Balloon-borne measurements of heating and cooling rates in Arctic stratocumulus

A02

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1 Introduction

Motivation:

- Stratocumulus strongly influences the surface energy budget and can lead to surface warming or cooling depending on the cloud and atmosphere properties
- Evaporative and radiative cooling at the top of stratocumulus control the cloud dynamics

Main goal:

Quantifying vertical profiles of turbulent fluxes (Poster by Ulrike Egerer (#4)) and radiative fluxes in the cloudy ABL for different stratification and cloud types in the central Arctic

Research questions:

How do the different energy fluxes influence the cloud evolution and the Arctic boundary layer?

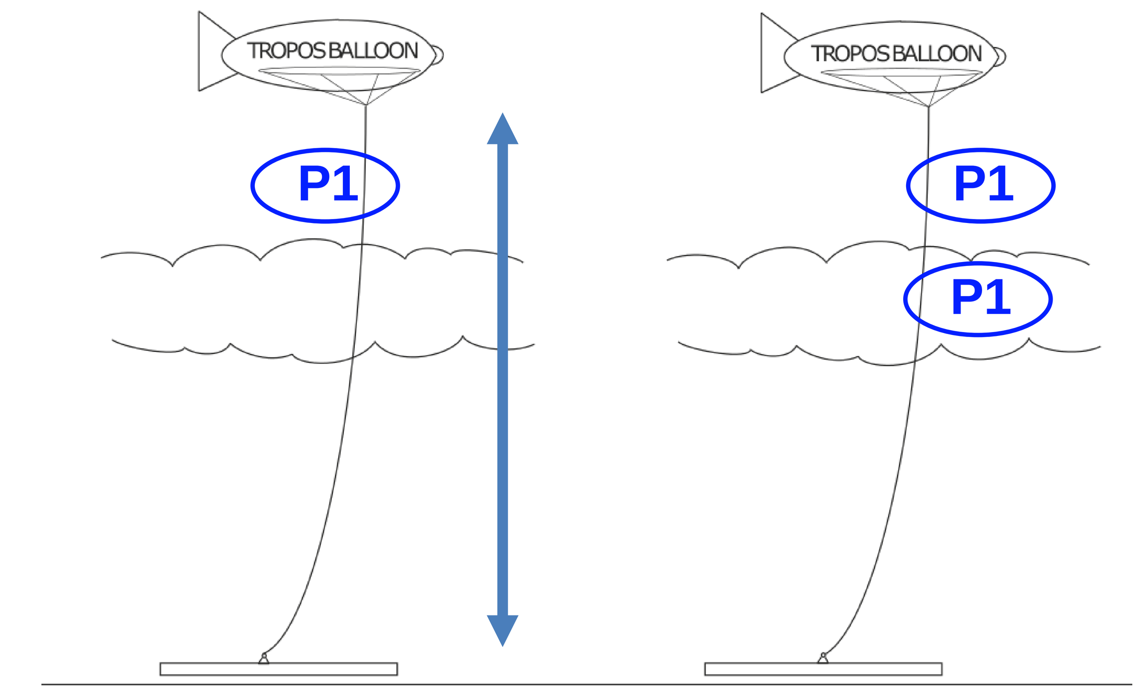
2 Measurement strategy

Calculate heating rate:

$$\frac{\partial T}{\partial t} = \frac{1}{c_p \rho} \frac{\partial F_{net}}{\partial z}$$

discretisation: heating rate $\left(\frac{\partial T}{\partial z}\right)$ calculated for a layer

$$\frac{\Delta T}{\Delta t} = \frac{(F^{\downarrow}_{top} + F^{\uparrow}_{bot}) - (F^{\uparrow}_{top} + F^{\downarrow}_{bot})}{c_p\ \rho\ (z_{top} - z_{bot})}$$



A: Single platform approach → profiles

B: Collocated approach → temporal variability

Fig 1: Measurement strategies for the balloon deployed during ABEX-PASCAL

- Balloon = slow moving platform with vertical speed of ca. 1 m s^{-1}
- 2 different measurement approaches
- Deployed from sea ice during ABEX-PASCAL May/June 2017

→ J. Stapf, poster #7

3 Instrument setup

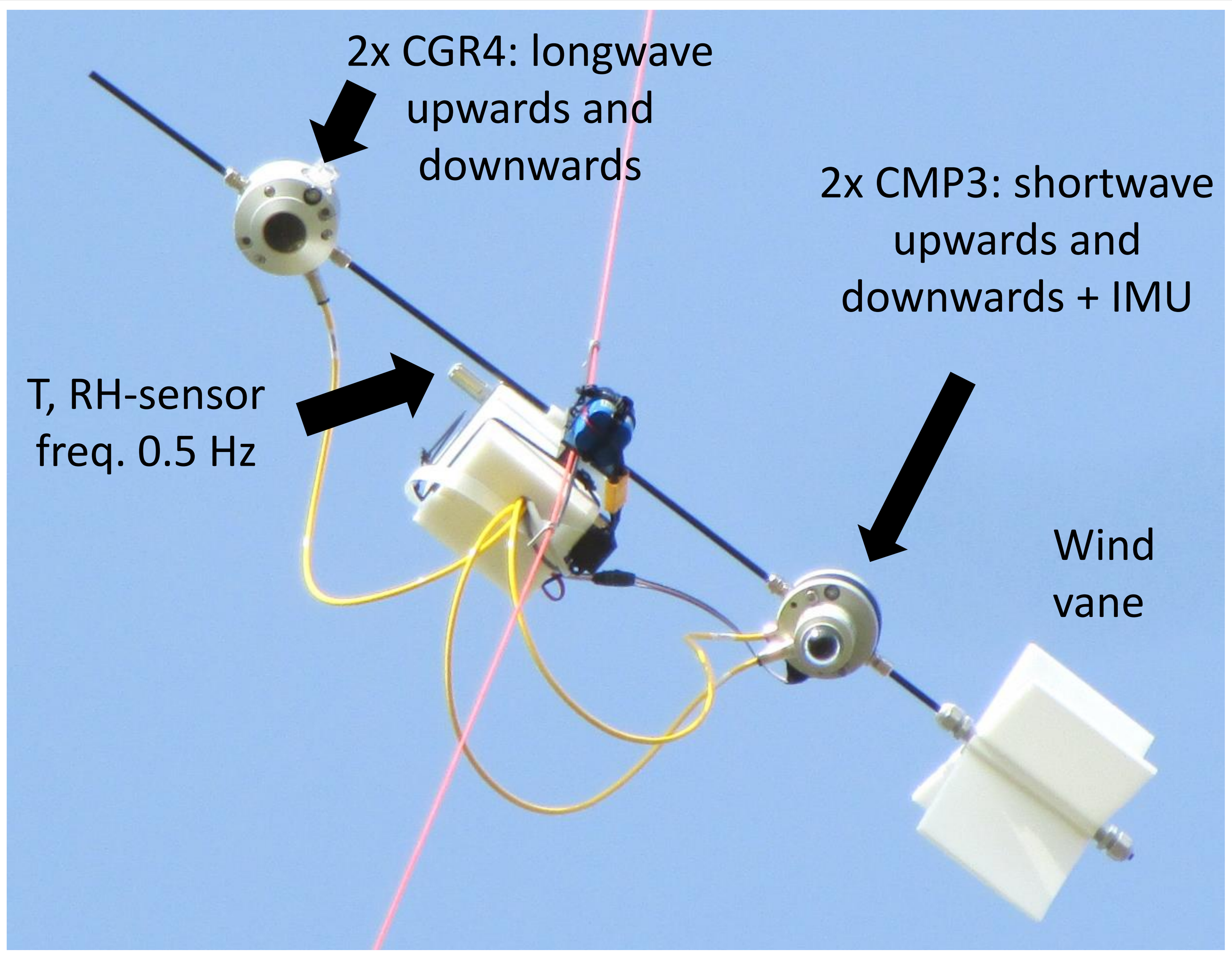
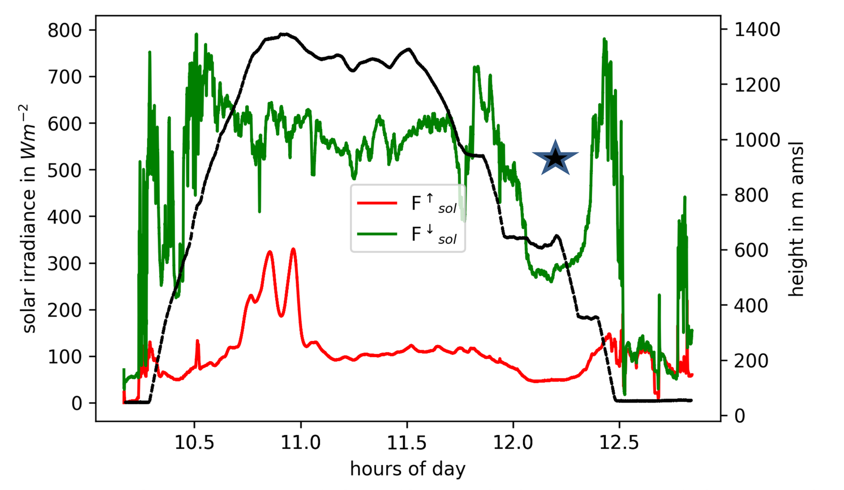


Fig 2: Broadband balloon probe attached to the tether of the balloon

- Pyranometer (CMP3) + pyrgeometer (CGR4) at 25 Hz
- Improved pyrgeometer housing to reduce thermal effects and weight
- Rasberry Pi 3 as data acquisition system: light weight and easy hardware access
- battery time up to 4 hours
- Additional sensors:
  - Temperature and humidity
  - Tilt, heading, pressure
  - 3D GPS position
  - Camera for the detection of icing

4 First field experiments



★ incoming altocumulus

Fig 3: Solar upward (red) and downward (green) irradiance on 09.03.17 including height profile (black)

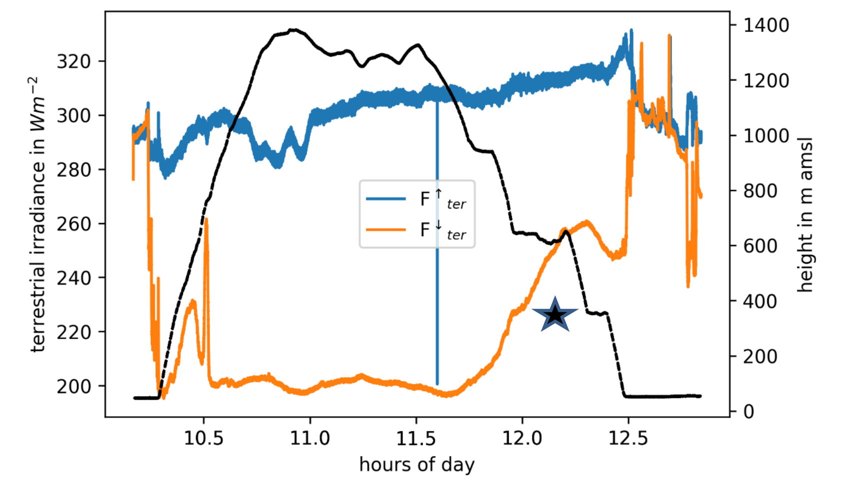


Fig 4: Terrestrial upward (blue) and downward (orange) irradiance on 09.03.17 including height profile (black)

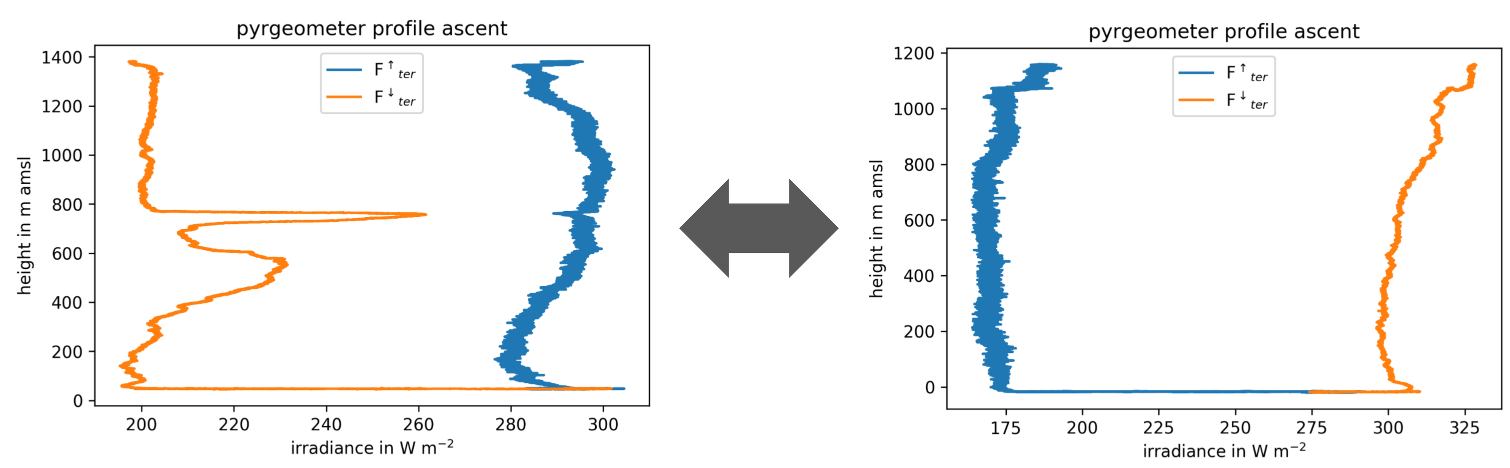


Fig 5: Comparison of profiles of terrestrial upward (blue) and downward (orange) irradiance during ascent with low level clouds on 09.03.2017 (left) and without low level clouds on 13.03.2017 (right)

Determine heating rates

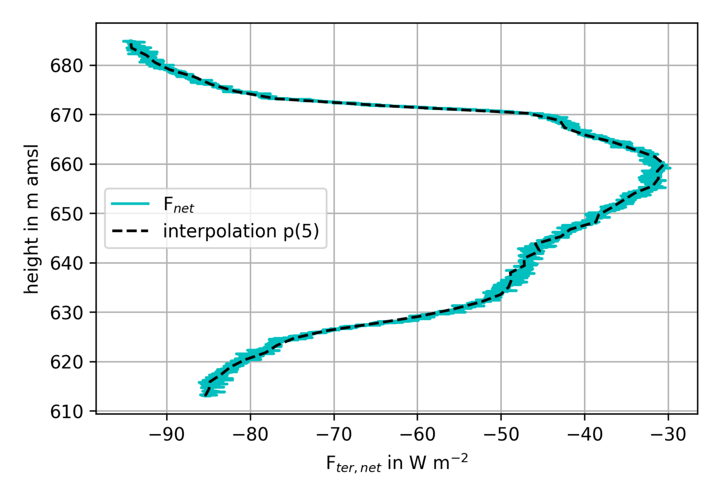


Fig 6: Net terrestrial flux (cyan) from 09.03.2017 and 5th order polynomial fit (black dashed)

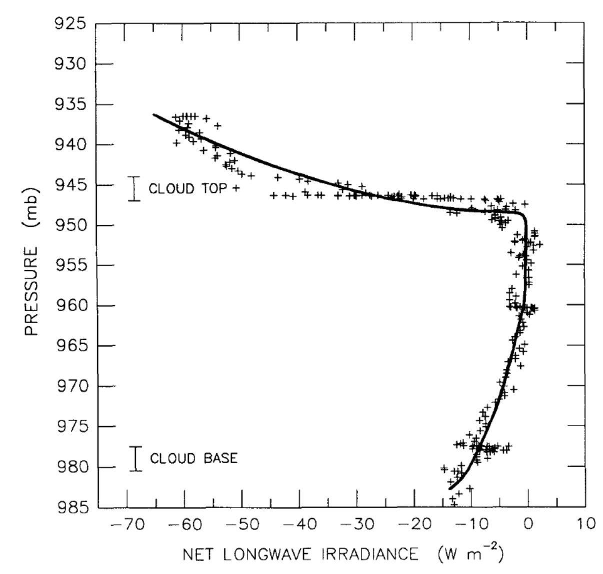


Fig 7: Profile of net longwave radiative flux measured on 07.07.1987. The solid line represents the least squares fit. (from [1])

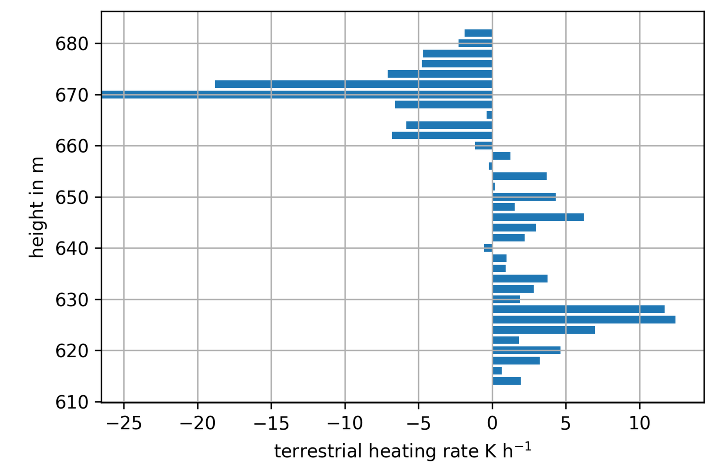


Fig 8: Heating rates determined from the interpolation of fig 6.

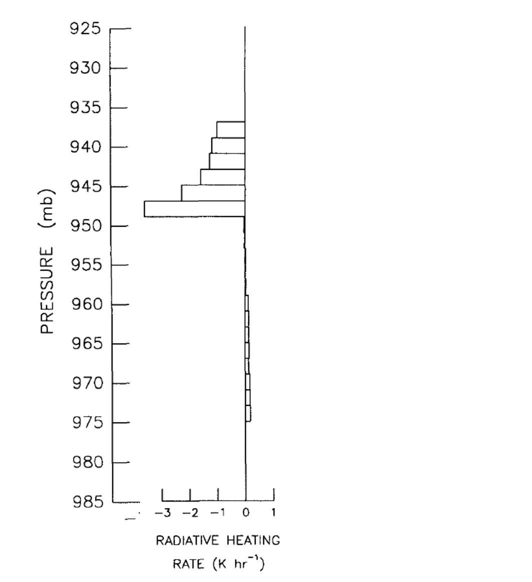


Fig 9: Heating rates determined from the solid line in fig 7 (from [1])

5 Summary and Outlook

Summary:

- Development of light weight balloon payload measuring the full radiative energy budget
- First test measurements in Arctic like conditions show reasonable results for cloud top cooling rate

Outlook:

- Test of collocated approach
- Measurements within ABEX-PASCAL
- Uncertainty assessment and calibration
- Development of spectral payload

References

[1] Duda, D. P., Stephens, G. L., Cox, S. K., Microphysical and Radiative Properties of Marine Stratocumulus from Tethered Balloon Measurements, *Journal of Applied Meteorology*, **30**, 170-186 (1991)

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