# Tethered balloon-borne energy budget measurements in the cloudy central Arctic

A02

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## 1. Summary

Research questions:

**Q1** How does the **local thermodynamic environment**, as compared to remote processes influence Arctic ABL processes?

**Q2** Are the locally observed **aerosol particle concentrations** sufficient to notably modify the microphysical properties and radiative effects of Arctic ABL clouds?

**Q3** How do **cloud microphysical, radiative, and turbulent processes** interact during the life time of mixed-phase clouds in the central Arctic?

## Hypothesis (Phase II)

**The Arctic cloudy atmospheric boundary layer and its effects on Arctic amplification are mainly influenced by local processes; remote forcings (advection) are of minor importance.**

## 2. Achievements in phase I

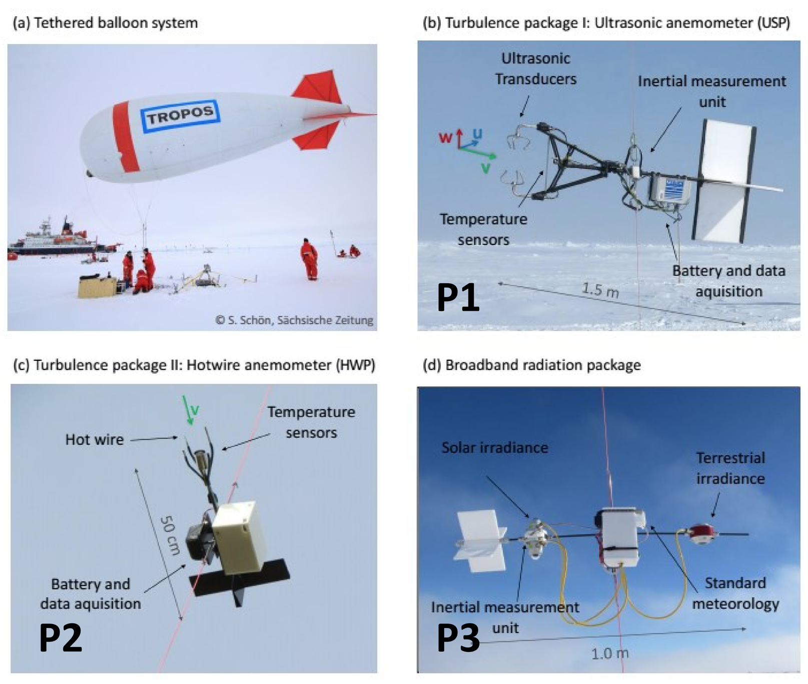
Development of the BELUGA setup:
Balloon-bornE moduLar Utility for profilinG the lower Atmosphere

Instrumental payload for tethered balloon observations in harsh Arctic conditions (*Fig. 1*):

**P1**: 3D-ultrasonic anemometer/thermometer & highly accurate attitude measurements

**P2**: Light-weight 1D-hotwire probe & Pitot-static probe

**P3**: Broadband radiometers (upward and downward-looking pairs of solar pyranometer and terrestrial pyrgeometer)




Technical data

- **Balloon**: 90 $m^3$ filled with helium
- **Payload**: 8—10 kg, revised for phase II may carry up to 20 kg
- **Operation**: Light icing conditions possible
- **Ceiling**: 1500 m
- **Maximum wind speed**: 15 m $s^{-1}$

*Fig. 1: BELUGA: (a) Tethered balloon during the PASCAL cruise, (b) ultrasonic probe, (c) hot-wire probe, (d) broadband radiometer probe (Egerer et al., AMT, 2019).*

Profile measurements of turbulence and radiation during PASCAL

Successful BELUGA operation during 10 days of ice floe camp during PASCAL with frequent soundings under different cloudy/cloudless conditions:

- Measurements of **profiles** of thermodynamic, turbulence, and radiation properties
- Detection of layers with **increased specific humidity** above cloud layers (*Fig. 2*)
- Demonstration of **linkages** between cloud-top cooling and turbulence inside clouds
- Verification of reduced turbulence and cloud top cooling in lower cloud in case of **multiple cloud layer** situations (*Fig. 3*)

**Shallow layers of high humidity just above clouds support cloud persistence**

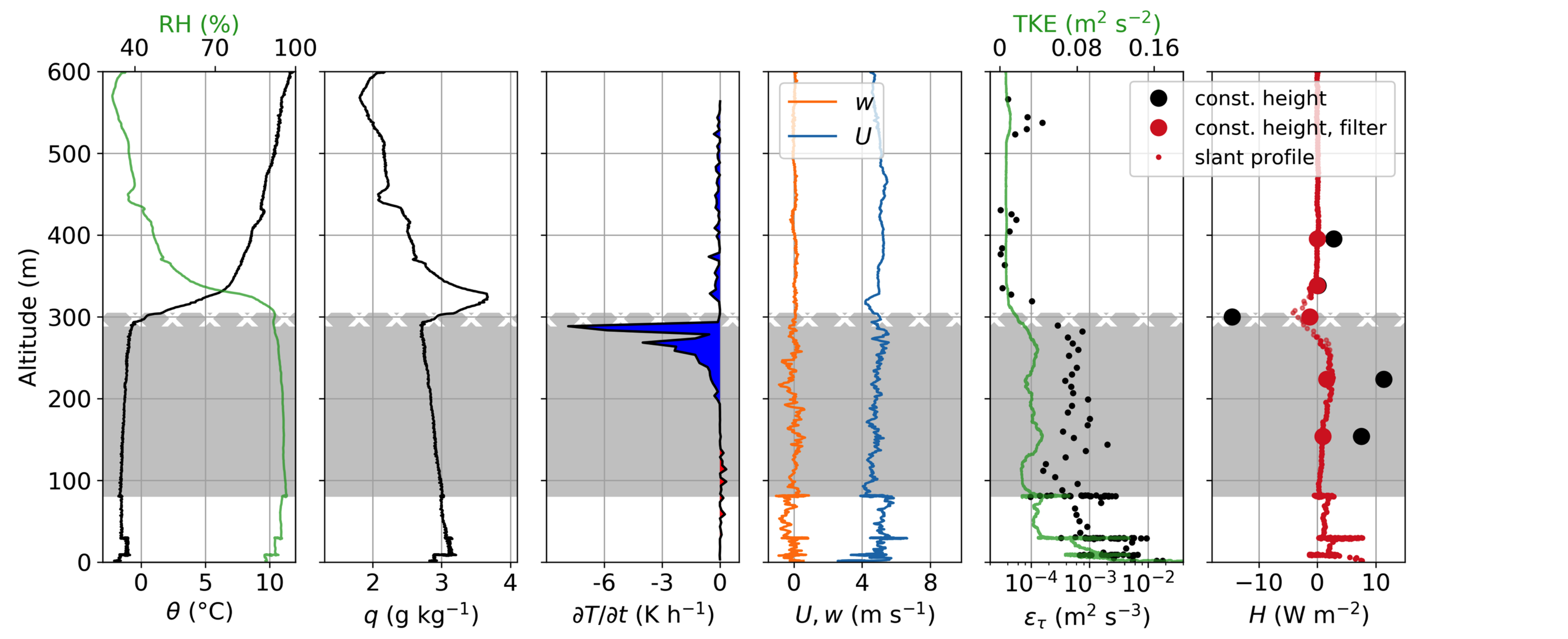



*Fig. 2: Vertical profiles of potential temperature $\Theta$ and relative humidity RH, specific humidity q, terrestrial heating rate $\delta T/\delta t$, horizontal wind velocity U and vertical wind velocity w, local dissipation rate $\varepsilon_T$, virtual sensible heat flux H measured on June 6th, 2017 (Egerer et al., ACP, 2019, to be submitted).*

**Reduced cloud-top cooling and heat flux in multi-layer clouds**

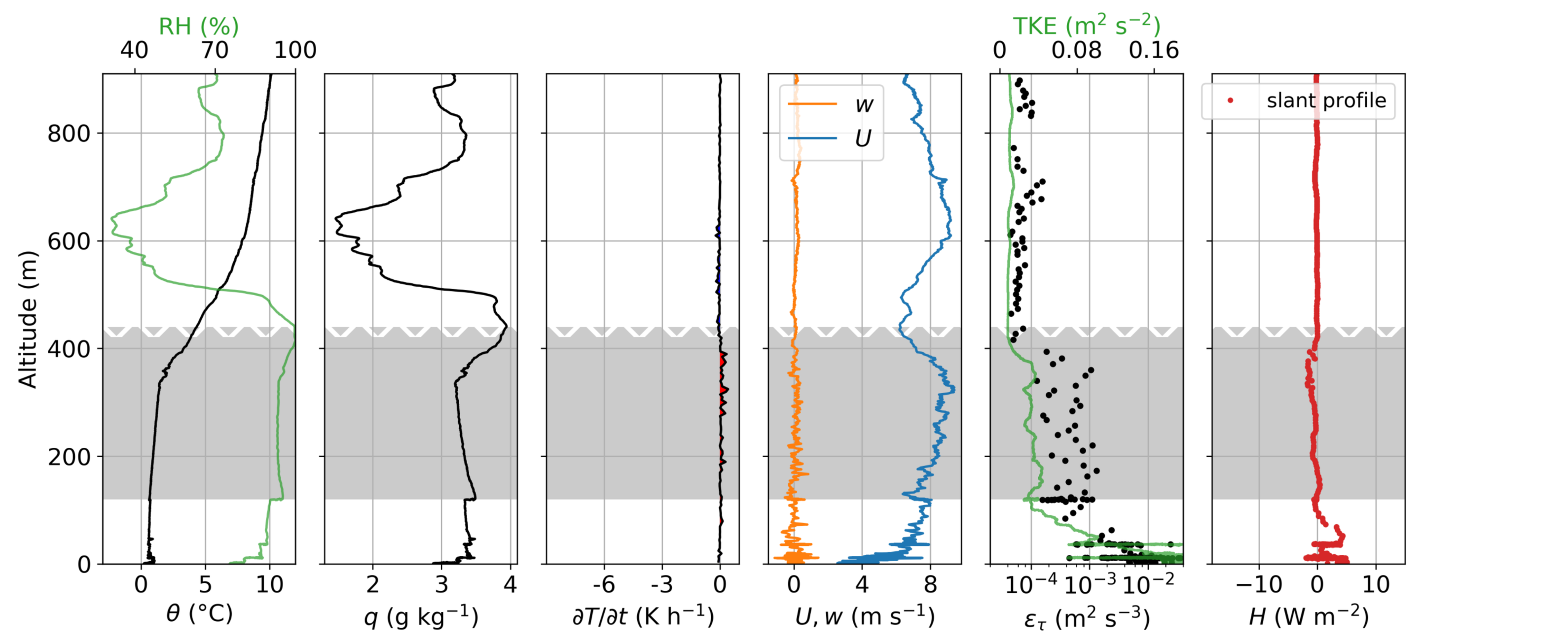



*Fig. 3: Same variables as for Fig. 2 but measured on June 14th, 2017 (adapted from Egerer et al., AMT, 2019). A second cloud layer has been observed above 1000 m (not shown here).*

## 3. Research plan for phase II

Application of BELUGA during MOSAiC (leg 4, Apr—Jun 2020)

- Compilation of **statistics** of stratification & turbulent flux profiles under different cloud conditions for the inner Arctic
- **Comparison** of BELUGA observations with remote sensing results
- Investigation of aerosol, cloud, radiation **interactions**
- Evaluation of the role of moisture advection & humidity inversions for **cloud development** & lifetime

Further development of BELUGA instrumentation for phase II

*Fig. 4: Photo of aerosol cube.*

- Improved **humidity** sensor
- **Aerosol cube** (*Fig. 4*):
  - Two particle counters
  - Absorption photometer
  - Aerosol spectrometer
- Video **Ice Particle Sampler** VIPS (*Fig. 5*):
  - Particle shape and sizes
  - Estimate of size distribution
- **Cloud** sensor (miniOFS)

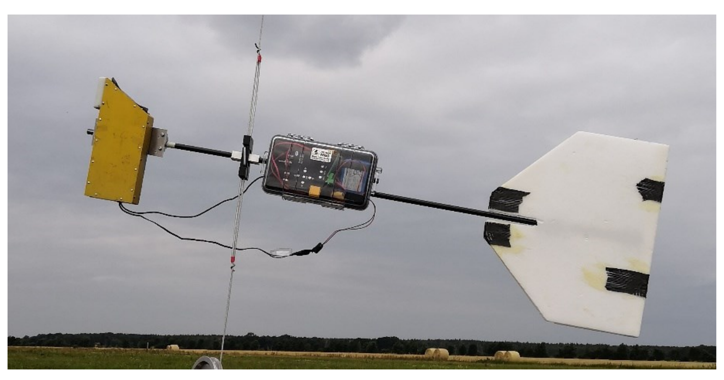


*Fig. 5: Photo of VIPS.*

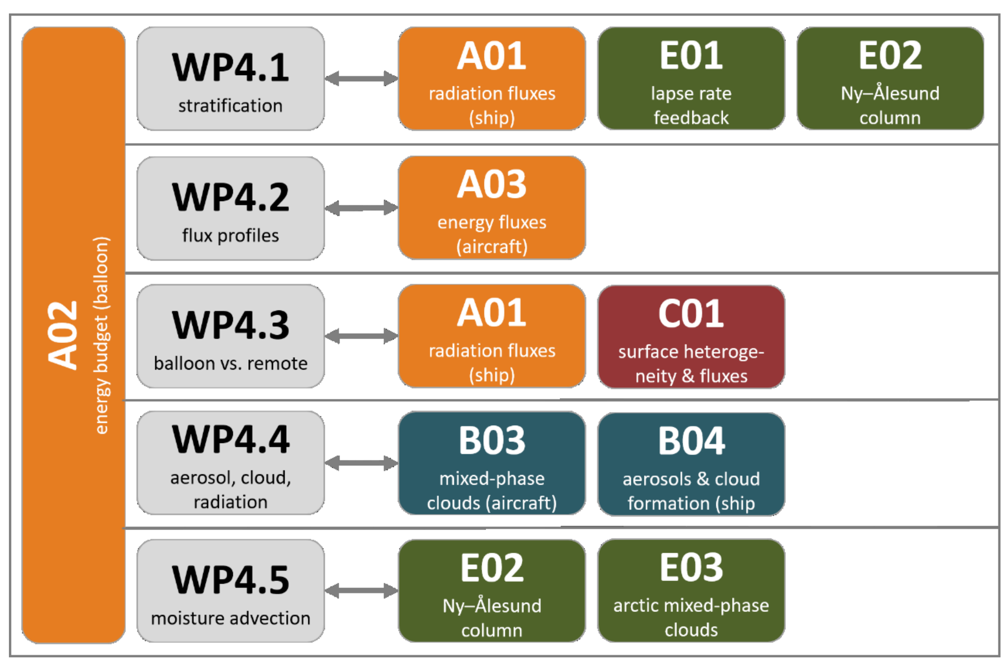
## 4. Role within (AC)³ & perspectives

Perspectives

- **Long-term deployment** of BELUGA in Ny-Ålesund or Villum Research Station
- Measurements in **different seasons** to establish robust statistics

Collaborations within (AC)³

- Within Cluster A:
  - A01, A03: Radiative transfer simulations, LES
  - A03: Comparison turbulence obs.
- With projects in other cluster:
  - B03: Aircraft measurements
  - B04: Aerosol data
  - C01: Surface properties
- Links with crosscutting activities:
  - CCA1: Lapse rate feedback
  - CCA2: Surface processes

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