Instrumentation and data processing: StratoClim 2016 balloon campaign

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1 StratoClim Balloon Campaign

In the scope of the StratoClim project, a Balloon Sounding Campaign will take place in Nainital (29.4°N), southern slopes of the Tibetan Plateau and in Nagpur (21.15°N), central India during the Asian Summer Monsoon of 2016, in collaboration with the Indian Institute of Tropical Meteorology (IITM). The campaign will be coordinated with other balloon sounding campaigns in the region (Arabic Peninsula with Jean-Paul Vernier and North of Tibetan Plateau, China with Jianchun Bian) using similar payloads during the same period and with the Geophysica aircraft campaign.

The main goal of StratoClim Balloon campaign is to collect ozone, water vapor and particle backscatter atmospheric profiles with high vertical resolution up to 30 km altitude (UT-LS). The night-time payload will include ECC O_3 cells, CFH for H_2O and COBALD for distinguishing H_2O inside and outside clouds and aerosol layers. The radiosonde will be RS41 from Vaisala. The day-time payloads will include RS41, RS92 and CFH for H_2O measurement comparison. All data will be collected within GRUAN philosophy. 25 night-time payloads and 10 day-time payloads will be launched from the two locations (between 18 July and 18 August).

A short overview is given of CFH and COBALD operating principles and data post-processing. As well as a sneak peek of the development of a new frost point hygrometer instrument.

2 StratoClim balloon payload

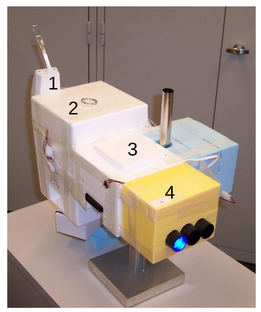


Fig. 1. Night-time payload

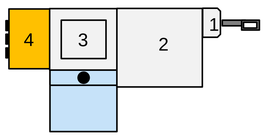


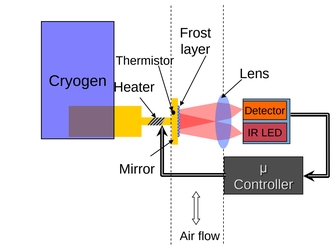
Fig. 2. Night-time payload schematics – top view

Legend:
1. **RS41**
2. **ECC O_3 cell**
3. **CFH**
4. **COBALD**

The recent Vaisala RS41 radiosonde was chosen to host the payload because it supports the "xdata"-protocol for add-on sensors, and data is post-processed according to GRUAN guidelines.

Technical partners: mylab elektronik GmbH, VAISALA

3 Cryogenic Frostpoint Hygrometer (CFH)



The CFH is a small balloon borne instrument, which measures water vapor from the surface to the middle stratosphere. It is based on the chilled mirror principle and regulates the temperature of a mirror such that the bulk reflectivity of the frost covered mirror remains constant. The dashed lines indicate the vertical inlet tubes. Only the lens and the mirror are exposed to the airflow inside the tube.

Reference: Vömel et al (2007): J. Geophys. Res., 112, D08305, doi:10.1029/2006JD007224.

CFH performance characteristics:

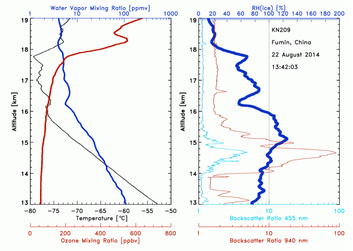
Frostpoint stability	0.2 K (typ.)
Mirror temperature uncertainty	< 0.1 K
Mixing ratio uncertainty troposphere	1.5 % (typ.)
Mixing ratio uncertainty stratosphere	4 % (typ.)
Vertical resolution (troposphere)	< 10 – 25 m
Vertical resolution (stratosphere)	< 100 – 200 m

The performance of the CFH is limited by the ability of the controller to maintain a constant frost layer on the mirror. Recent advances have led to significant improvements shown above.

Contamination after going through wet clouds is the most important limitation for CFH water vapor in the stratosphere and needs to be carefully considered in balloon operations.

Data transmission through Xdata protocol, using either Intermet Imet1 or Vaisala RS41 radiosonde.

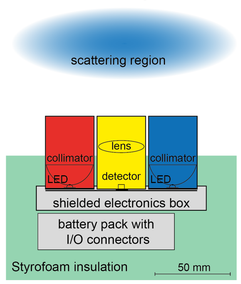
Data processing identifies outlier data due to clearing pulses and contamination, applies corrected pressure data to the mixing ratio calculations, applies proper condensate phase to partial pressure calculation, and determines the vertically resolved uncertainty and resolution of the data. This information is provided in the final data product.



Example profile for water vapor, temperature, ozone and cloud backscatter at Fumin, China

4 Compact Optical Backscatter AerosoL Detector (COBALD)

Instrument Setup



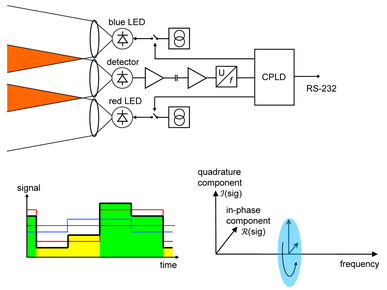
dimensions: 15x12x1cm³, mass: 515g

LED collimation 4°, detector FOV 10°

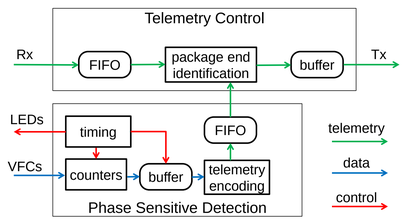
Characteristics

wavelength (nm)	455	940
LED power (W)	>0.45	>0.32
detector noise (pW)	0.87	0.22
Rayleigh SNR	220	30

Principle of operation

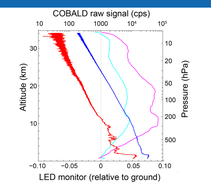


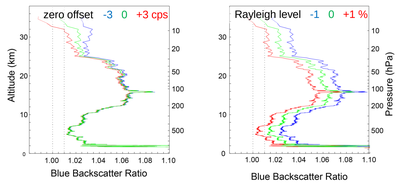
Firmware



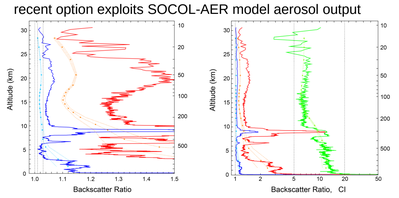
Data Post Processing

- normalize signal to LED power
- adjust zero offset and STP Rayleigh level
- express as backscatter ratio (BR)
- process red channel via color index $CI = \frac{BR_{940}-1}{BR_{450}-1}$





recent option exploits SOCOL-AER model aerosol output



5 Development: Peltier Cooled Frostpoint Hygrometer (PCFH)

Motivated by the increasing interest in accurate UTLS water vapour measurements, a project is being led at ETHZ to develop an improved Peltier cooled frost point hygrometer.

As seen in Fig.3 , differences between frost point and ambient air temperatures for different latitudes, does not exceed -30°C in regions as cold as -75°C: frost point temperatures that could be reached by optimally designed and controlled Peltier cooled balloon borne hygrometer.

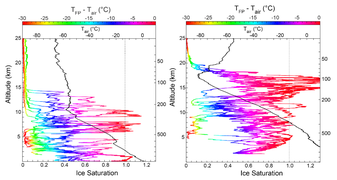


Fig. 3. Difference between frost point and ambient air temperature (colored) and normal air temperature profile (black) for mid and low latitudes (Lindenberg and Fumin).

PCFH	Chiller mirror frost point hygrometer with Peltier cell cooling
Condensate detector	Optical phase sensitive detection scheme with reference surface for temperature stabilization
Temperature measurements	Copper-constantan thermocouples with characterization traceable to the Swiss national standard, and temperature reference with digital individual calibration
Configuration	Redundant construction: 2 frost point detectors (Peltier cell, mirror, flume tube and source) independently controlled by one central microcontroller
Cooling range UTLS conditions	Estimated operating conditions for Peltier cell (Kryotherm-TB-7-0.6-0.8) @ **Lindenberg**: T_{air} = -65 °C, T_{FP} = -95 °C, dT_{max} (T_{air} = -65 °C) = -37 °C → Q_{cmax} = 0.1 W, $Q_h(Q_{cmax})$ = 1 W, I_{max} = 1.5 A, U_{max} = 0.6 V @ **Fumin**: T_{air} = -75 °C, T_{FP} = -90 °C, dT_{max} (T_{air} = -75 °C) = -34 °C → Q_{cmax} = 0.25 W, $Q_h(Q_{cmax})$ = 1.1 W, I_{max} = 1.5 A, U_{max} = 0.55 V
Optimal Control	Based on a three loop controller, two known and one optimized with test flights for different set points. Control parameters adaptable to flight (RH and Temp.) conditions
Communication	xdata protocol

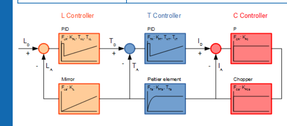


Fig. 4. Three loop controller (light, temperature and current)

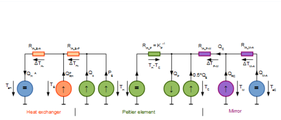


Fig. 5. Peltier cooler thermal model

6 Conclusions and Outlook

The night time payload combination of instruments will yield particularly interesting microphysical information of the UTLS in the region. The transitioning to the stratosphere can be identified by three distinct methods: with the ozone tracer data, the temperature inversion and drying of the air. And as mentioned above the ability of COBALD to differentiate for each water vapor concentration observed by the CFH between inside/outside cloud and aerosols will provide information in dehydration events and water vapor intrusions into the stratosphere.

The data will be included in StratoClim data set, and hopefully will also be integrated with the above mentioning balloon campaigns in the region.