Airborne and in situ ground-based measurements of surface albedo, bidirectional reflectivity BRDF and snow properties on the Antarctic plateau

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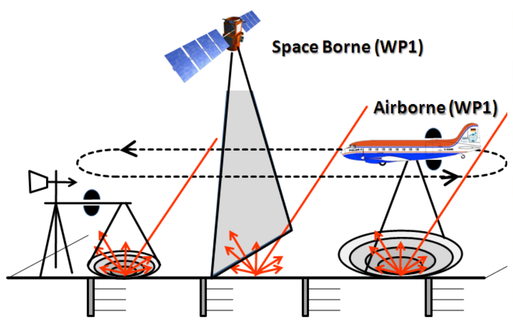
1. Motivation and Objectives



Satellite Data (WP1)	
Surface albedo	Retrieval
Airborne Data (WP1)	
Surface albedo	In situ
Surface BRDF	In situ
Surface roughness	Retrieval
Grain size	Retrieval
Ground Based Data (WP2)	
Surface albedo	In situ
Surface BRDF	In situ
Grain size profile	In situ
Surface roughness	In situ
Meteorology	In situ

Figure 1: *Illustration of measurement strategy*

MEASUREMENTS

Broadband and spectral radiation
Irradiance (↑, ↓), Radiance

+

Atmospheric properties
temperature, humidity, wind, clouds, precipitation, aerosol content

↓

Snow radiative properties
surface albedo, BRDF

RETRIEVAL

Microphysical and macroscopic snow properties
specific surface area SSA (snow grain size), surface roughness

Coupling of...

- **Airborne** measurements of the **spatial variability** of surface albedo, BRDF, SSA and surface roughness
- **Ground-based** measurements of the **temporal variability** of surface albedo, BRDF and SSA

to improve prognostic snow models.

2. Campaign ANT-Land 2013/2014

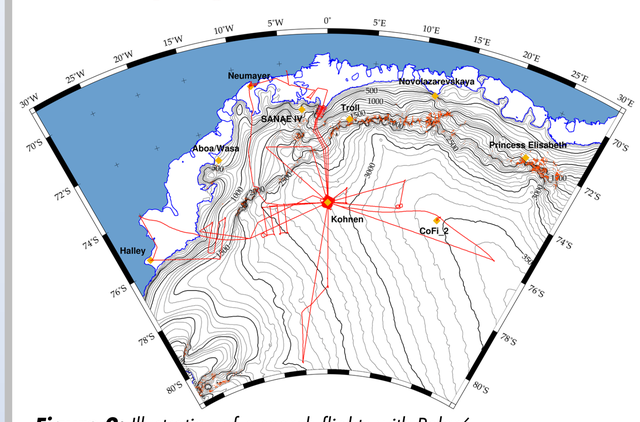


Figure 2: *Illustration of research flights with Polar6, by Daniel Steinhage (AWI)*

Key facts

10/12/2013 – 31/01/2014: Measurements
Kohnen station: 75°00'S, 0°04'E, 2892m a.s.l.
Research flights P6: 16 flights, 60 flight hours

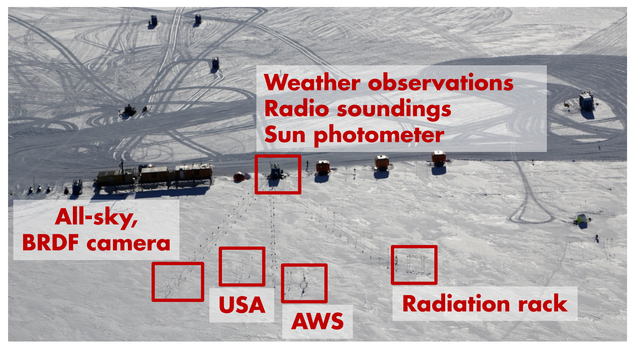


Figure 3: *Instrumentation during ANT-Land 2013/14 at Kohnen station*

3. Impact of surface roughness on HDRF

Measurement cases

SMOOTH case

Flight 25/12/2013
Time: 14:29:03-14:33:39 UTC (~4min30s)
Mean of 25 pictures

Figure 4: *Photograph of smooth surface, taken from P6*

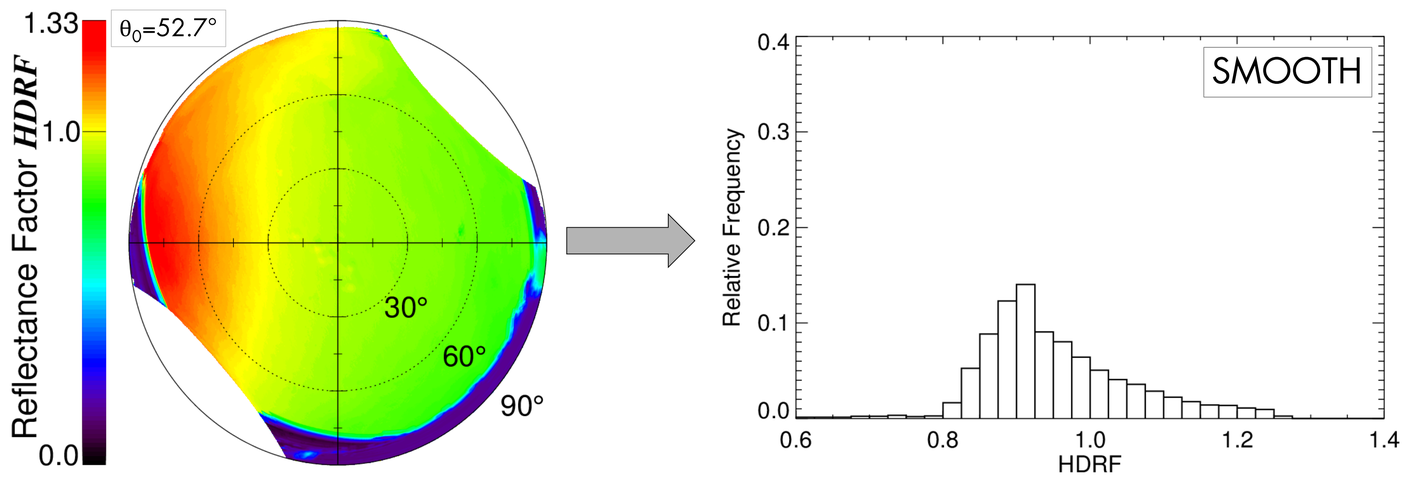


Figure 6: *Mean HDRF over smooth surface - sun is left **(left)** and corresponding histogram of HDRF values **(right)***

Literature case

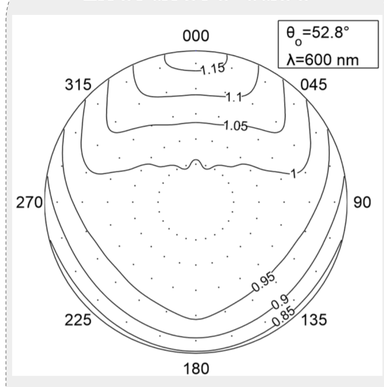


Figure 8: *Polar contour plot of anisotropic reflectance factor of snow at Dome C, θ_0=52.8°, λ=600nm, sun at 0°, from Hudson et al. (2006)*

ROUGH case

Flight 25/12/2013
Time: 13:50:03-13:56:39 UTC (~6min30s)
Mean of 36 pictures

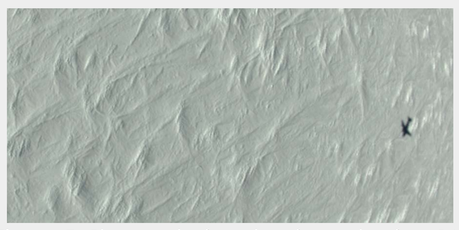


Figure 5: *Photograph of rough surface, taken from P6*

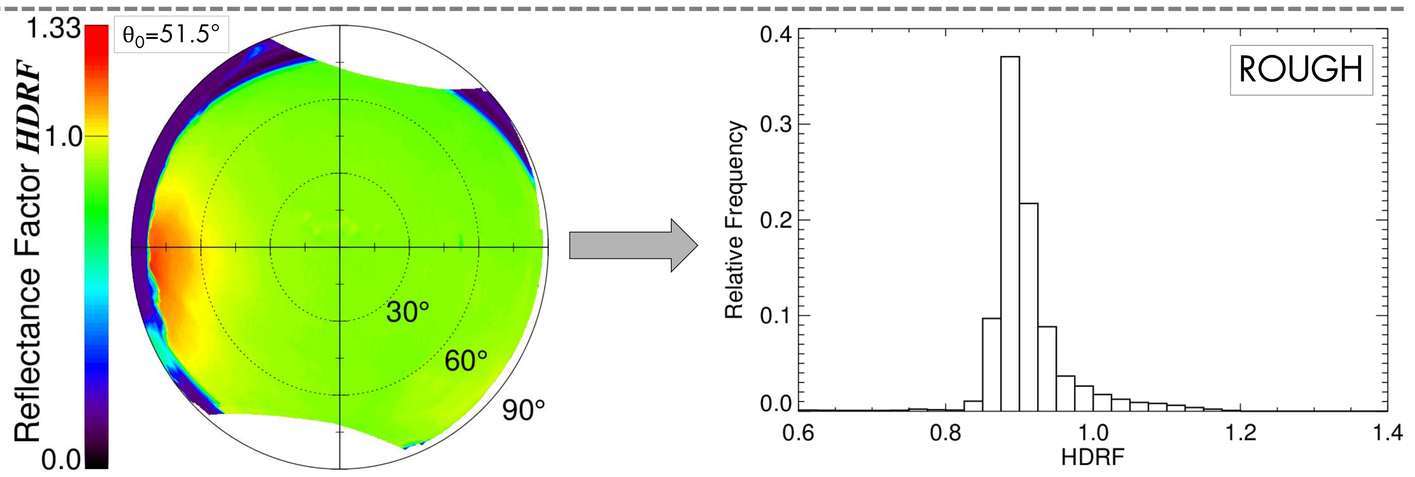


Figure 7: *Mean HDRF over rough surface - sun is left **(left)**, and corresponding histogram of HDRF values **(right)***

Figure 9: *BRDF camera*

4. Impact of specific surface area and clouds on surface albedo

Instrumentation

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

Free surface area

ICE-Cube System
(by A2 Photonic Sensors)

@1310nm

daily, along 100m profile

Figure 10: *Snow sampling for SSA measurement, by Katharina Klein (AWI)*

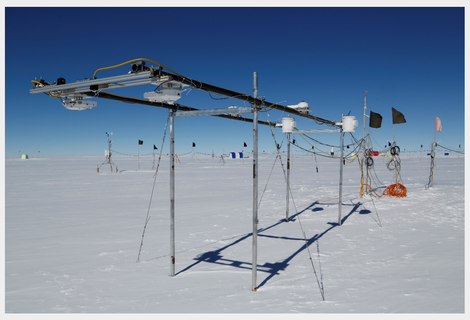


Figure 11: *Radiation rack with broadband radiation sensors*

Broadband radiation

two CM22 pyranometers
(Kipp&Zonen)

spectral range: 300-3600nm

1-min-mean values

albedo uncertainty: ±1.6%

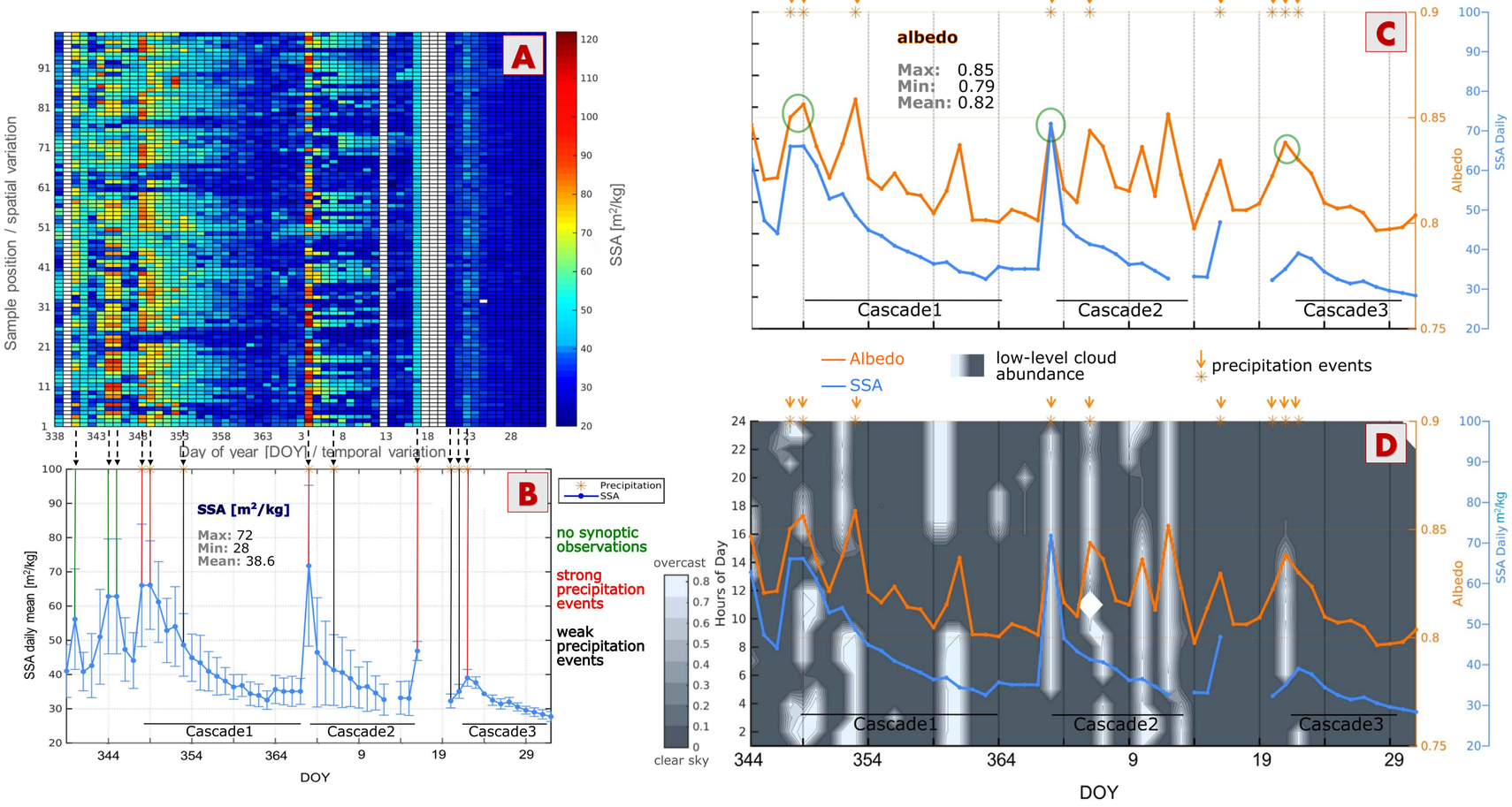


Figure 12: ***Part A:*** *Spatial and temporal grid for measured SSA, each square corresponds to one sample, x-axis: each step = one day, y-axis: 100 samples along 100m profile*
Part B: *Daily mean of SSA values (100 samples);* ***Part C:*** Correlation of seasonal broadband surface albedo (orange) with SSA (blue), peaks in SSA mirrored by albedo (○)
Part D: Cloud influence on broadband albedo (SSA – blue, surface albedo – orange, low-level cloud cover – grey color table)

5. Conclusions

- **surface roughness** has significant effect on HDRF, especially in the forward scattering direction
- **cloud abundance** in the lowest cloud layer increases albedo by 3%
- albedo increase by 3% is also provoked by **SSA increase** of 18m²/kg
- average **precipitation** induced increase in SSA is 20m²/kg

6. Outlook

I. **Retrieval** of snow properties from remote sensing (SSA, surface roughness)
II. **Comparison** with in situ measurements of snow properties
III. **Simulation** and **validation** of temporal variability of snow optical properties by prognostic snow models (SCIATRAN, SNICAR, Crocus)

Reference: S. Hudson, S. Warren, R. Brandt, T. Grenfell, D. Six, Spectral bidirectional reflectance of Antarctic snow: Measurements and parameterization, Journal of Geophysical Research, Vol. 111, 2006

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