Radiation, clouds and precipitation at Princess Elisabeth, Antarctica

A first step to surface mass balance modeling and COSMO-CLM evaluation

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The project website

1. Project overview

AEROCLOUD project:
- Collaboration between KU Leuven / Royal Meteorological Institute (RMI) and Royal Belgian Institute for Space Aeronomy (BIRA)
- What is the role of clouds and aerosols in the East Antarctic climate system?
- What is the relation between aerosols and clouds in East Antarctica?
- Achieve by using the observational framework at the Princess Elisabeth station (Figure 2) and climate modeling
- Maintenance of the observatory

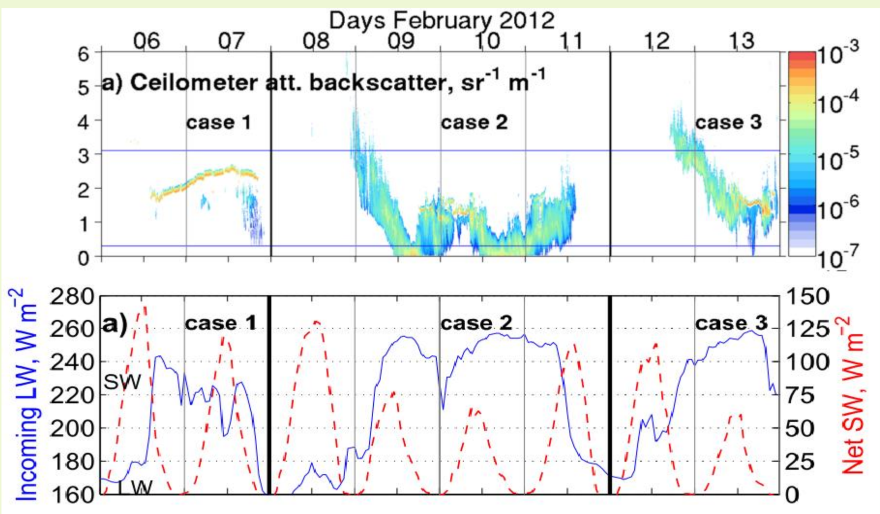

Figure 1: Case study including ceilometer backscatter values (upper panel) and the effect of different cloud types / precipitation on the radiative fluxes (lower panel) (Gorodetskaya et al., 2015)

- Role of KU Leuven: investigate clouds, precipitation and the surface mass balance using observations and COSMO-CLM
- Cloud properties over Princess Elisabeth have been analyzed in Gorodetskaya et al., 2015 using the observational framework (Figure 1)

Focus is shifted now to local surface mass balance modeling and the representation of cloud (radiative) properties in the COSMO-CLM model

2. Instrumentation and data availability

Cloud and precipitation observatory at (the roof of) the Princess Elisabeth station (Figure 2):
- Ceilometer: backscatter profiles to detect cloud bases
- Micro Rain Radar (MRR)
- Pyrometer: cloud base temperatures
- Automatic weather station: basic meteorological variables including temperature, pressure, RH, wind speed, including radiative fluxes
- Webcam

Aerosol observatory including e.g. spectrometers, sunphotometers,…

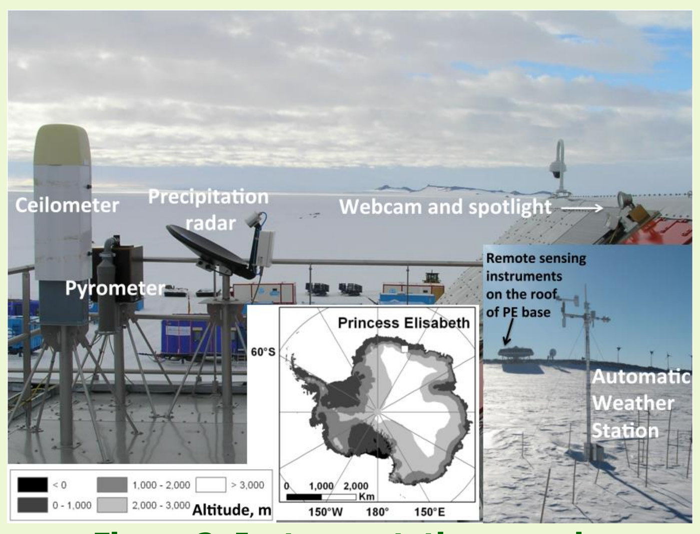

Figure 2: Instrumentation overview

New instrument installed in January 2016: Snowflake Video Imager (Newman et al., 2009; Figure 3):
- High speed camera (380 frames per second)
- Captures snowflakes passing in front of camera and tracks these (if captured at least twice)
- Particle Size Distributions
- Fall Speed Distribution
- Precipitation rates
- High potential in improving MRR precipitation rates and recording snowdrift

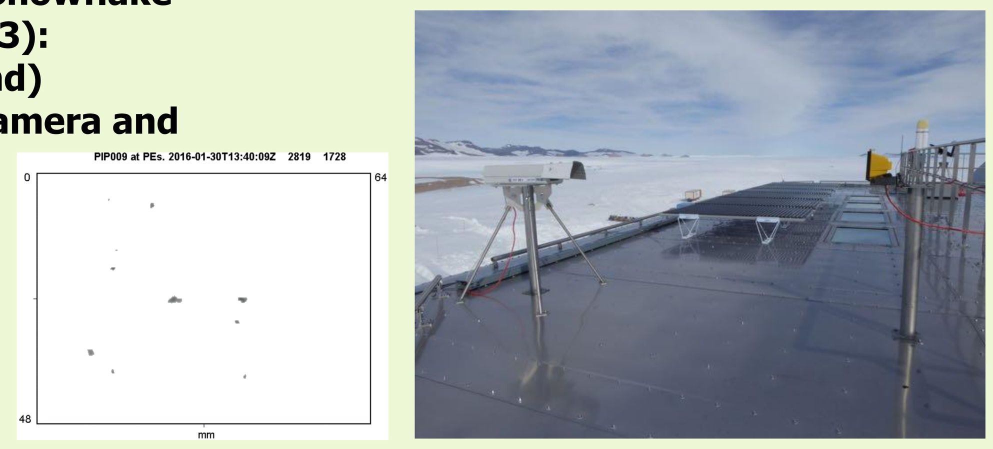

Figure 3: Snowflake Video Imager and a raw video image

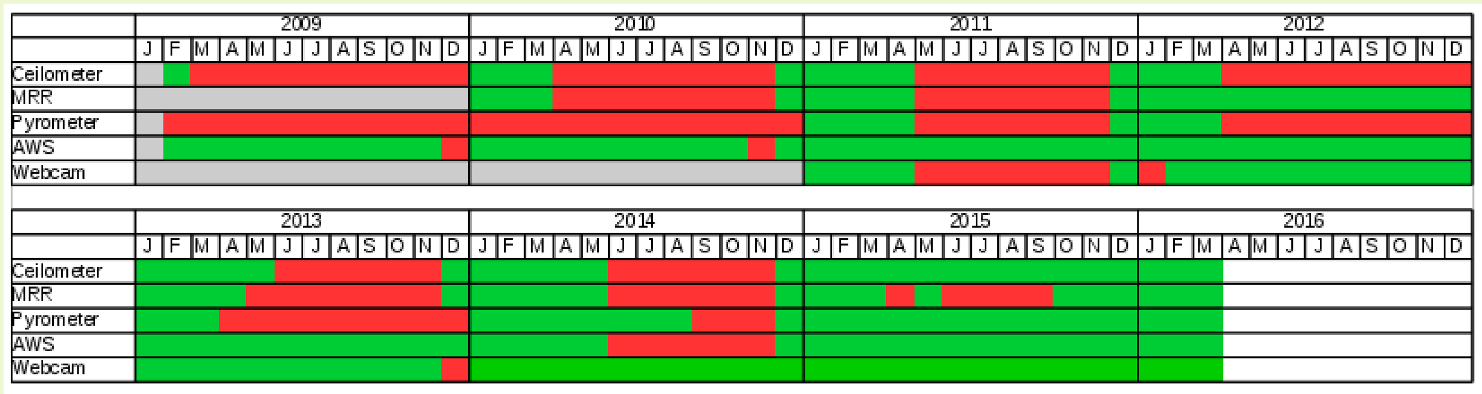

Figure 4: Overview of the months in which data was acquired

3. Surface mass balance

SMB:
- Locally the surface mass balance is represented by the snow height (SH)
- Measured by the AWS
- Converted to water equivalent using local snow density measurements

S (snowfall):
- Radar reflectivity (Ze) measured by the MRR
- Post-processed using Doppler spectra to improve solid precipitation measurements (Maahn and Kollias, 2012)
- Average of 9 Ze-SR is calculated to get an estimate of the snowfall rate

RU (runoff):
- Negligible

SUs (surface sublimation):
- Calculated based on the surface latent heat flux
- Bulk flux profiles of q, u and θ (details in Thiery et al., 2012)
- Data obtained from AWS

SUds (drifting snow sublimation):
- Based on RH, T and wind speeds exceeding a threshold
- Average of three parameterizations (details in Thiery et al., 2012)
- Data obtained from AWS

ERds (erosion / deposition by drifting snow):
- Residual term including uncertainties

$$\mathrm{SMB = S + RU + SU_s + SU_{ds} + ER_{ds}}$$

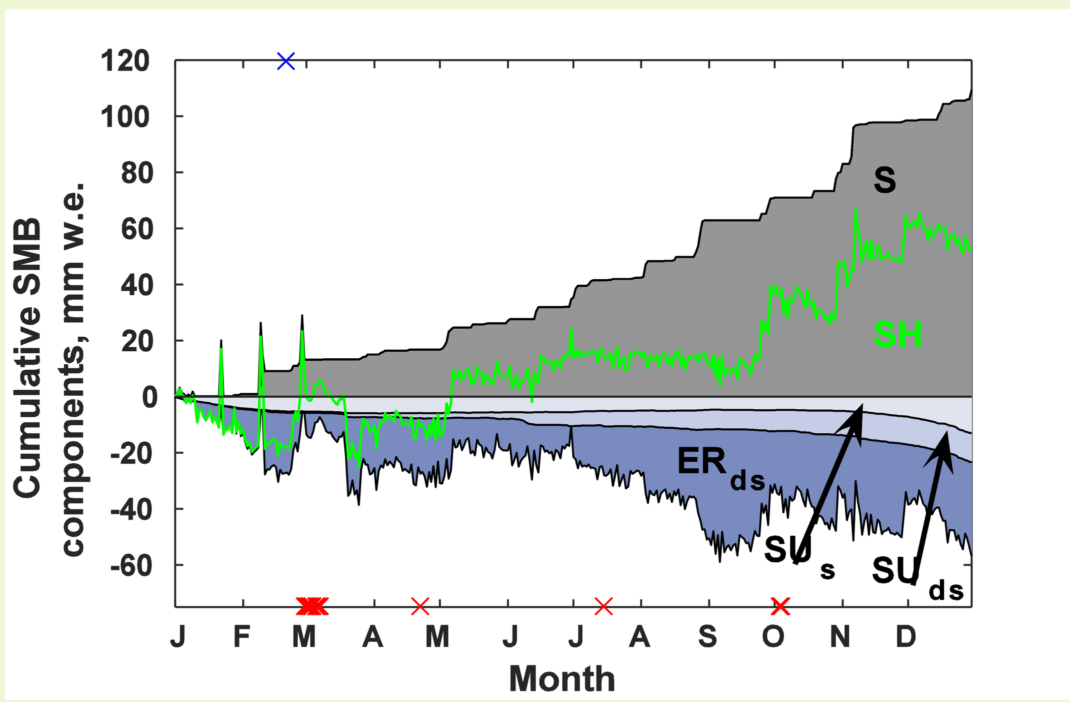

Figure 5: Cumulative daily surface mass balance components during 2012 (explanation of terms see left). Negative values indicate ablation, while positive values denote accumulation. Red crosses at the bottom indicate days of missing MRR data, while blue crosses at the top denote days of missing AWS data. Letters on the x axis mark the first day of each month.

Several improvements / clarifications are possible:
- Snow rate is calculated arbitrarily, but there is a high potential in improving Ze-SR relations by using Snowflake Video Imager results (Figure 6)
- Precipitation (MRR) does not always imply accumulation (what is the role of erosion?)
- Compaction is not taken into account
- Scale of the precipitation system might play a role

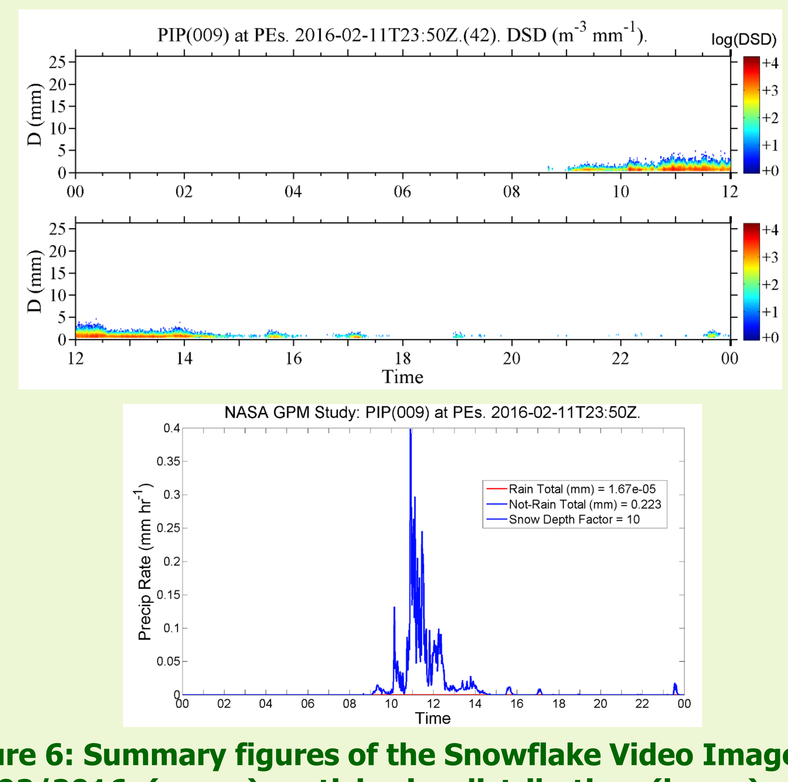

Figure 6: Summary figures of the Snowflake Video Imager for 11/02/2016. (upper) particle size distribution, (lower) snowfall rate.

4. Radiation, cloud and precipitation statistics

Goal: improve cloud (radiative) properties over Antarctica in climate models i.e. COSMO-CLM

Long-term records facilitate the evaluation and improvement of the COSMO-CLM model:
- Basic meteorological variables available for 7 years: radiation, pressure, temperature, wind speed, humidity (Figure 7)
- Cloud occurrence / properties and its effect on the radiative balance (Figure 8)
- Precipitation numbers (data gaps!) (Figure 9)

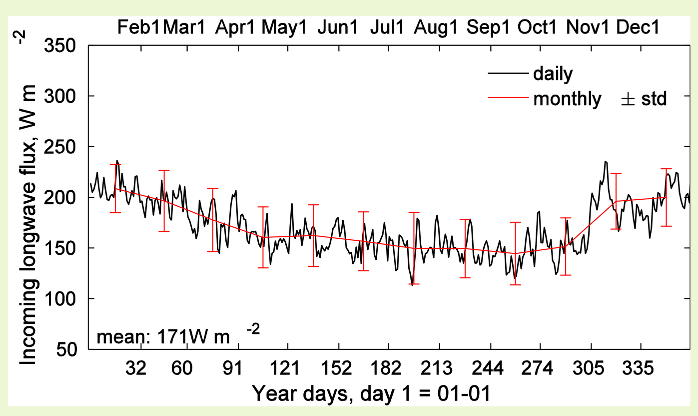

Figure 7: Daily and monthly incoming longwave radiation averaged for the period 2009-2016

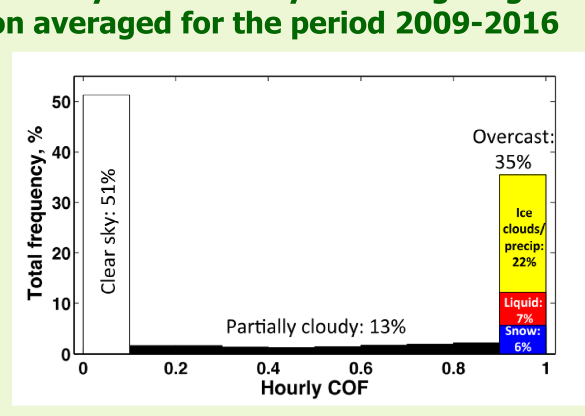

Figure 8: Hourly mean cloud frequency for 2010-2013 (Gorodetskaya et al., 2015)

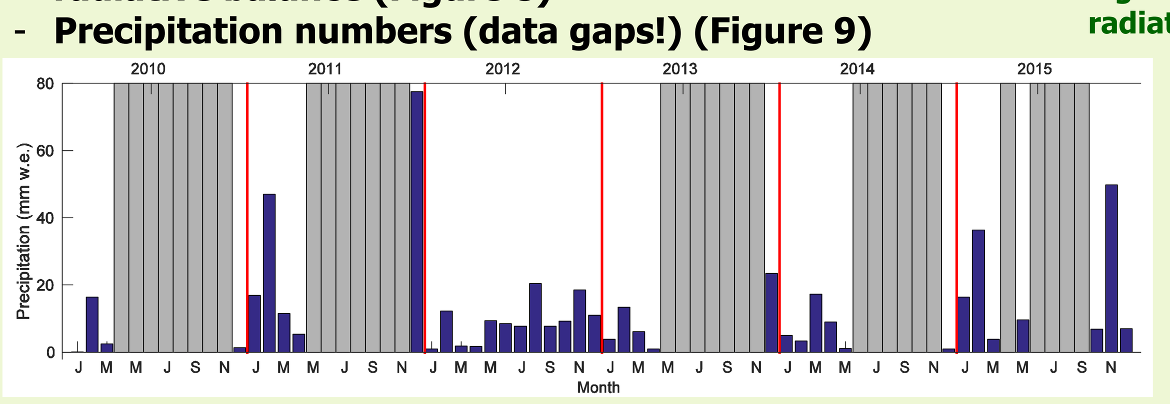

Figure 9: Total precipitation amounts per month measured by the MRR. Grey bars denote missing months.

5. Conclusions and future work

- A large observational framework studying clouds, precipitation and aerosols is set up at Princess Elisabeth station in Antarctica in 2009.
- There is a strong need to keep all instruments up and running in order to get reliable estimates of e.g. the surface mass balance.
- First surface mass balance integrations give promising results, however a lot of improvements are possible and need to be implemented.
- The Snowflake Video Imager has a high potential contributing to this.
- Climate statistics calculated from various instruments have the potential to evaluate the COSMO-CLM climate model and improve the representation of clouds and cloud radiative properties.

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