The impact of specific surface area and clouds on surface albedo: Investigations made at Kohnen Station, Antarctica, during summer 2013/2014

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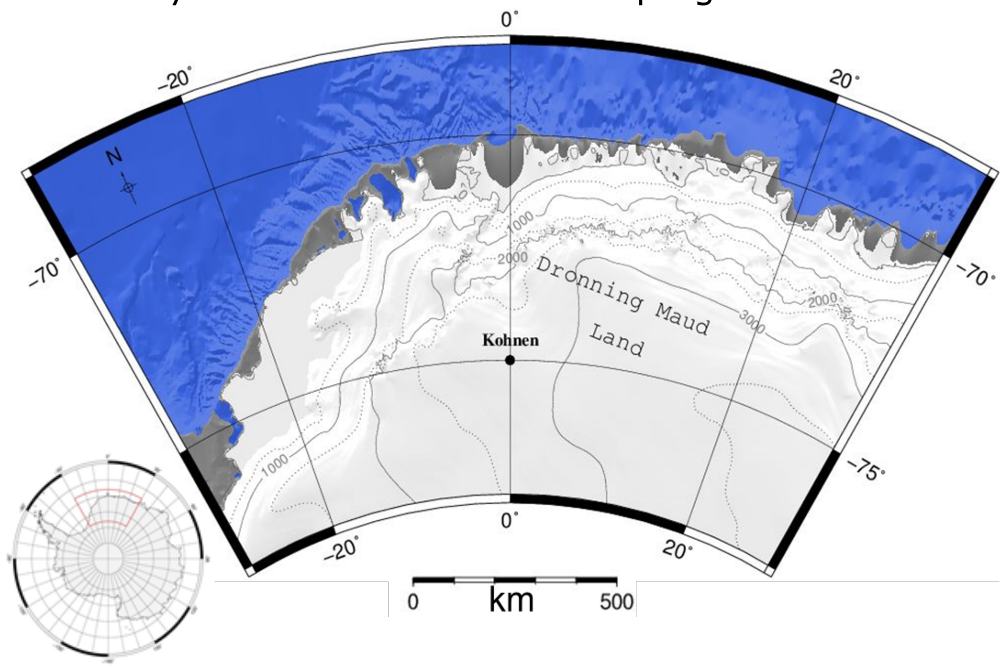
Introduction

Antarctic snow physical properties and atmospheric conditions are considered to change with increasing temperatures, hence also modifying surface albedo. **Albedo is one of the most important factors determining near-surface energy fluxes and is therefore a key parameter in regional and global climate models. Albedo is, however, highly variable**, and it is of great interest to incorporate albedo variability into models for accurate prognoses.

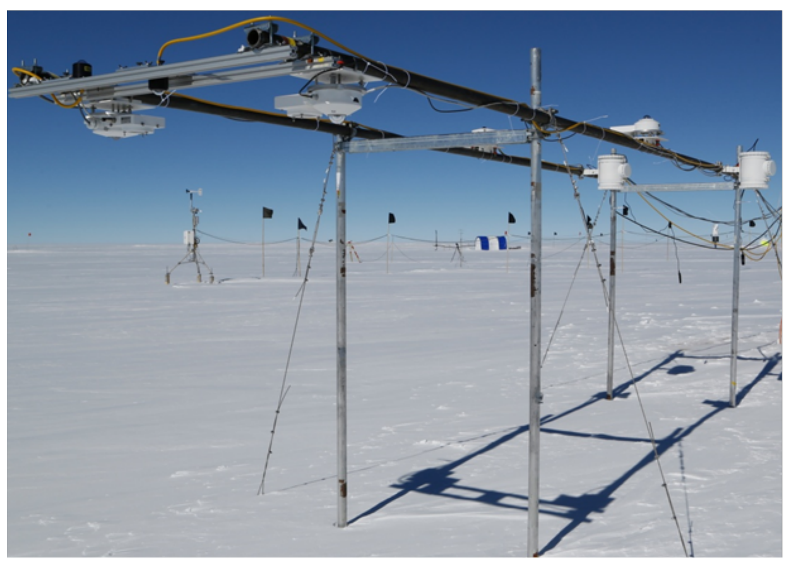


In Dec 2013 and Jan 2014 a field campaign was conducted at Kohnen Station (75° 00' S, 0° 04' E). **Broadband albedo** and **Specific Surface Area (SSA) of snow**, as a measure of grain size, were investigated simultaneously for the first time in Antarctica. Furthermore, synoptic observations were documented for nearly the whole measuring periode. This offers the unique opportunity to analyze and correlate synchronized data sets of atmospheric and snow physical properties with surface albedo of the Antarctic plateau. Questions to answer are:

What are the characteristic variations of SSA?

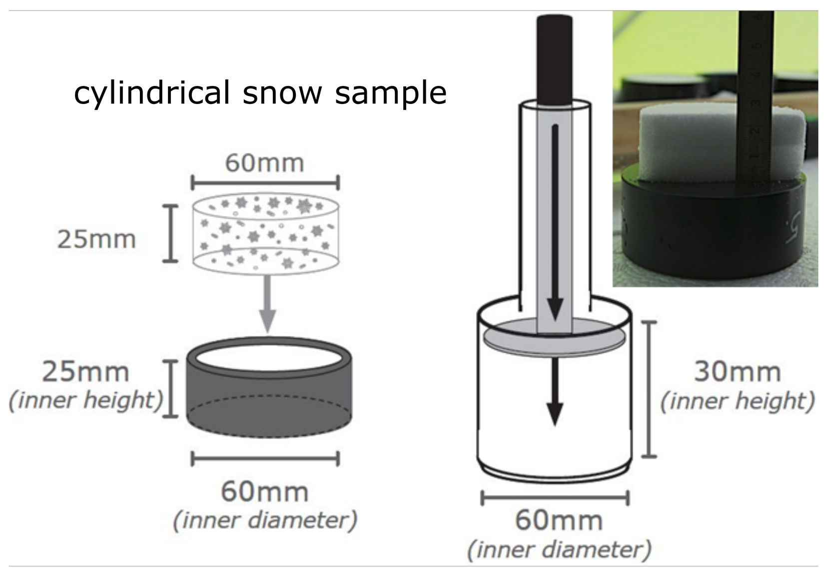
What is the impact of changes in SSA and abundance of low-level clouds on snow albedo?

Measurements: *Radiation*



Albedo:
> two CM22 pyranometers (K&Z)
> spectral range 300 to 3600 nm.
> irradiances stored as min-by-min mean
> albedo uncertainty ± 1.6%.

SSA



SSA [m^2/kg] = $\frac{\text{free surface area of air-snow interface}}{\text{snow mass of sample}}$

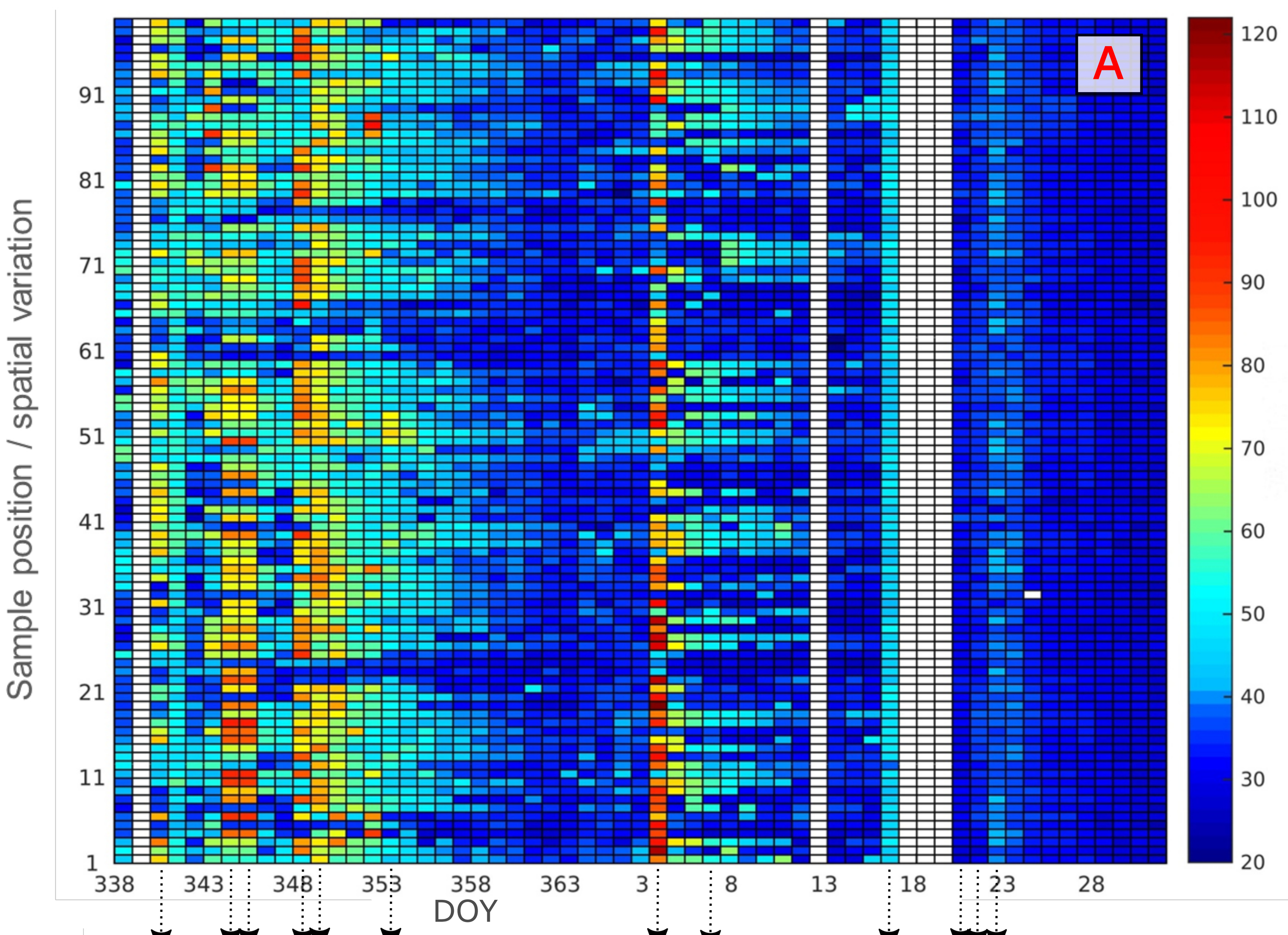
free surface area: determined at 1310 nm (ICE-Cube System by A2 Photonic Sensors)
samples: daily extracted along a 100m profile.

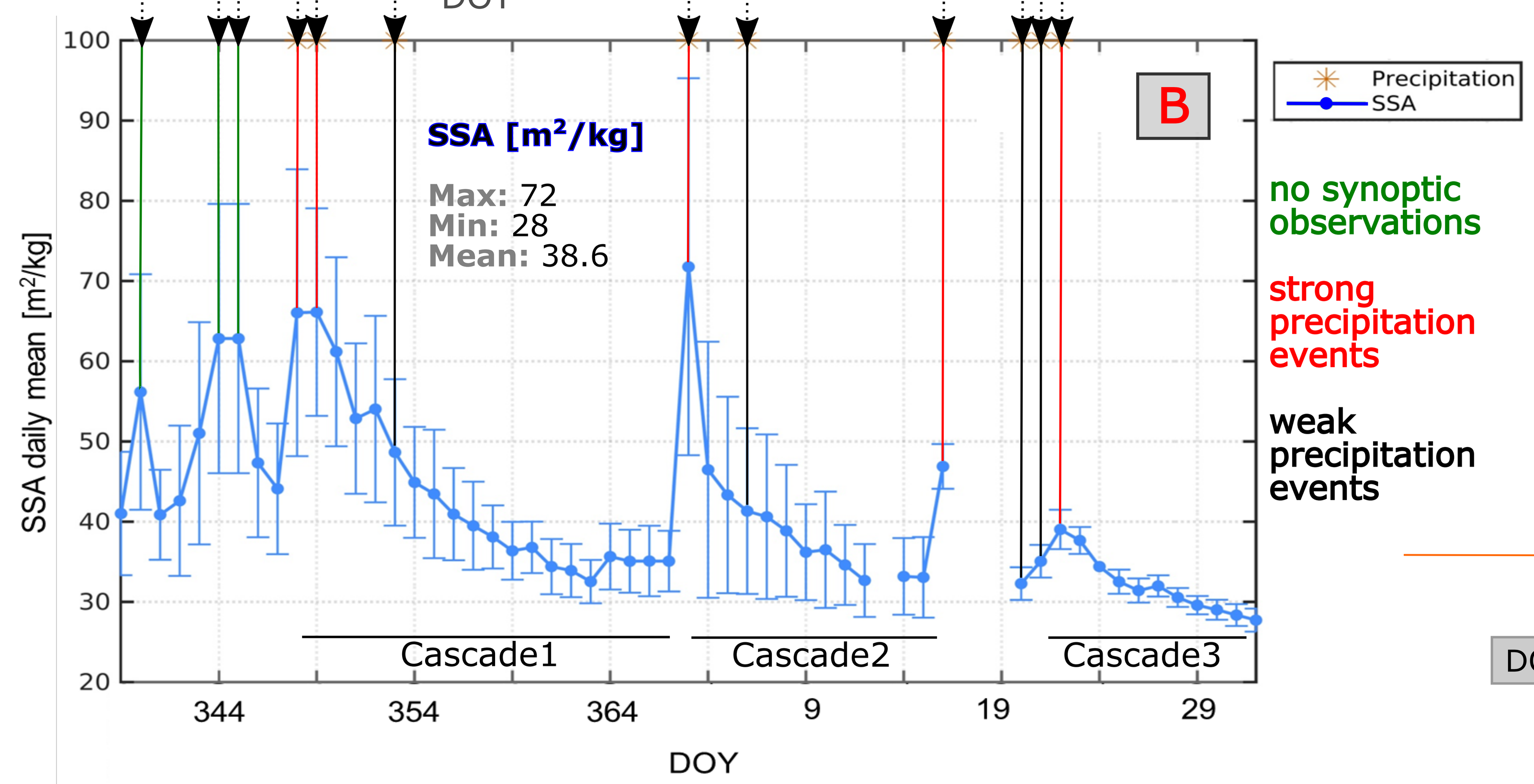
Results

Figure A: > *grid* with SSA values, each square = one sample.
> *y-axes:* 100 samples along a 100m profile measured at the same day.
> *x-axes:* each step = one day.
> *squares:* color coded with red colores for high and blue for low SSA values.

Observations: In time, several days with high SSA events can be seen. However, appearance of high SSA is not homogeneous along the whole profile and this spatial variation is considered to result from small scale topography, where SSA values at ridges remain low.

Figure B: > daily mean SSA values (of 100 samples, which were taken every day).
Observations: The high SSA events, here visible as peaks (marked by red lines), correlate with heavy precipitation events (max. total accumulation of 1mm). High SSA values are followed by a gradual decrease resulting in a cascading pattern throughout the season.





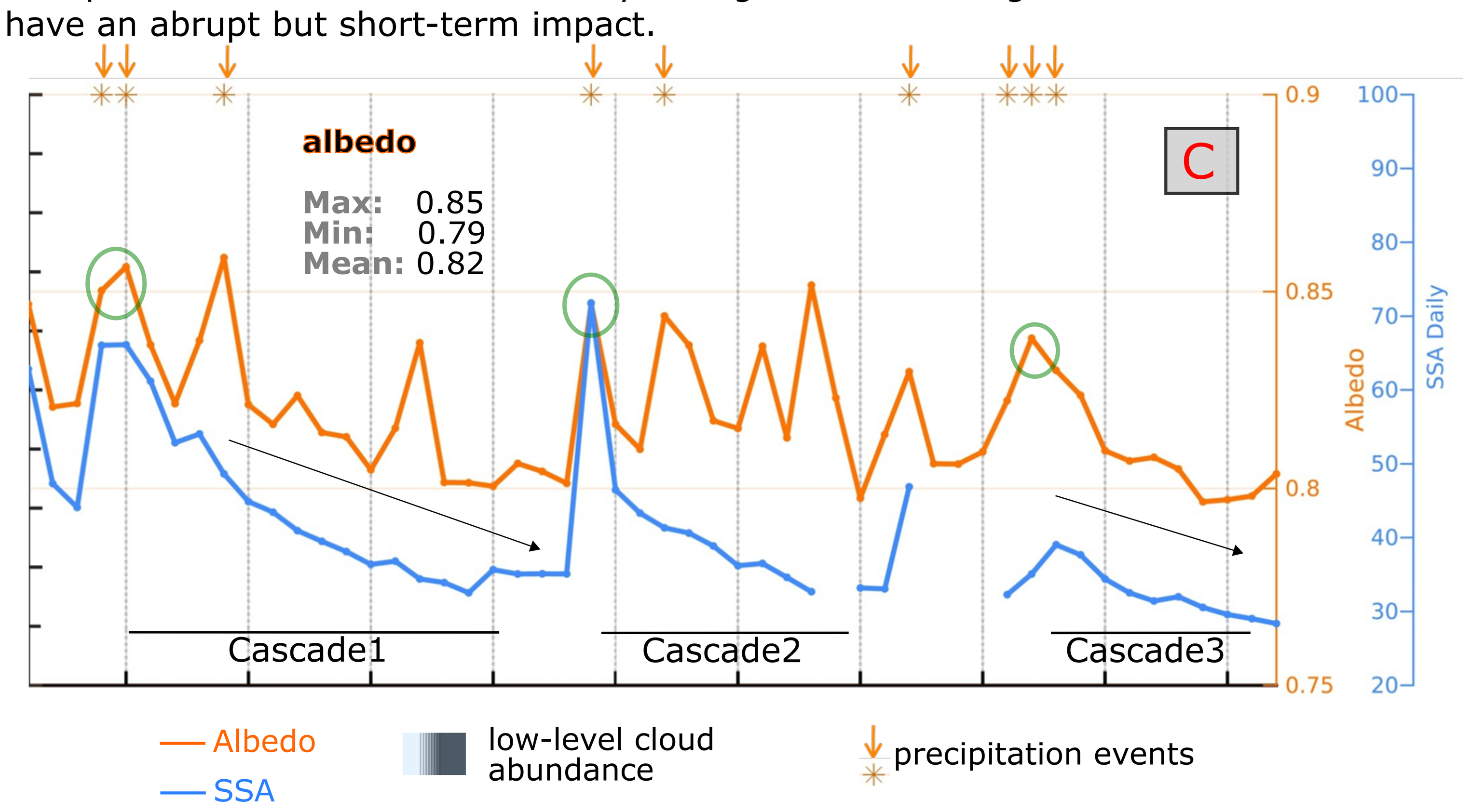
SSA influence on albedo

DOY = Day of Year

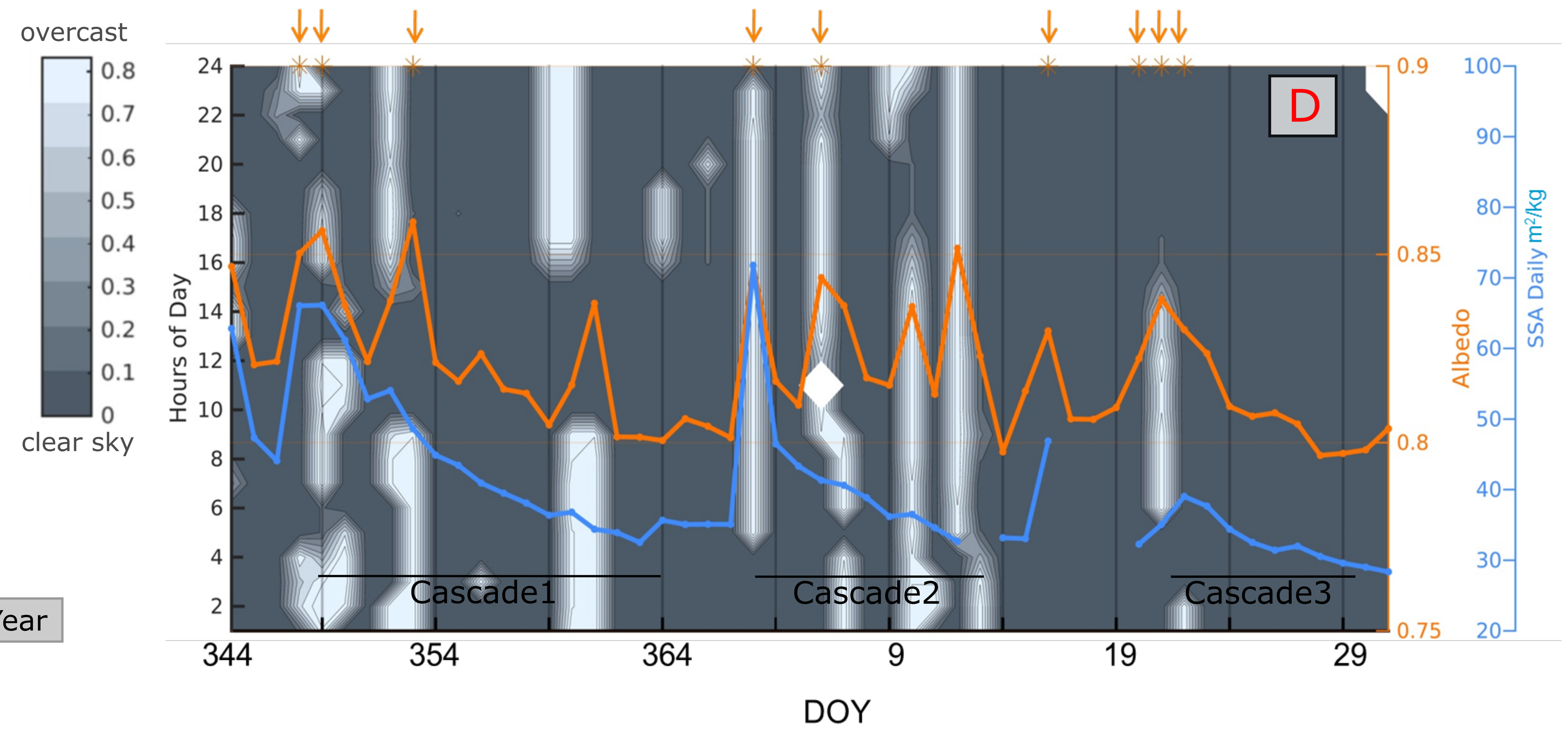
Figure C: > seasonal broadband surface albedo (orange) correlates with SSA (blue).
Observations: Seasonal albedo variations were found to have a cascading shape, which is interrupted by high albedo peaks. The peaks in the SSA plot are clearly mirrored by the albedo (O) as well as the first and third cascade pattern (↘). However, many peaks can be seen in the albedo plot, which do not correlate with the SSA values.

Figure D: > SSA (blue), albedo (orange) and low-level cloud-cover (white area in the background grid) are displayed together.
Observations: Albedo peaks not matching the SSA pattern were found to correlate with low-level cloud-cover. Whenever cloud abundance comes along with precipitation, albedo and SSA are increased. Cloud abundance without precipitation increases only albedo.

Both SSA and clouds have an instantaneous increasing effect on albedo. However, the SSA provoked increase is followed by a long-term cascading decrease whereas clouds have an abrupt but short-term impact.



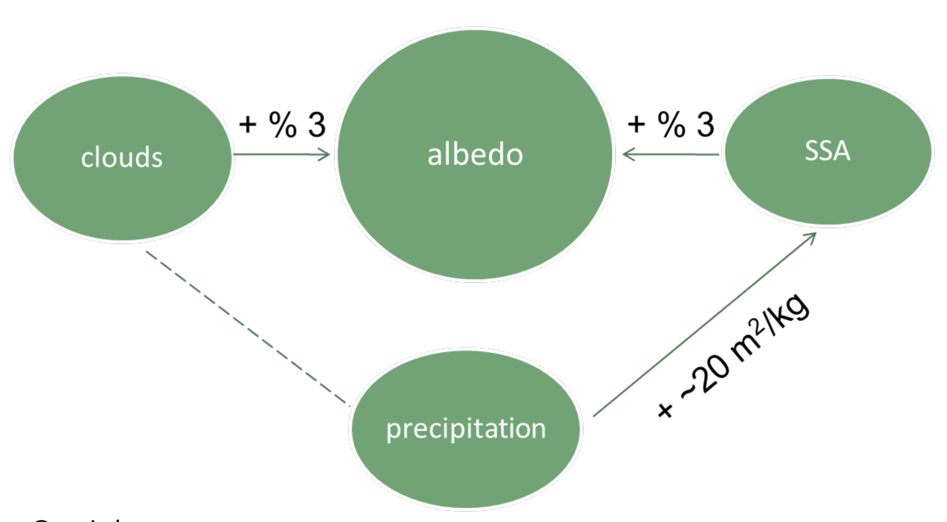
cloud influence on albedo



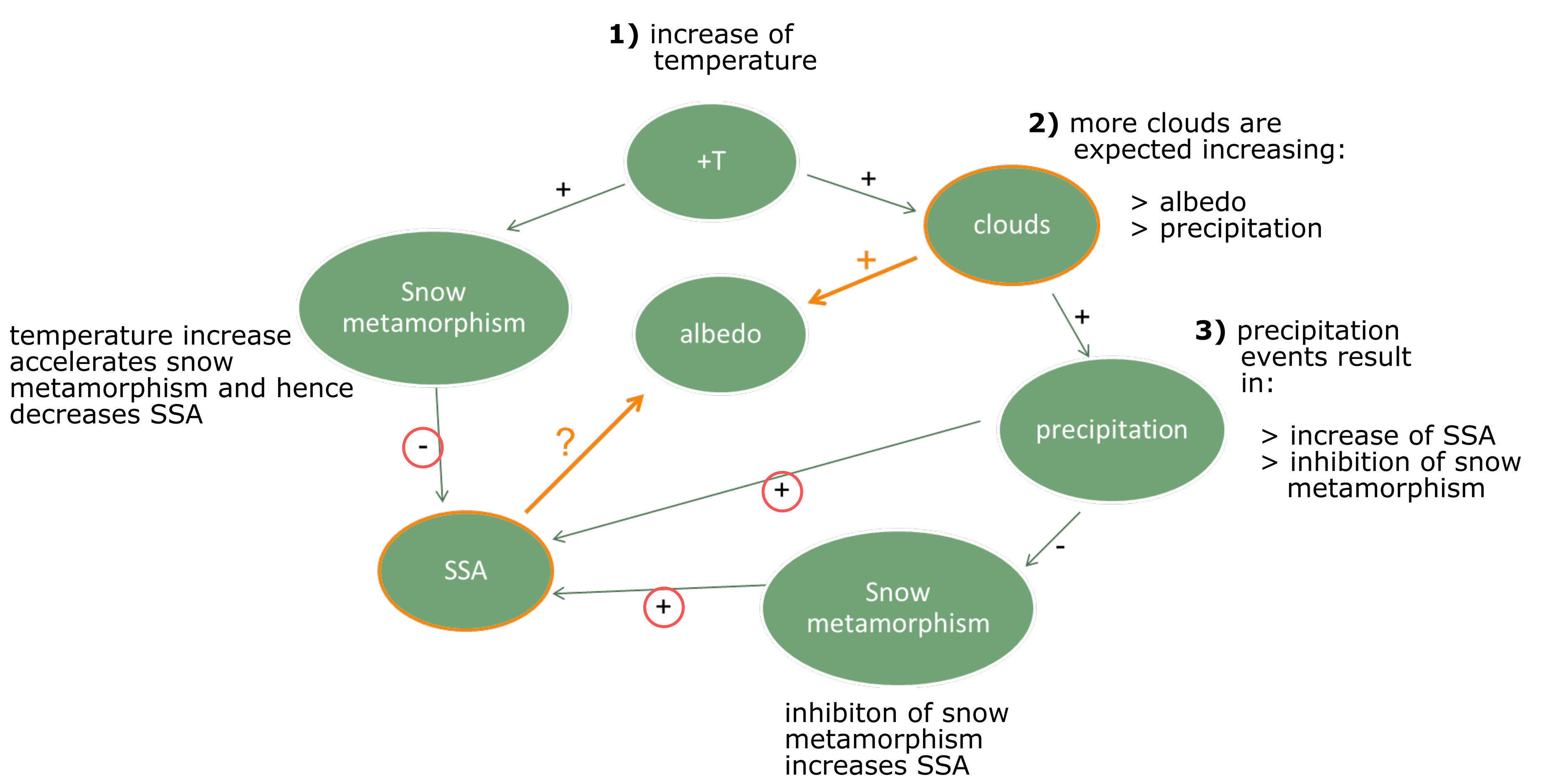
Discussion and Conclusion

Sketch below:
> **cloud** abundance in the lowest cloud layer increases albedo by **3%**
> albedo increase of **3%** is also provoked by **SSA** increase of 18 m^2/kg
> average precipitation induced increase in SSA is 20 m^2/kg

--> Both clouds and SSA have a similar power to modify albedo. However, cloud abundance results in an abrupt, short-term increase whereas changes in SSA provoke a sudden increase, too, but with a long-term cascading decrease, which is a result from metamorphic processes within the snow increasing the grain size. SSA is therefore considered to alter the basic seasonal albedo pattern whereas clouds overprint the seasonal trend only for the periode of their abundance.



Consequences of changing climate



Due to those opposing trends no final conclusion can be drawn about the future developement of SSA, and hence albedo, with increasing temperatures.

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