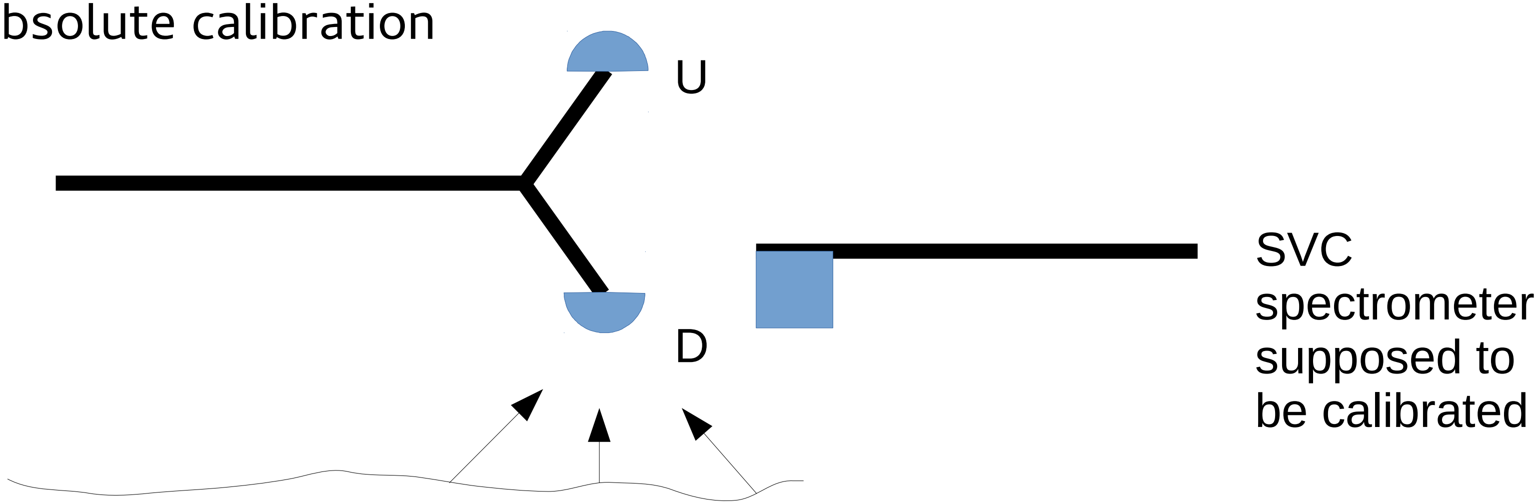
- Calibration in 2 steps

1 – cross calibration between the uplooking and downlooking channels

Reverse experiment before the installation :



2 – absolute calibration

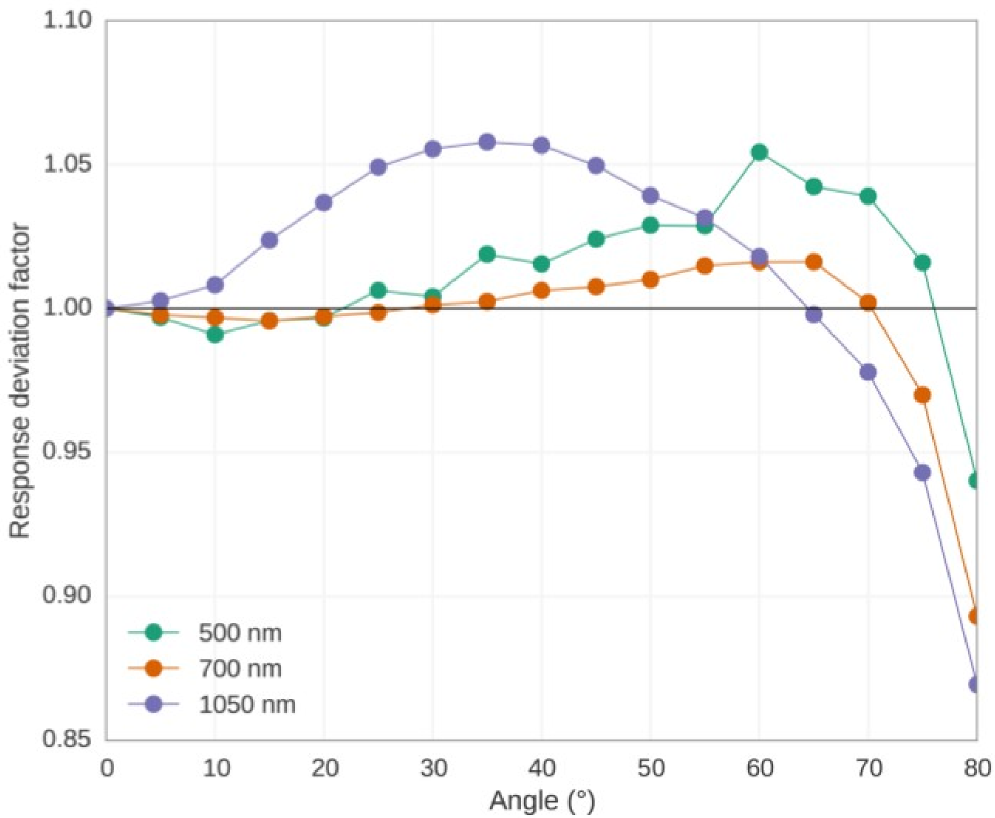


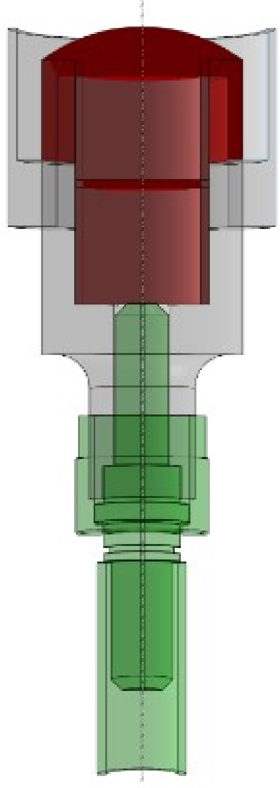
Data processing

- Angular response correction of the light collector

This is the most critical step for the estimation of the SSA (Picard et al. 2016) because the quality of the diffuser is wavelength dependent. This introduces a spurious wavelength dependence on the albedo spectrum.

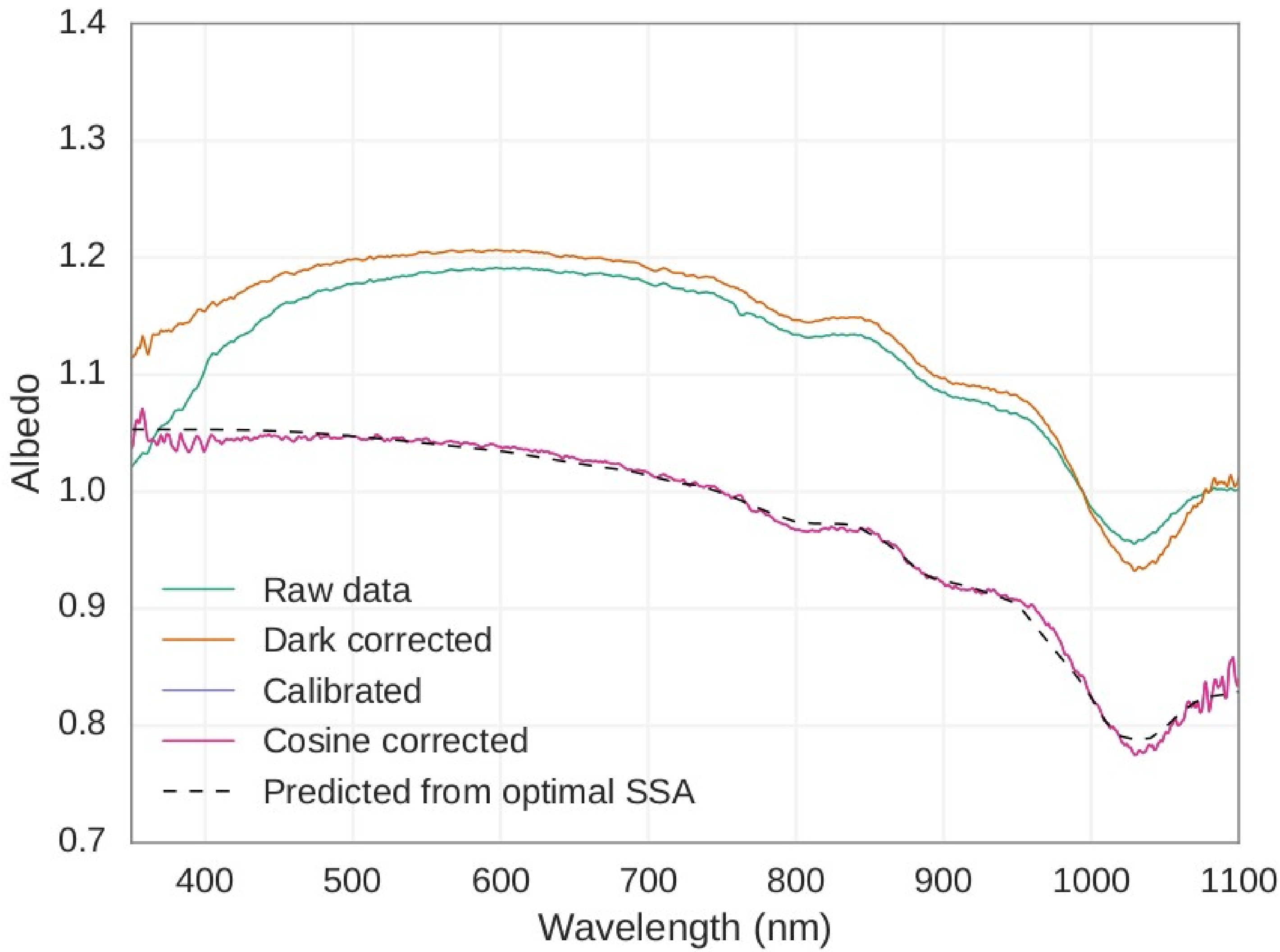
First, we built our own collectors by try-error → an improved response compared to others in the literature. Departure from cosine is <6% up to 75°.





Data processing

Second, we built a setup to in our dark laboratory to automatically record the actual response for each collector and use this response to apply a correction following Grenfell 1994, Carmagnola 2013



Data processing

- Estimation of SSA using analytical closed-form proposed by Kokhanosky and Zege 2004 (Asymptotic Radiative Transfer)

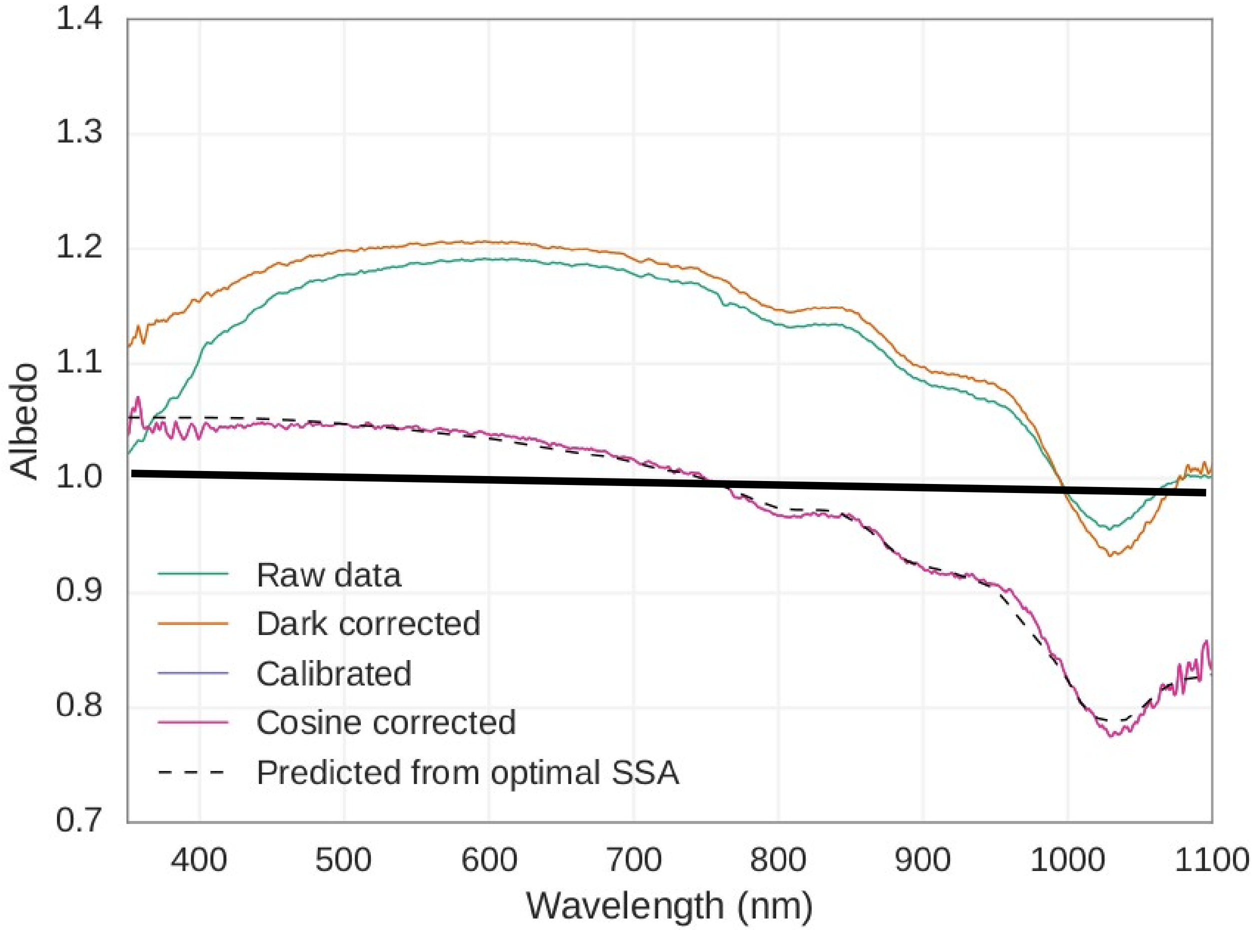
Diffus albedo
$$\alpha^{\text{diff}}(\lambda) = \exp\left(-4\sqrt{\frac{2B\gamma(\lambda)}{3\rho_{\text{ice}}\text{SSA}(1-g)}}\right) \quad (1)$$

Direct albedo
$$\alpha^{\text{dir}}(\lambda,\theta) = \exp\left(-\frac{12}{7}(1+2\cos\theta)\sqrt{\frac{2B\gamma(\lambda)}{3\rho_{\text{ice}}\text{SSA}(1-g)}}\right), \quad (2)$$

Total
$$\alpha^{\text{1-param}}(\lambda,\theta) = \left[r^{\text{diff}}(\lambda,\theta)\alpha^{\text{diff}}(\lambda) + \left(1-r^{\text{diff}}(\lambda,\theta)\right)\alpha^{\text{dir}}(\lambda)\right], \quad (3)$$

Direct/diffuse ratio is taken from generic simulation with SB-DART based on the solar zenith angle.

Data processing



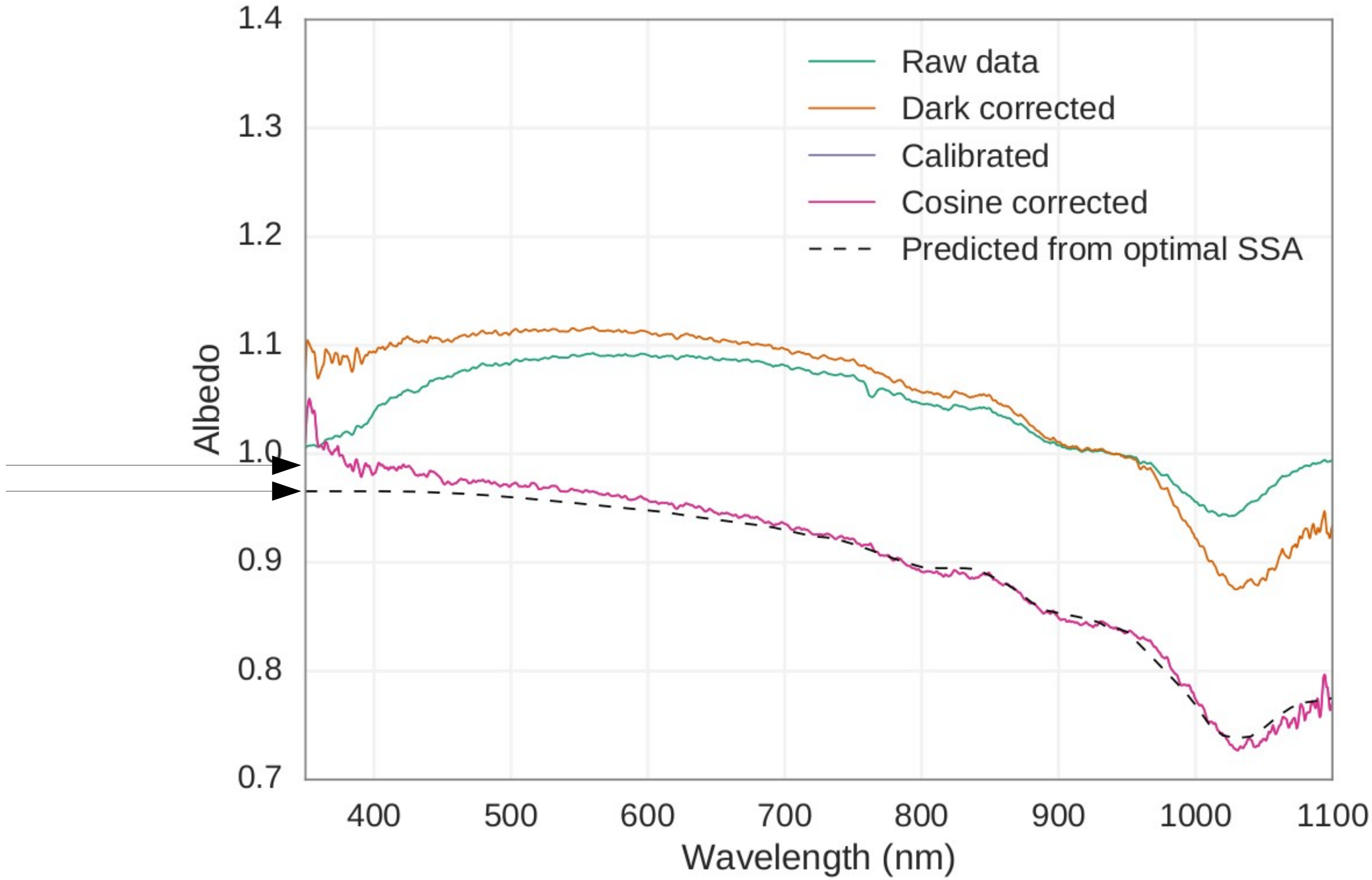
Joint estimation of SSA and A a scaling factor (A is independent of the wavelength but is independent for each spectrum).

$$\alpha^{\text{2-param}}(\lambda,\theta) = A\left[r^{\text{diff}}(\lambda,\theta)\alpha^{\text{diff}}(\lambda) + \left(1 - r^{\text{diff}}(\lambda,\theta)\right)\alpha^{\text{dir}}(\lambda)\right]. \tag{4}$$

Data processing

- Filtering of the albedo spectra based 1) on the solar zenith angle, 2) cloudiness and 3) quality of the fit in the visible.

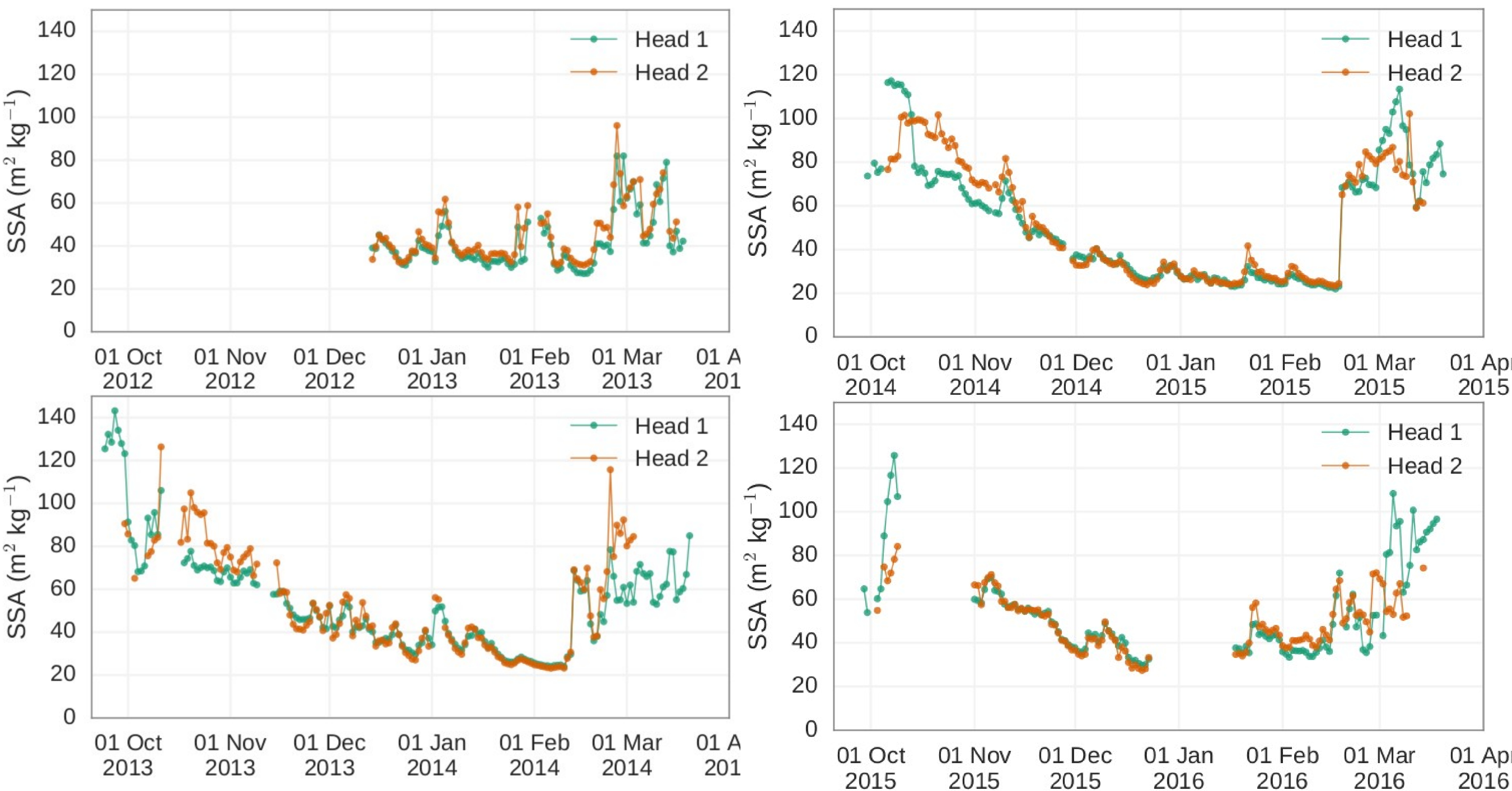
Use the difference between the fitted and observed spectra (Picard et al. 2016)



Conclusion

Nearly 4 seasons!

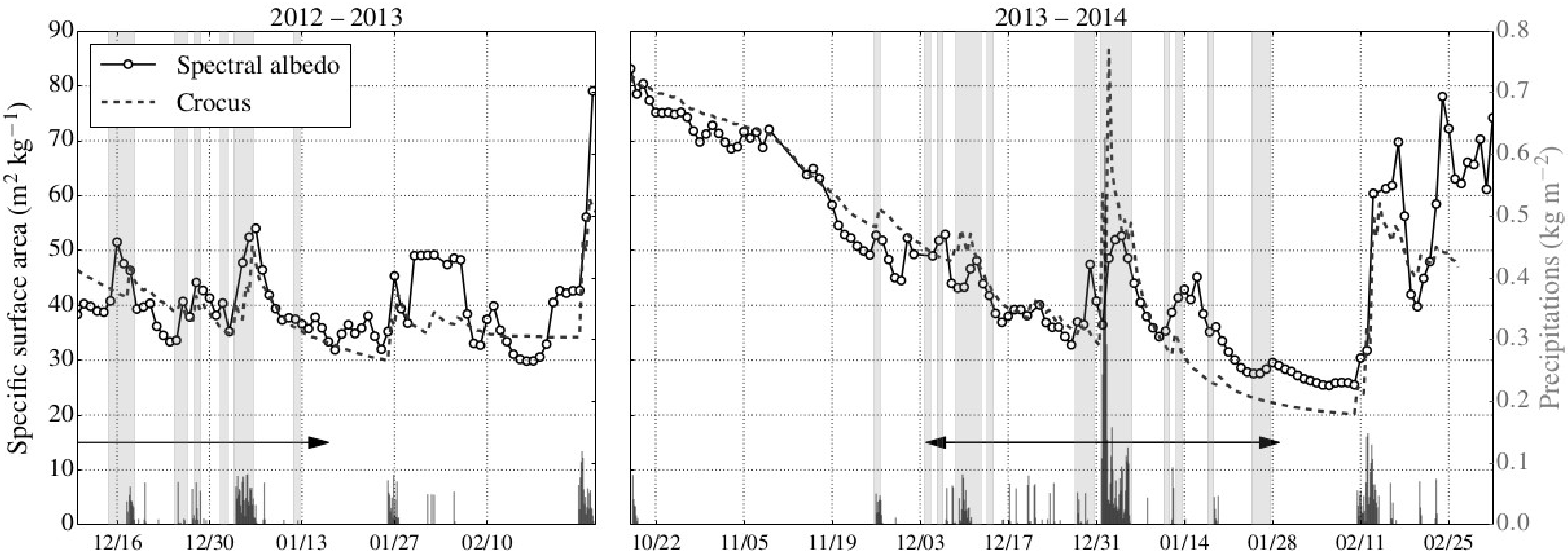
Albedo and SSA data available as doi:10.1594/PANGAEA.860945



Confirm the grain growth in summer. Weak inter-annual variations compared to the satellite observations

Conclusion

Good agreement with Crocus snow model predictions. Libois et al. 2015.



Conclusion

In addition to Autosolexs@Dome C:

1 Autosolexs with 16 channels at Col de Porte in 2012-13 and 2013-14
→ Marie Dumont's presentation later

1 Autosolexs with 4 channels to be deployed at Col du Lautaret in 2016-17

Manual version using the same collector, fiber and spectrometer: Solalb
Same processing library

→ See Poster M. Belke Bré