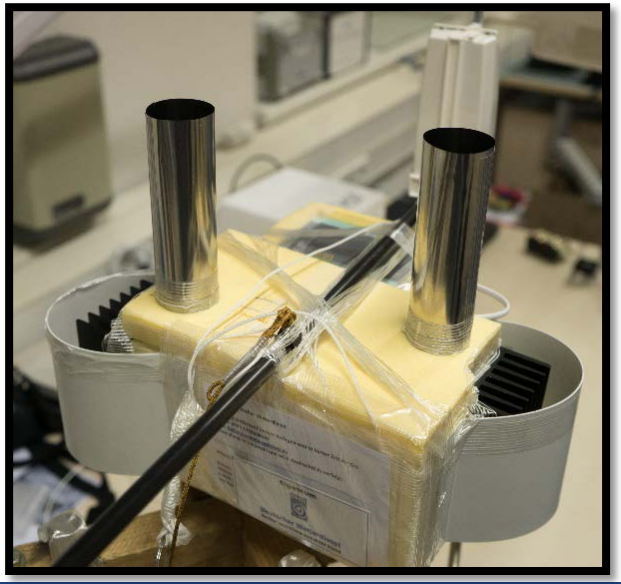
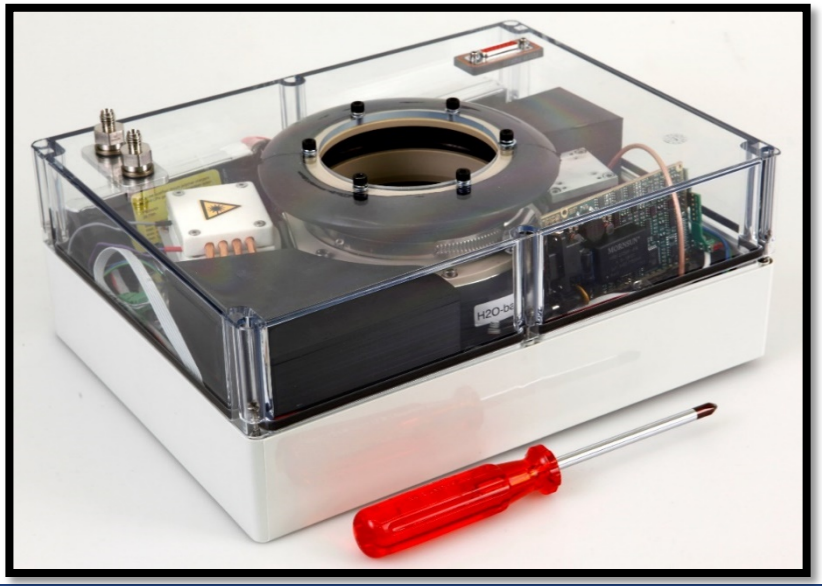
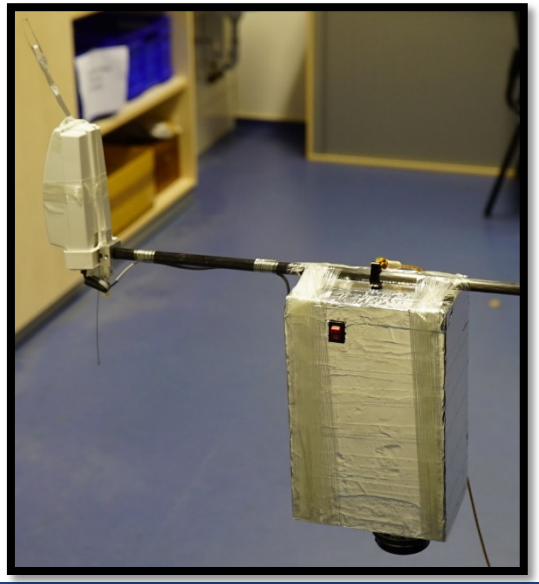
ETH zürich







# Progress report on: the Peltier-cooled frostpoint hygrometer (PCFH); and QCLAS and FLASH-B

Teresa Jorge[1], Manuel Graf[2], Sergey Khaykin[3], Yann Poltera[1]

[1]*Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland*

[2]*Swiss Federal Laboratory for Materials Science and Technology*

[3]*CNRS/INSU, LATMOS-IPSL, France*

**GRUAN ICM-11 Meeting Singapore, 23.05.2019**

# Peltier Cooled Frostpoint Hygrometer (PCFH): Report on 2018 Activities & Status

**slides adapted from**
**GAW-CH Landesausschuss Spring Meeting, 14 May 2019, Empa Dübendorf, Switzerland**

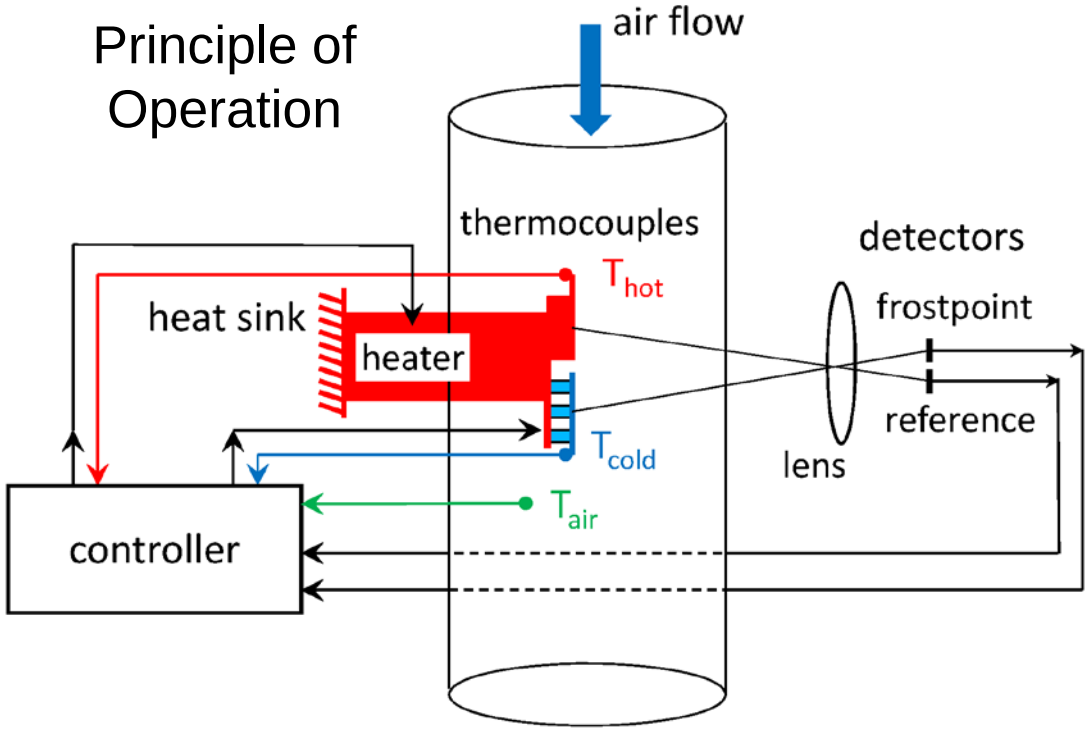
**T. Jorge[1], F. G. Wienhold[1], G. Cesbron[1], S. Brossi[2], T. Brossi[2], P. Oelsner[3], T. Naebert[3], S. Meier[3], and T. Peter[1]**

[1.] Swiss Federal Institute of Tech., Zürich, Switzerland
[2.] mylab elektronik GmbH, Bubikon, Switzerland
[3.] GRUAN Lead Center, DWD Meteorological Observatory, Lindenberg, Germany

# PCFH Fundamentals

- *Peltier*-cooled mirror hygrometer instead of *cryogenically*-cooled like FPH or CFH (phase down agreement of the Kigali Amendment to the Montreal Protocol, 2016).
- Research and test instrument: includes *two* independently cooled mirrors and boards.

Principle of Operation



# Field Campaigns at Lindenberg

- 1st Field Campaign in Lindenberg, 23 .. 27 July 2018: **2** flights
- 2nd Field Campaign in Lindenberg, 10 .. 14 December 2018: **3** flights

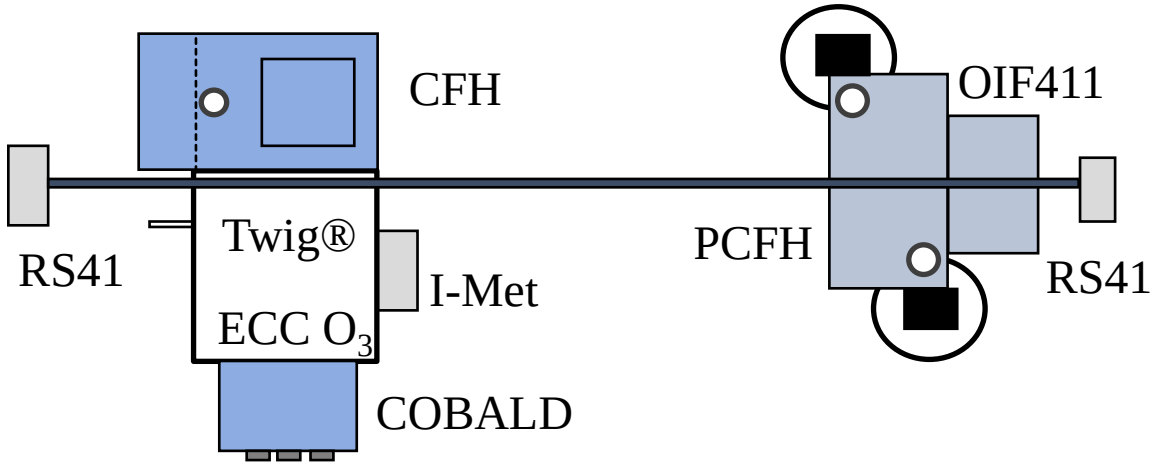
# Aims of the Field Campaigns

- *No frost point measurements!*
- Approval of basic concepts (optical, thermal, electrical, telemetry)
- Characterization of Thermal Electric Cooler (TEC) :
  - in lab
  - in flight environment
- Characterization of condensate formation and detection (mirror reflectivity monitoring)
- Gather data for instrument numerical model implementation

# 1st Field Campaign: Flights & Payloads

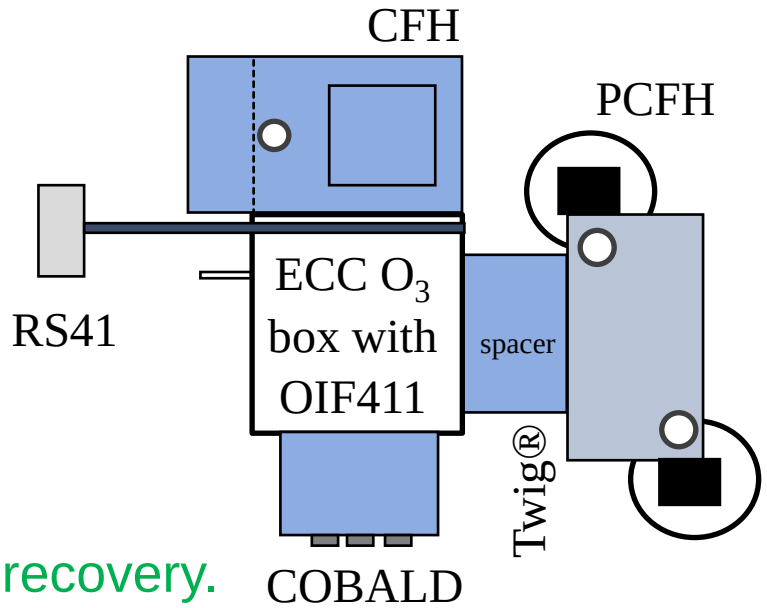
## PCFH Flight 1

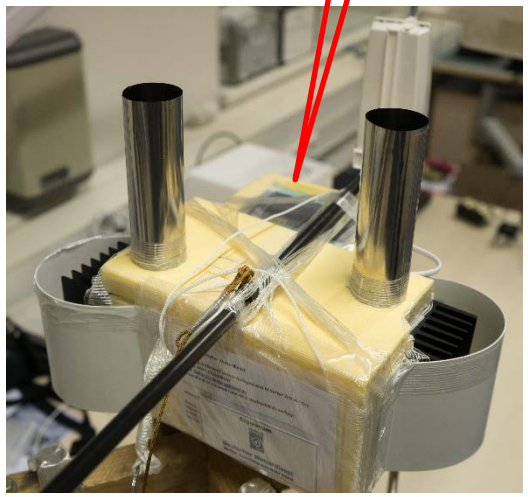
- 2018-0725-02UT_LI_LI236 (regular science)
- 2018-0725-02UT_LI_PCFH001
- Two separate RS41 telemetries




## PCFH Flight 2

- 2018-0725-20UT_LI_PCFH002: ECC O3, COBALD, CFH & PCFH
- One single RS41



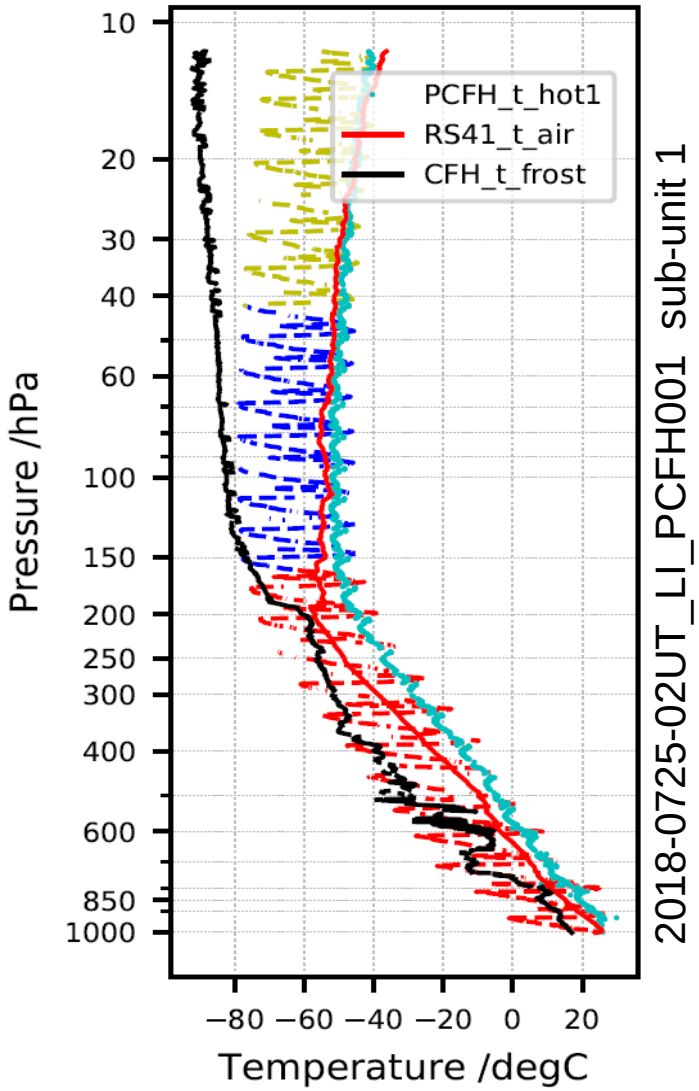



PCFH

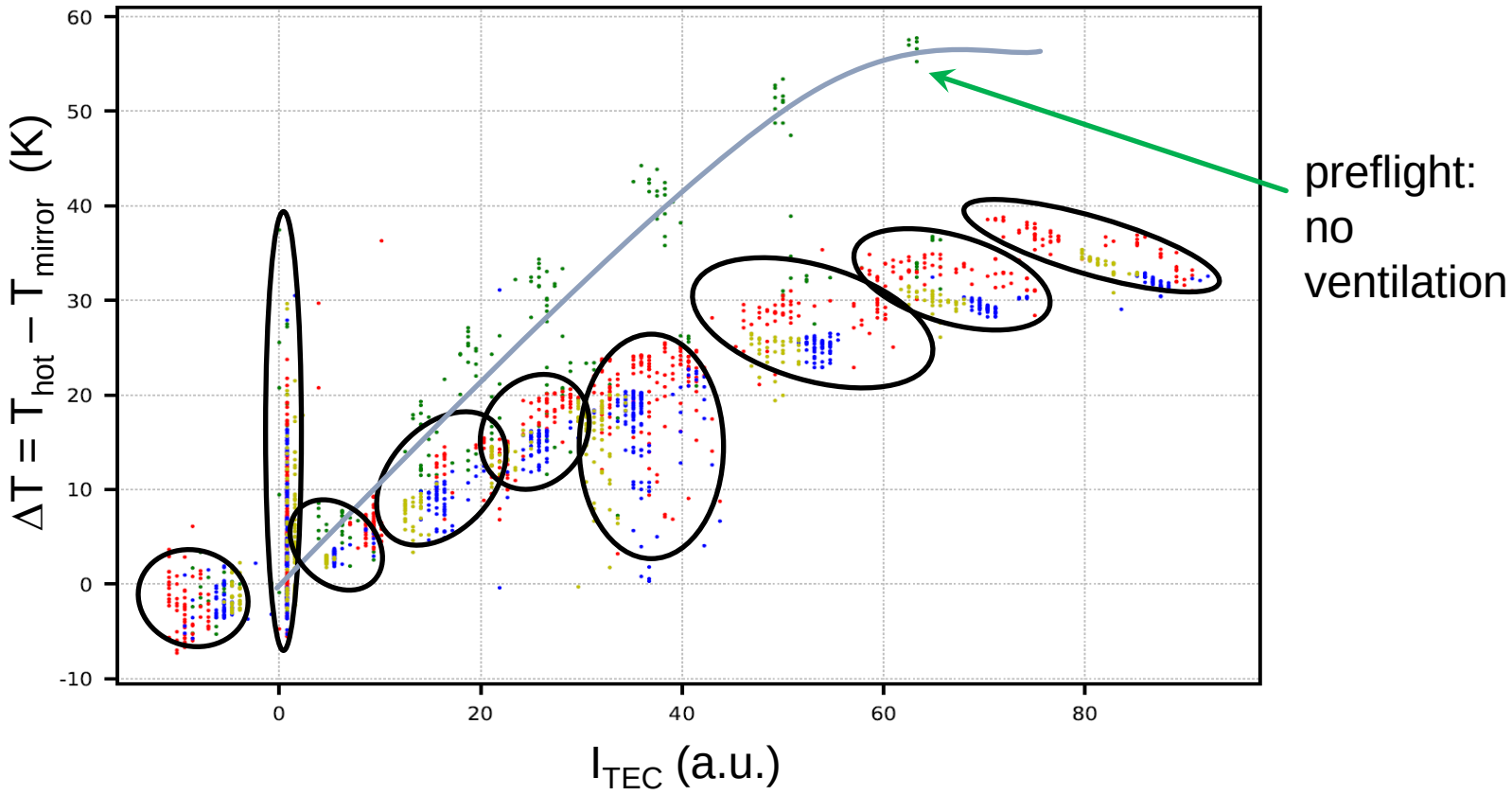
- Power supply: sufficient for one flight duration
- Robust: only battery replacement required after recovery.
- Telemetry issues

# 1st Field Campaign: Selected Results

Example Profile



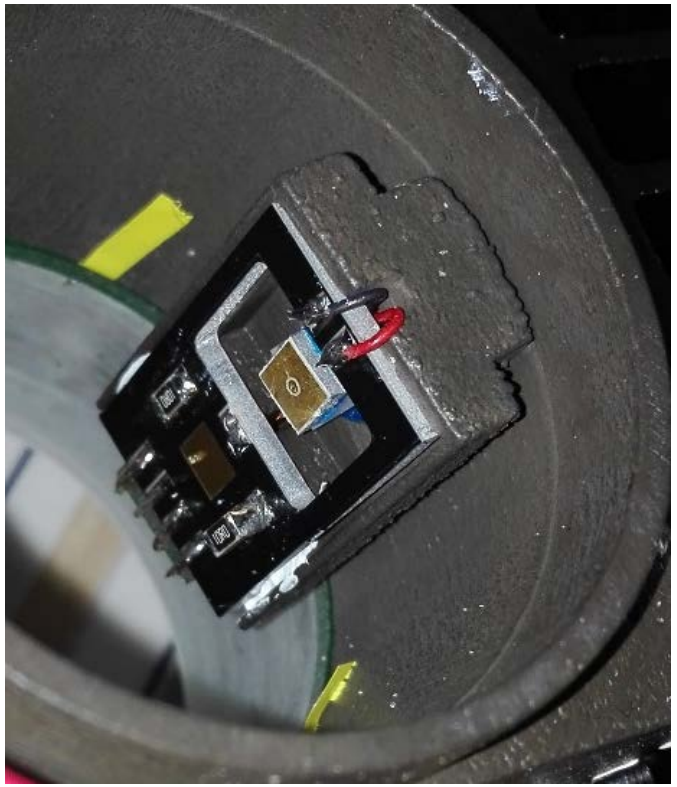

TEC Performance




- Frost point temperature reached only up to tropopause level.
- Heat load was underestimated → need lighter heat sink, protection (radiation shield) and better thermal coupling.

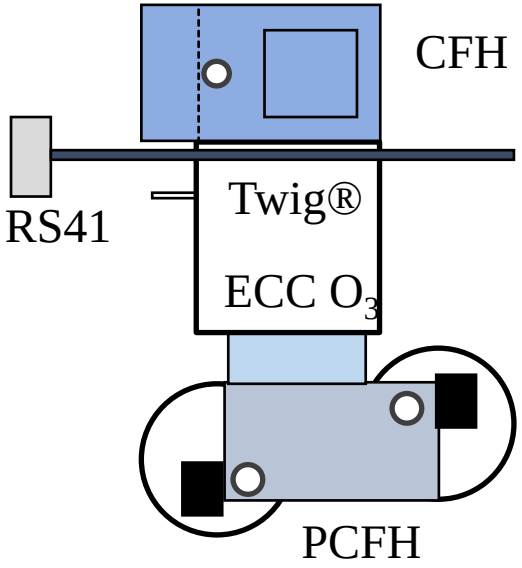
# PCFH Setup Revisions

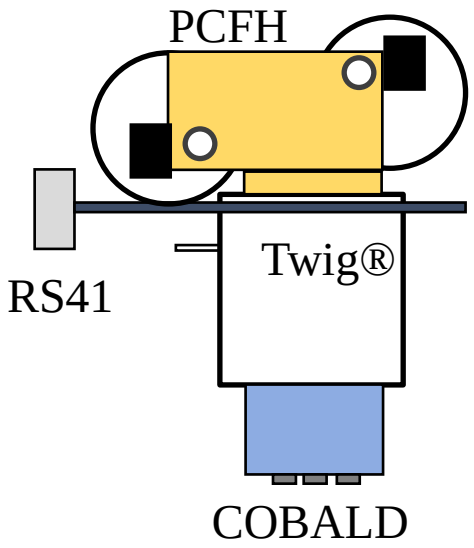
1st Flights' Version: not enough heat dissipation

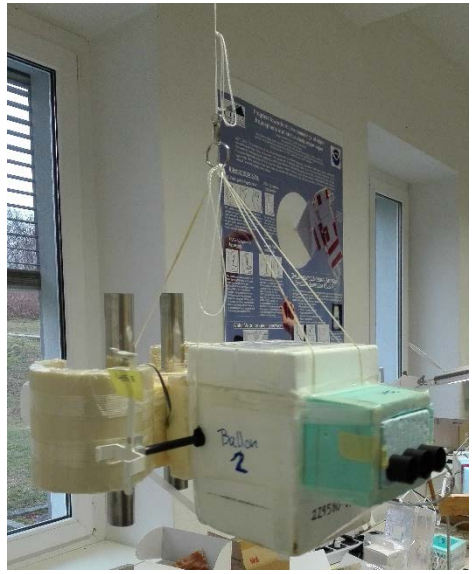


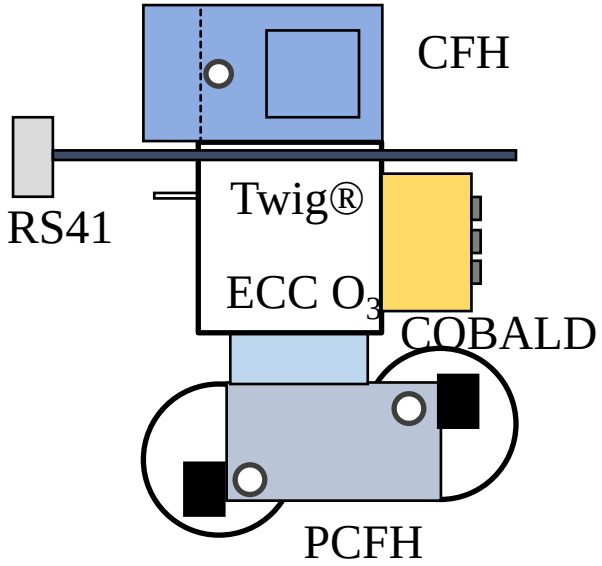
- More space and better thermal coupling
  → better heat dissipation
- new electronics design
  → higher TEC Current achieved

# 2nd Field Campaign: Flights & Payloads






**PCFH Flight 3 & 4** ("simultaneous" launch)

- 2018-1212-16UT_LI_LI246-CFH two single stage TECs
- 2018-1212-16UT_LI_LI246-COB single & double stage TECs

**All Flights**

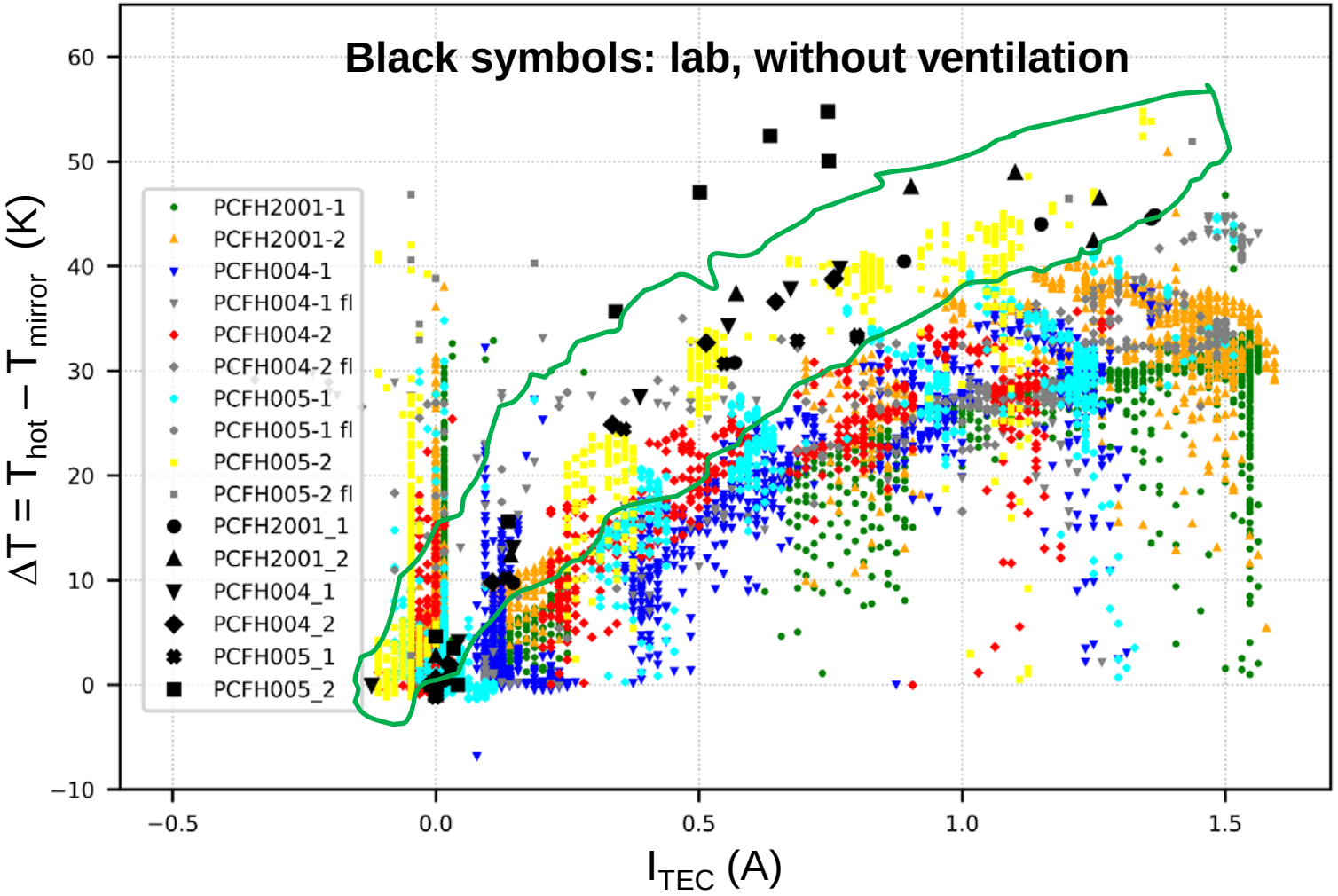
telemetry problem resolved

**PCFH Flight 5**

- 2018-1213-22UT_LI_LI247 single & double stage TECs

# 2nd Field Campaign Results: Cooling performance during ascent

$T_{hot} \cong T_{air} + 10$ K




One assembly version achieved the wished performance.

# Summary and Project Schedule

- Double stage TEC with increased spacing and with coupling with cupper block provides adequate temperature range
- *Next steps:*
  - Improve Peltier hot side to heat sink coupling to minimize $T_{hot} – T_{air}$ (Nov-Dec 2019)
    $\rightarrow$ e.g. use larger cupper block
  - Numerical instrument model (2019- early 2020)
    - Analyze ice formation dynamics and its effects on mirror reflectivity to introduce timing in the numerical instrument model
    - Add and test controller scheme in the numerical model
- *Field verification of the design changes*
  - Two campaigns in Lindenberg during November / December 2019
  - Four dual payload launches from Ny-Alesund in February 2020
- *Test Flights within Monitoring Networks* is postponed by approximately one year (as of May 2019).

# Quantum Cascade Laser based Absorption Spectroscopy (QCLAS) Balloon Instrument

alides from Manuel Graf, EMPA, Switzerland

Empa
Materials Science and Technology

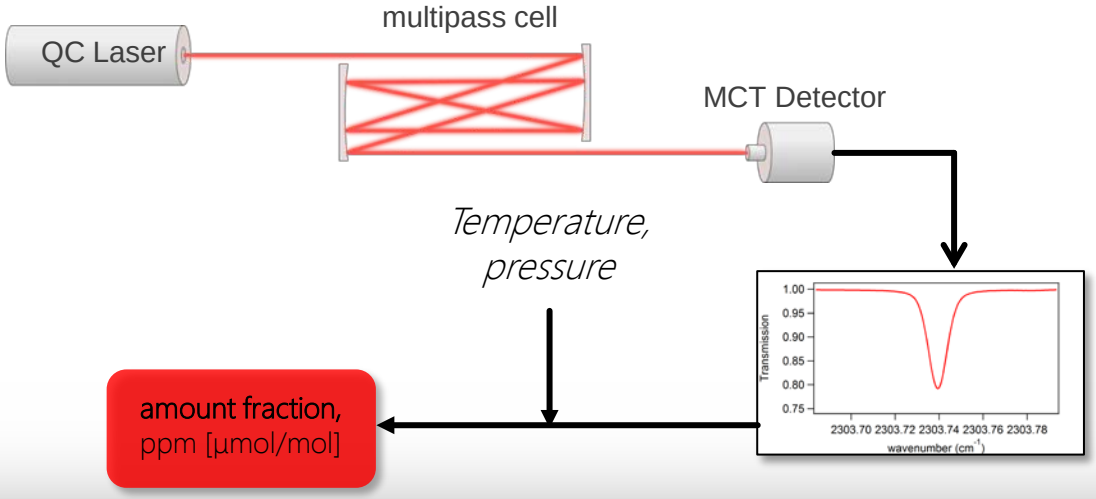
# Quantum Cascade Laser based Absorption Spectroscopy (QCLAS)

## Principles

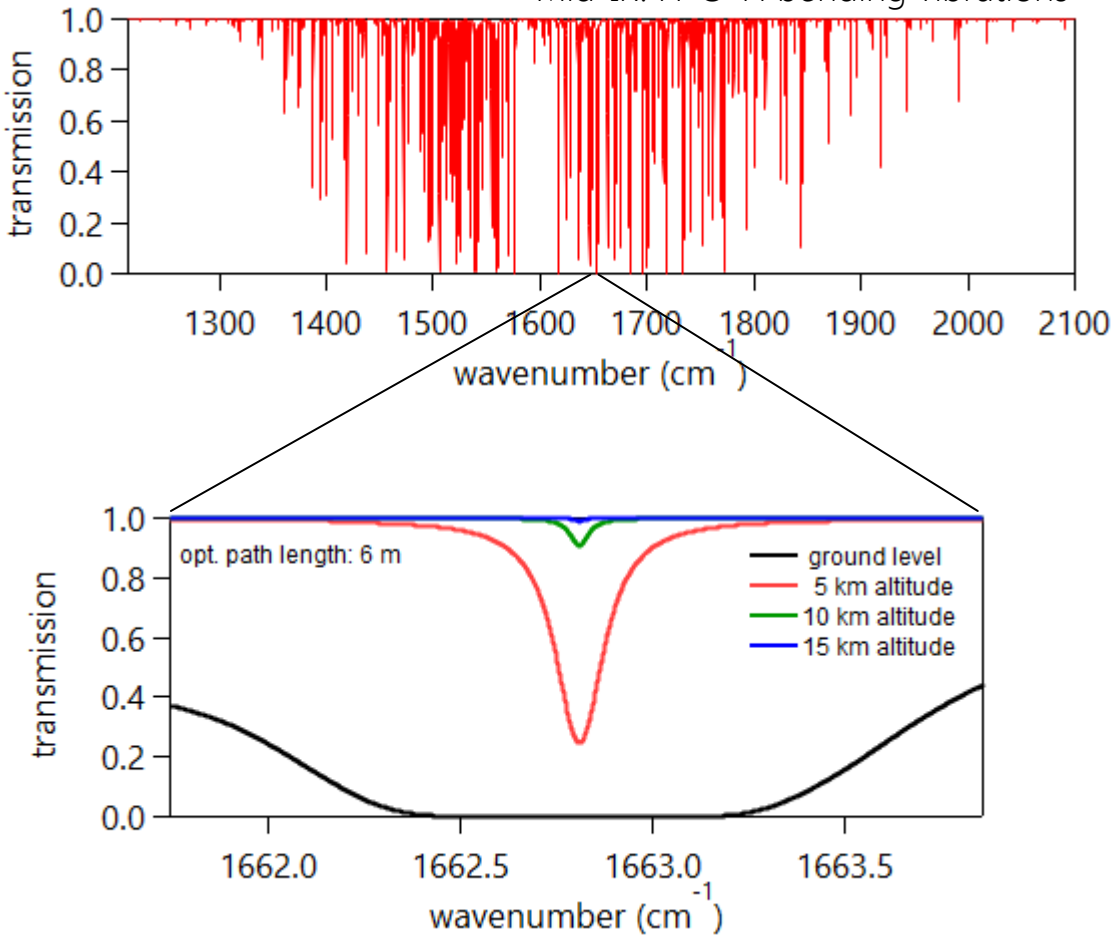
- Direct absorption spectroscopy
- Excitation of a rovibrational transition at 1662 $cm^{-1}$ (6.01 µm)
- Open path operation (L=6 meters)
- Novel circular multipass cell allows simple & robust setup[1)]

$$P_r = C * P_0 * \exp\left(-\left(N_{H_2O} * \sigma_{abs,H_2O} + \epsilon\right) * L\right) + P_b$$

## Method




Mid-IR: H-O-H bending vibrations



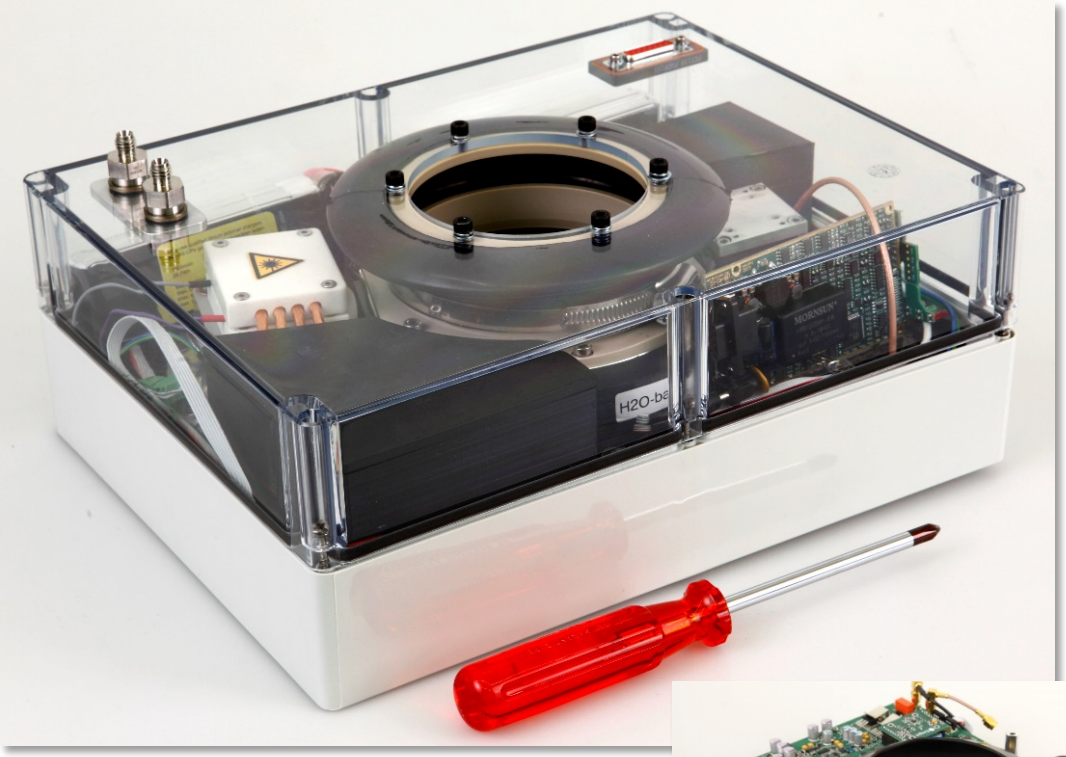

[1)] Graf et al. 2018, *Optics Letters*

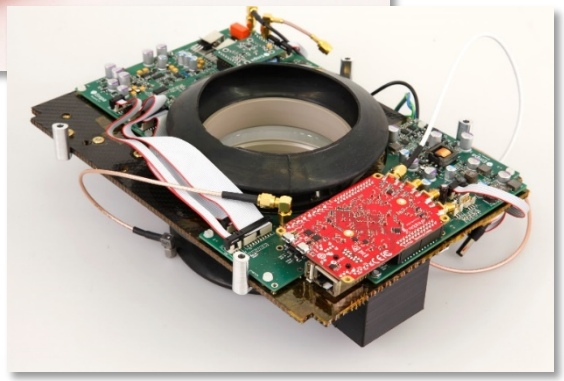
# The Instrument

## Specs

| | |
|---|---|
| size | 30 x 20 x 10 $cm^3$ |
| mass | 3 kg |
| gas exchange (5 m/s ascent speed) | 40 l/s |
| power consumption | 15 W |
| measurement precision | <1% |
| measurement accuracy | tba |

- On-board data storage
- Fully integrated electronics and batteries
- Thermal stabilization with phase change materials (PCM)
- 2 h autonomous operation





bottom view

Will be tested 2019-2020

Alexey Lykov,
Sergey Khaykin,

*Central Aerological Observatory, Russia*
*CNRS/INSU, LATMOS-IPSL, France*

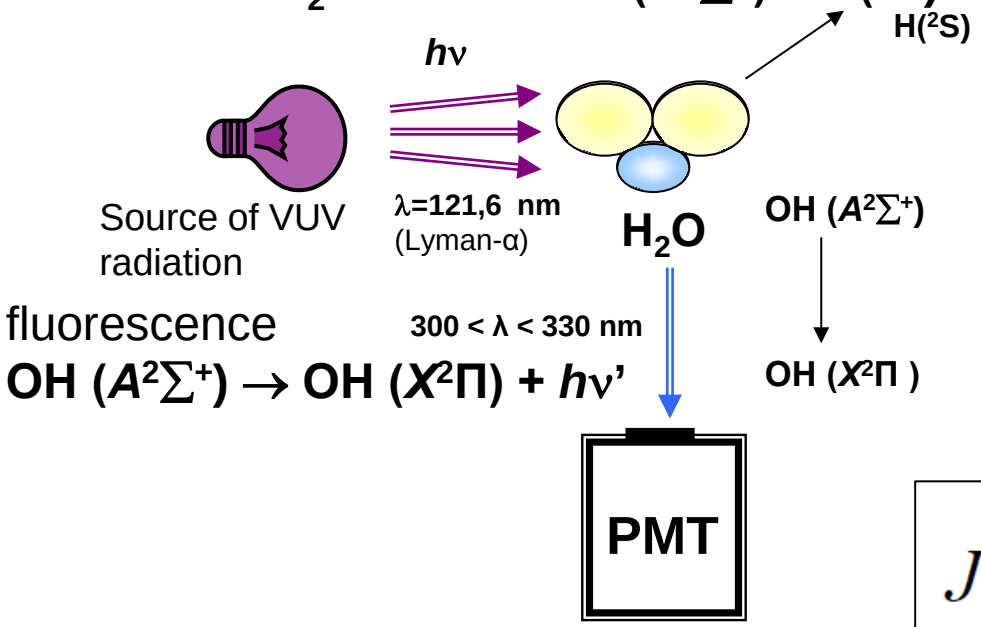
# Fluorescence Lyman-Alpha Stratospheric Hygrometer for Balloon (FLASH-B)

**slides from Sergey Khaykin**

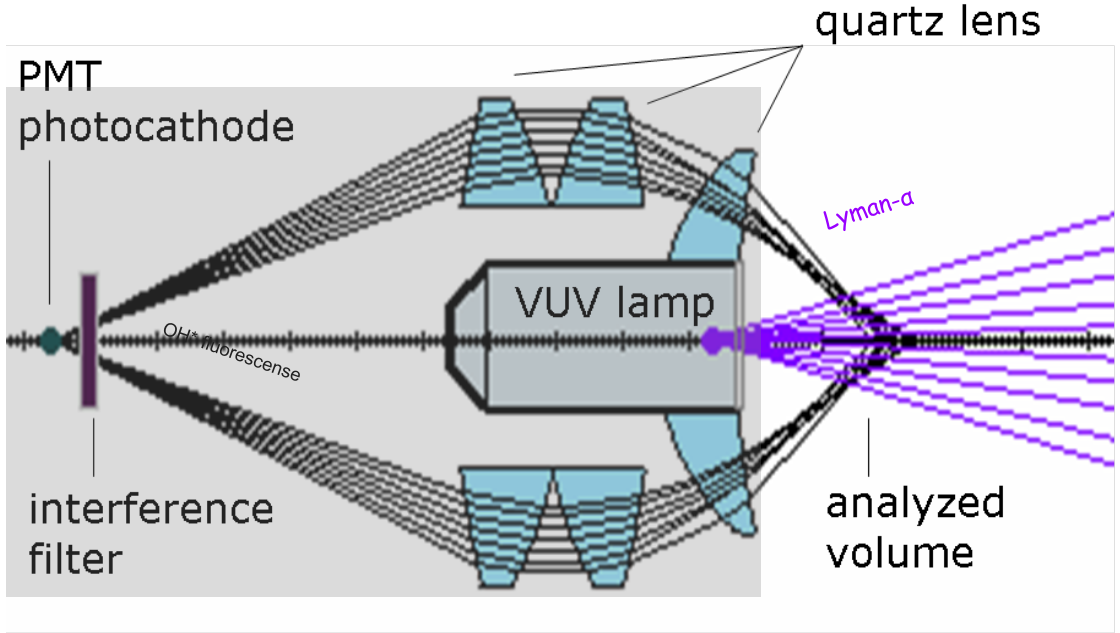
# Method of measurement and optical layout

**The fluorescent method is based on the photodissociation of H2O molecules under UV lamp light at wavelengths below 137 nm and subsequent fluorescent relaxation of the exited OH* radical produced.**

$$H_2O + h\nu \rightarrow OH\ (A^2\Sigma^+) + H(^2S)$$




$$J = C\frac{[H_2O]}{[air]}$$

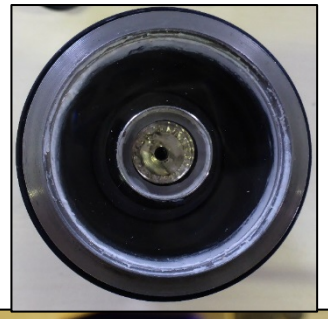


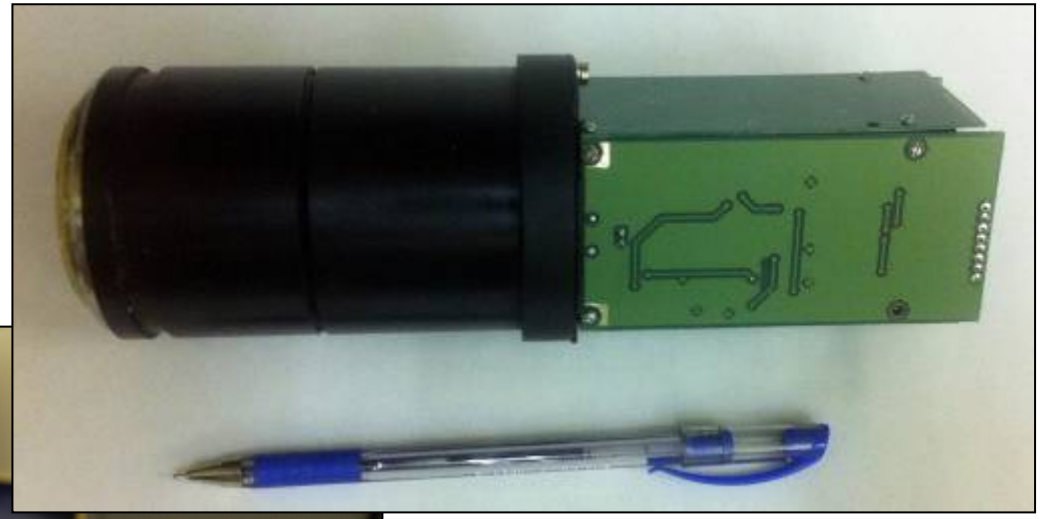

**Optical layout of the fluorescent hygrometer (FLASH) for balloon**

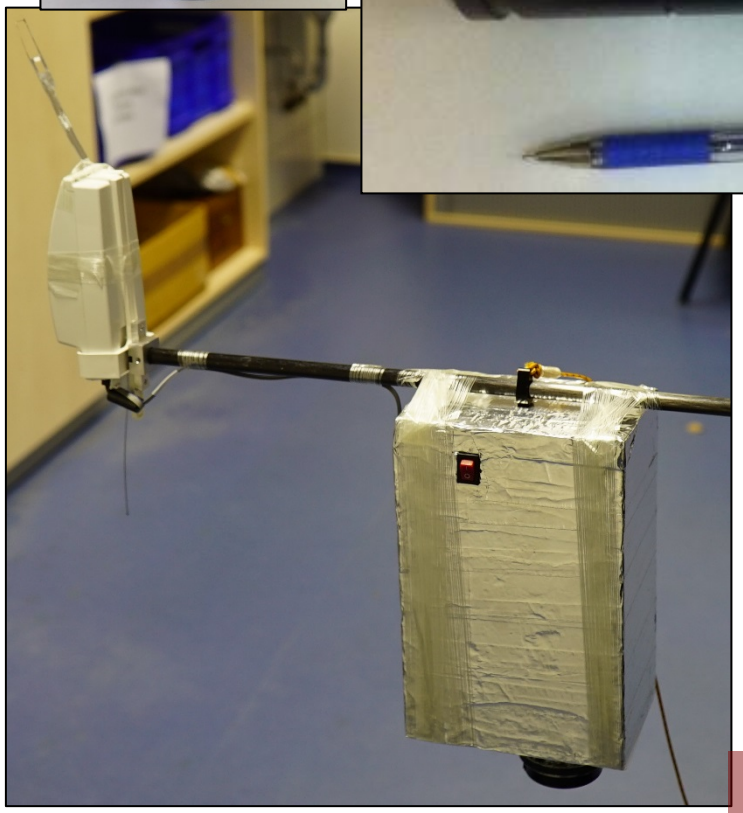
The instrument uses the open layout, where the optics is looking directly into the outside air. Therefore, measuring only <u>at night</u>. <u>For stratosphere, descent data only</u>

www.flash-b.ru

# Specifications



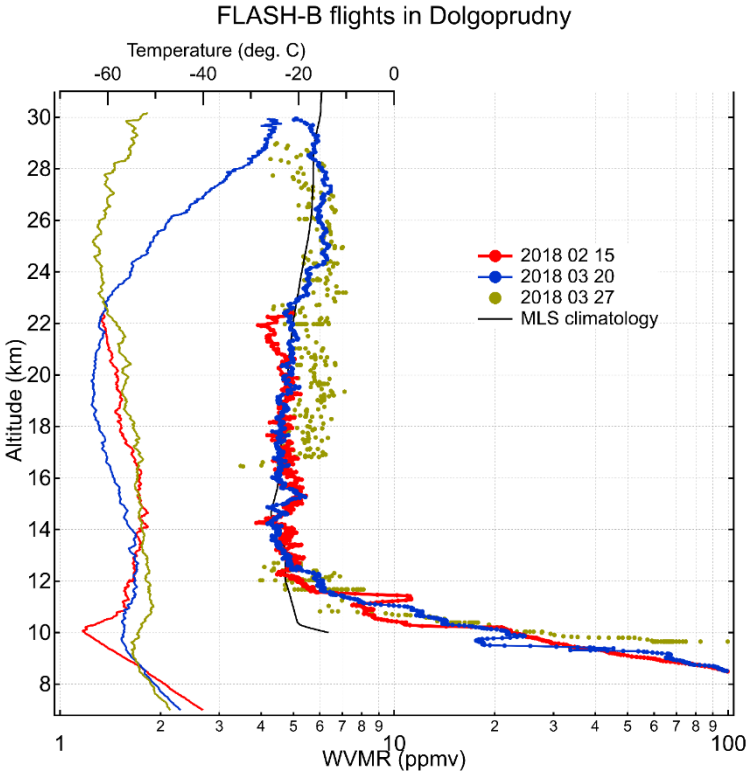




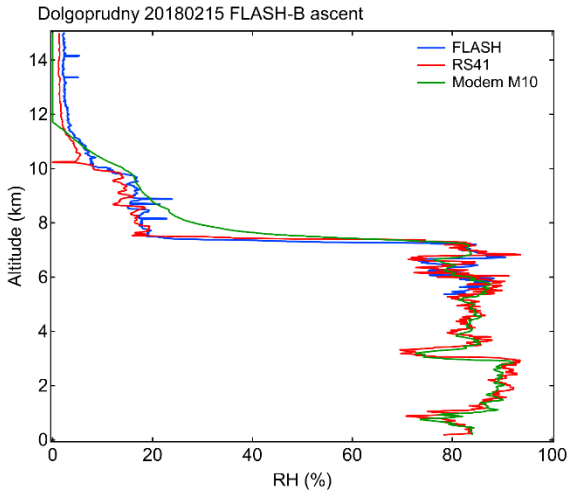
| | |
|---|---|
| Range of measurement | *0.5...1000 ppmv* |
| Resolution time | *1 sec* |
| Integration time | *4 sec* |
| Precision | *5.5%* |
| Total uncertainty | *<10 % (1σ) at μ> 3 ppmv* |
| Vertical resolution | *~ 50 m (descent in UTLS)* |
| Temperature range | *-95$^0$C … +40$^0$C* |
| Pressure range | *300… 5 hPa* |
| Required power | *9-30V, 1 W max* |
| Weight (w/o batteries) | *500 gr* |
| Size Insulation Box | *265 mm x 155 mm x 105 mm* |
| Flight weight | *1000 gr* |
| Interface to | *Vaisala RS92, RS41*<br>*Meisei RS-06G,*<br>*Meteolabor SRS34* |
| Protocol XData | *20 byte/sec* |

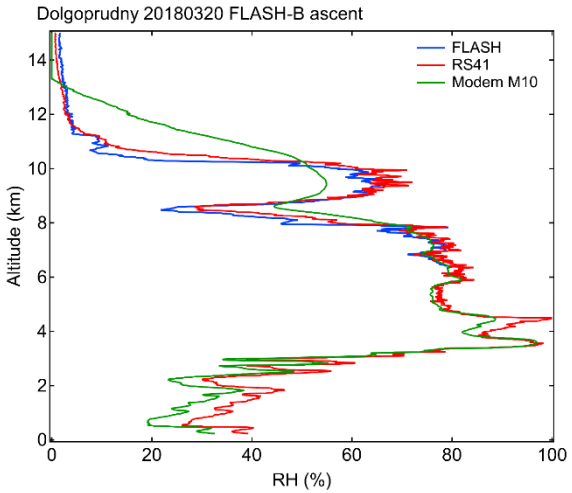
Plug-and-play concept

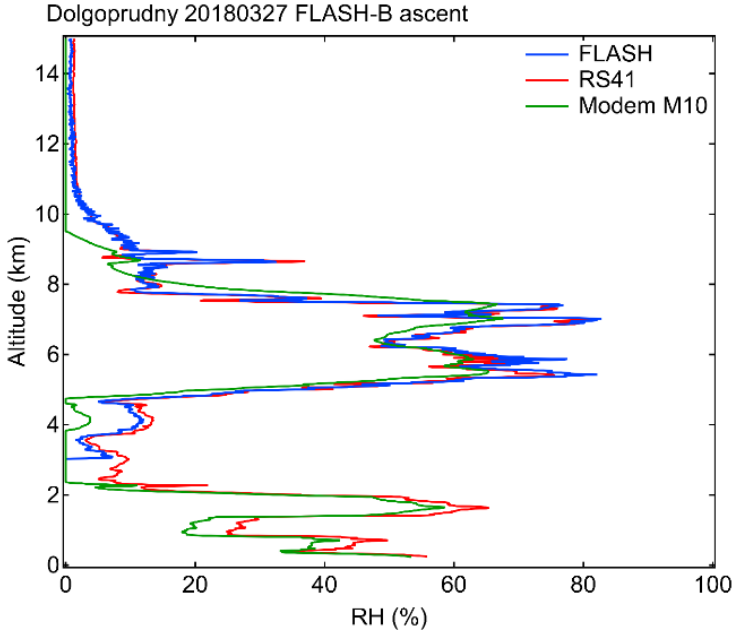
# Flights in Dolgoprudny




## Tropospheric comparison with RS41 and M-10



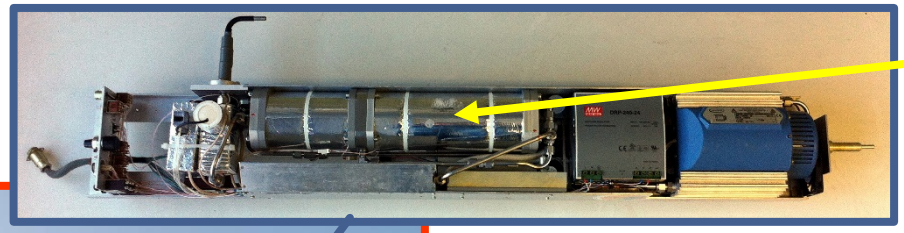




3 consecutive flights of the same FLASH sonde in Dolgoprudny with a series of calibrations before and after each flight

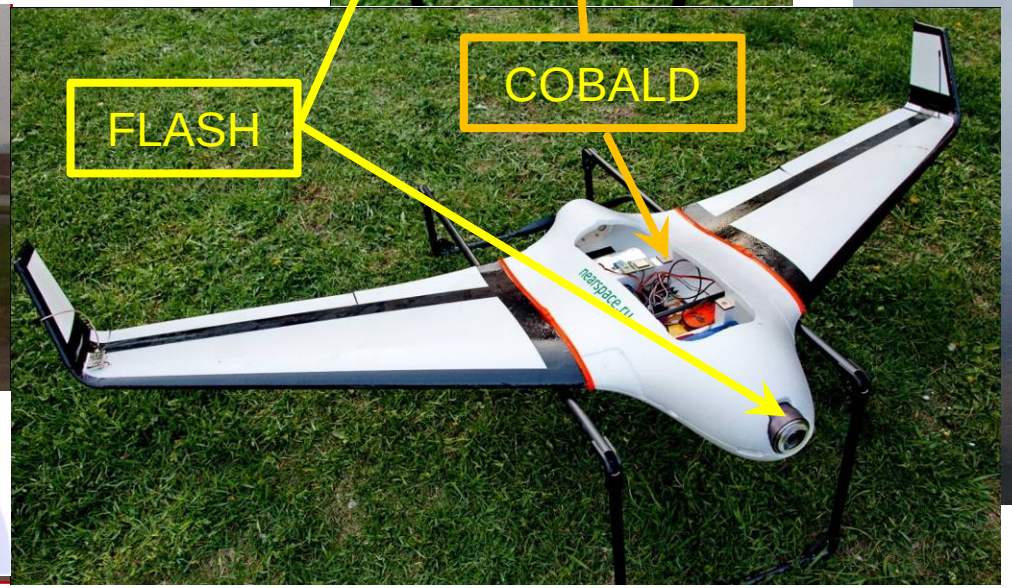
- Consistent water vapour vertical profiles in the stratosphere and good agreement with M10 and RS41 in the free troposphere
- Small change of sensitivity factor (<10 %) in between the calibrations/flights

www.flash-b.ru

# Application on different platforms



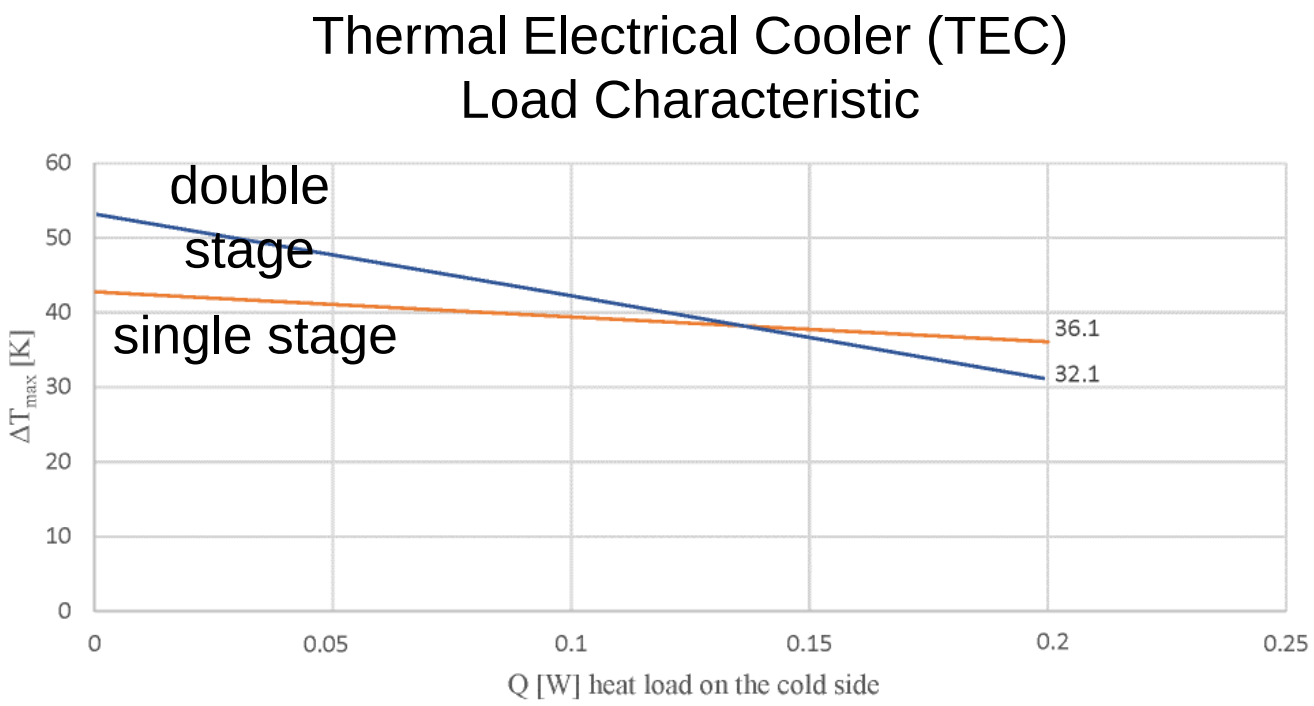
The Flash hygrometer was used on board stratospheric aircraft “Geophisia” M55 during StratoClim campaign and in test flight UAV.


***Thank you for your attention! Questions?***

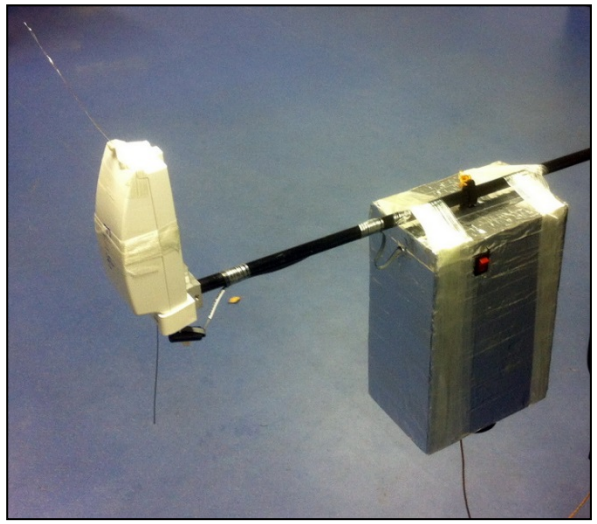
Central Aerological Observatory,
ROSHYDROMET

# Backup slides

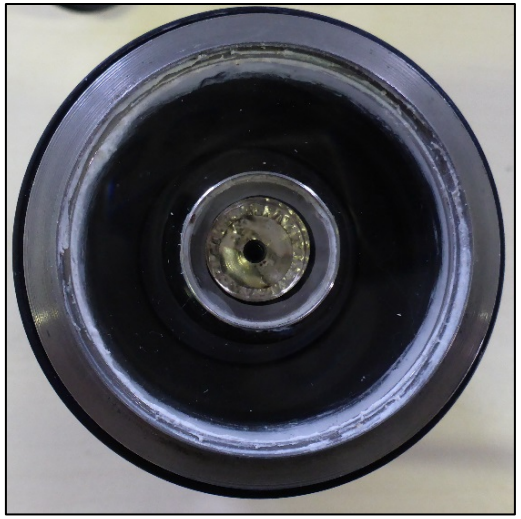


# Flight preparation

## Plug-and-play concept

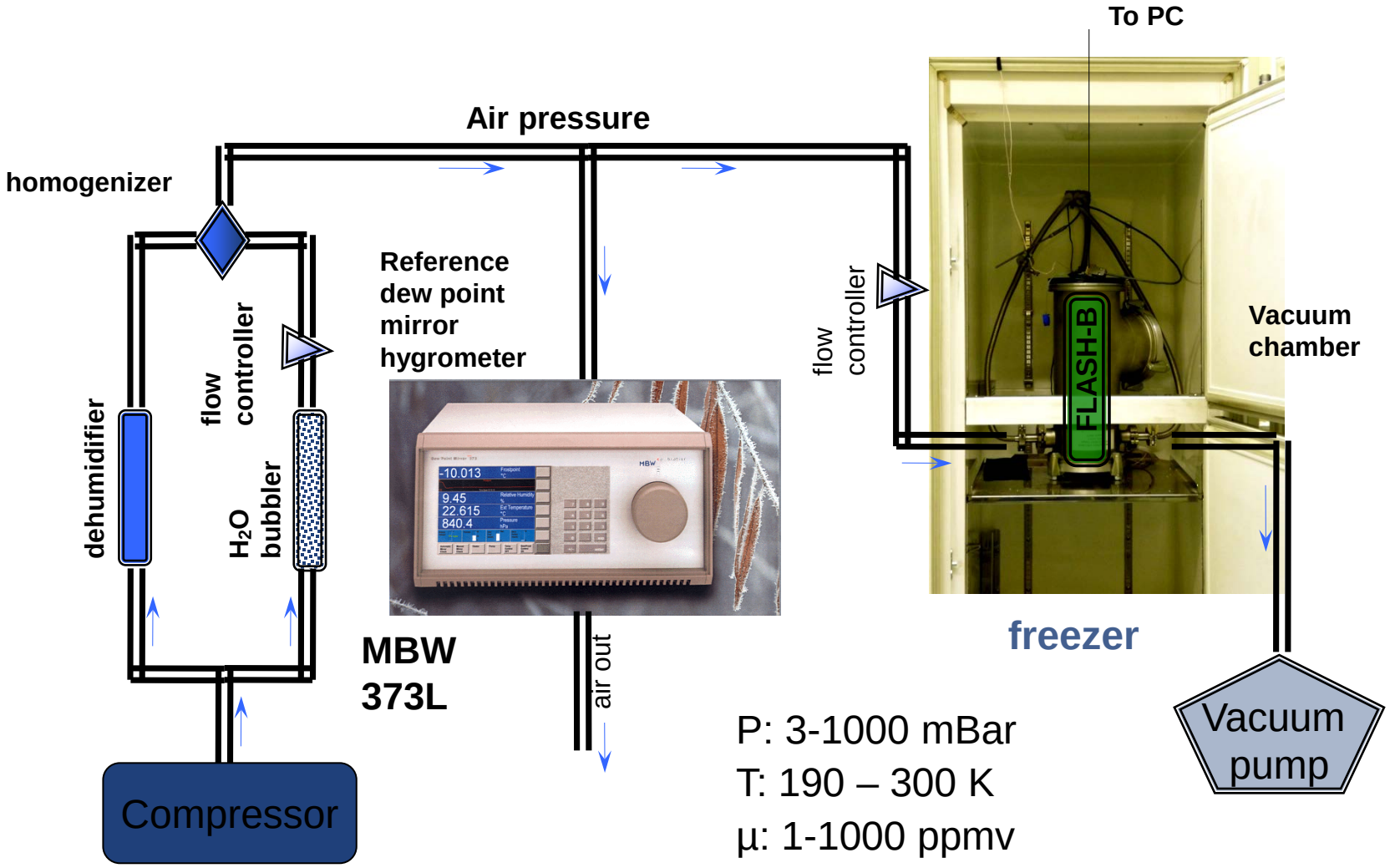


Sealant recommended against contamination in stratosphere

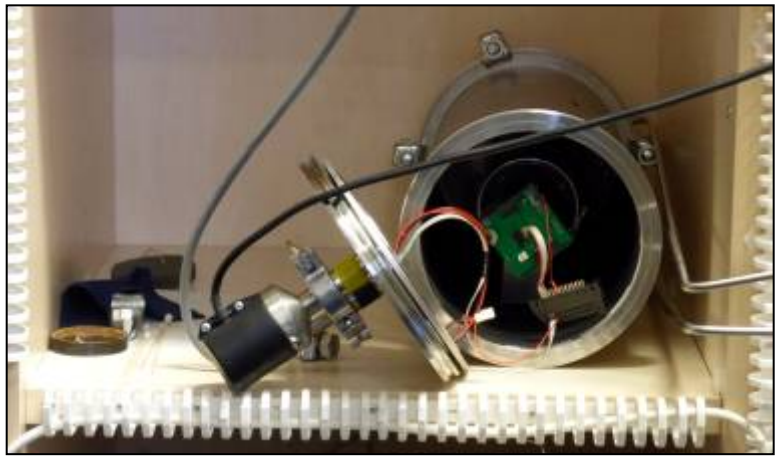


1. Recharge battery;
2. Fixing face down;
3. Clean optics;
4. Connect to radiosonde;
5. Switch on;
6. Check the data incoming;
7. Open cap;
8. Ready to fly!

# Calibration facility

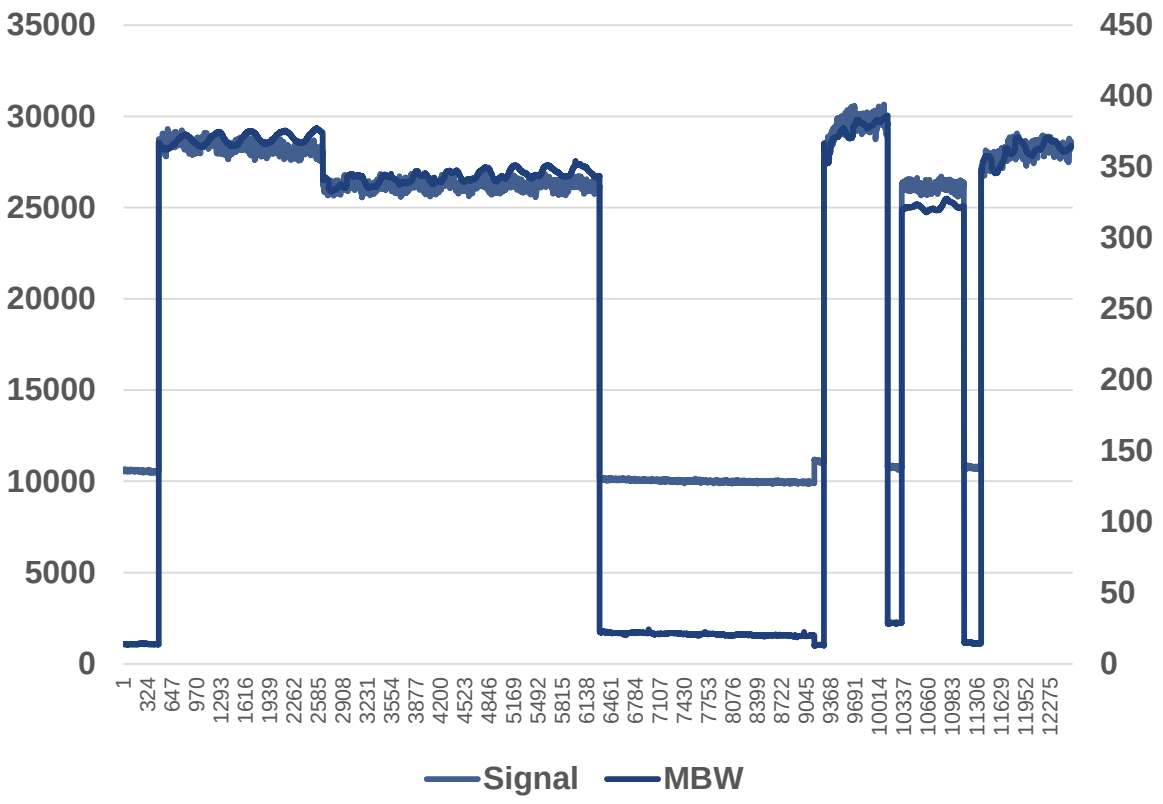


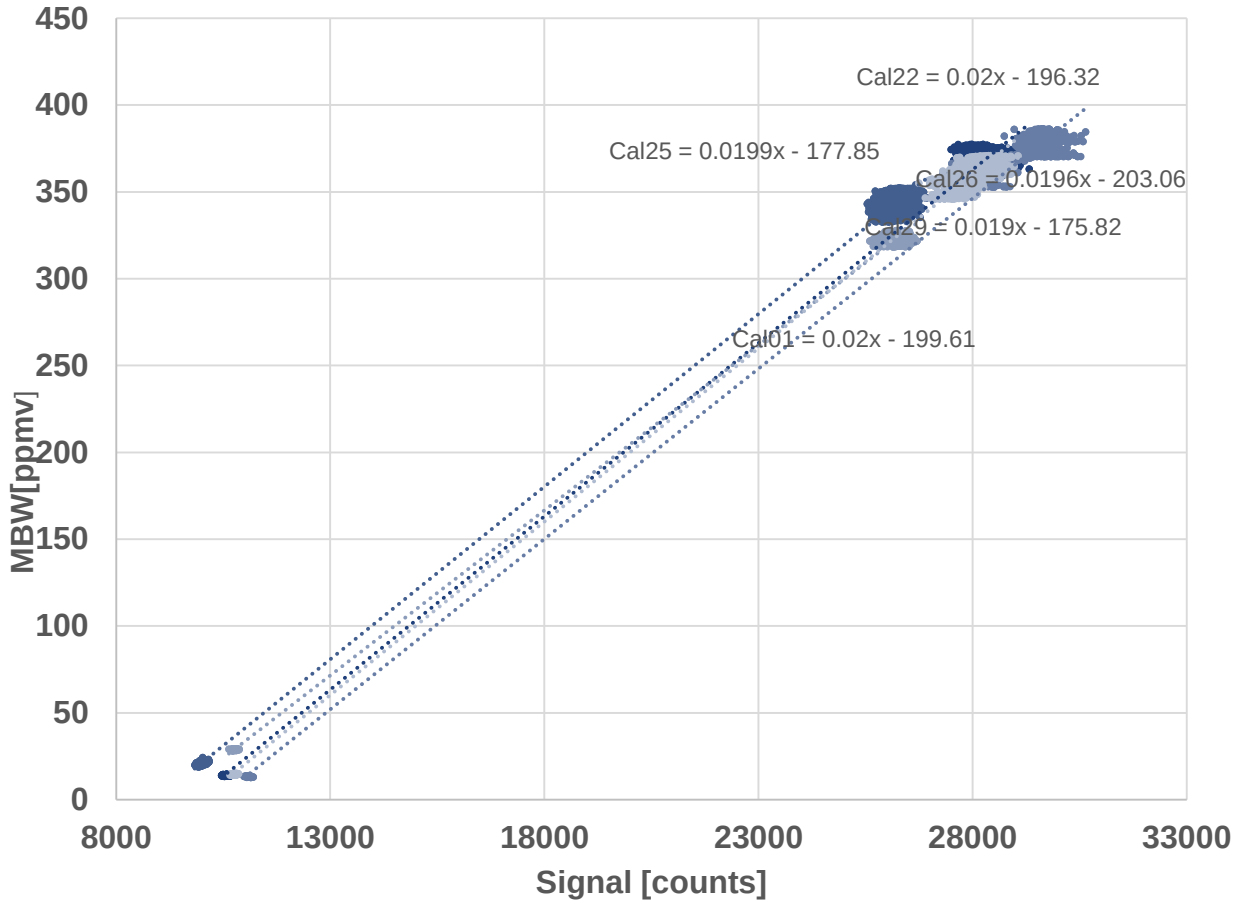

P: 3-1000 mBar
T: 190 – 300 K
μ: 1-1000 ppmv



# Calibration data

The calibration fit function is linear in the pressure range of 30 – 150 hPa and water vapor mixing range of 1 – 500 ppmv.

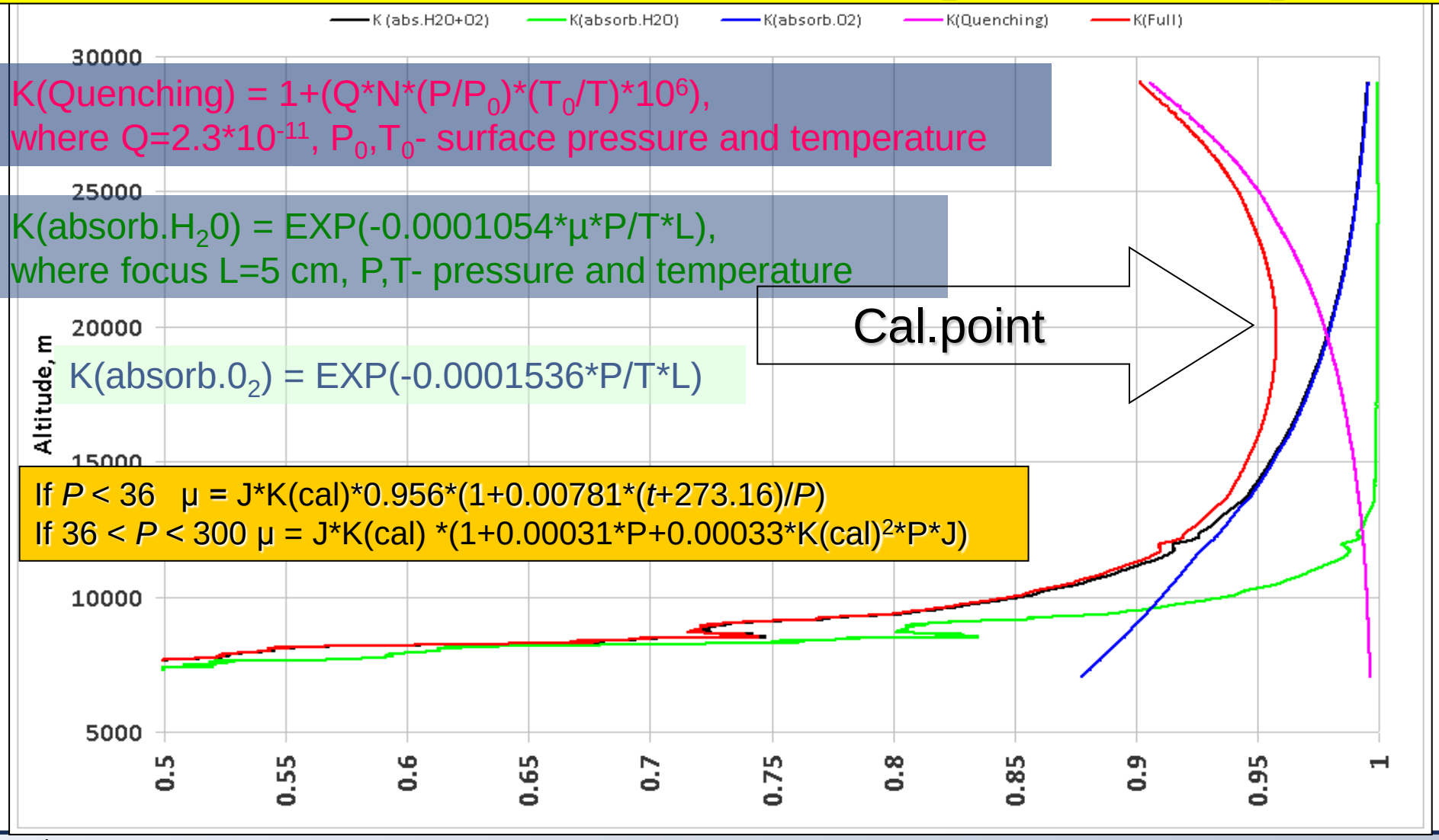



The total relative error of the calibration amounts to 4%.

# Calculation formula

WVMR = J*K(cal) * K(Quenching) * K(absorb.$H_20$) * K(absorb.$O_2$)




K(Quenching) = 1+(Q*N*(P/$P_0$)*($T_0$/T)*$10^6$),
where Q=2.3*$10^{-11}$, $P_0$,$T_0$- surface pressure and temperature

K(absorb.$H_20$) = EXP(-0.0001054*μ*P/T*L),
where focus L=5 cm, P,T- pressure and temperature

K(absorb.$0_2$) = EXP(-0.0001536*P/T*L)

If $P$ < 36 μ = J*K(cal)*0.956*(1+0.00781*($t$+273.16)/$P$)
If 36 < $P$ < 300 μ = J*K(cal) *(1+0.00031*P+0.00033*K(cal)$^2$*P*J)

# FLASH-B error budget

## Calibration error

- MBW373L dew point uncertainty (0.1 K)
- Pressure error (conversion to mixing ratio)
- Non-linearity of calibration curve
- Outgassing within calibration chamber
- Random error (operator-related factors)

Total relative error of calibration is estimated at 4% (1 σ)

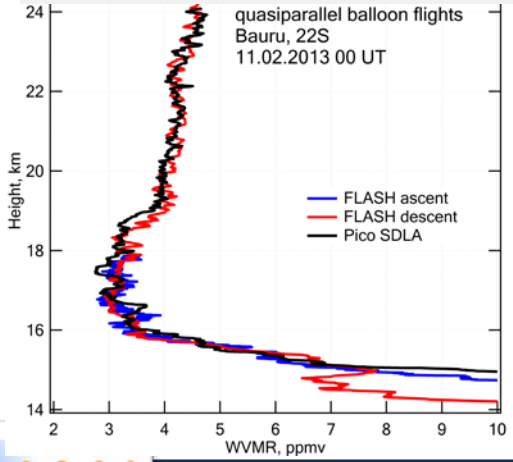
## Measurement error

- Instability of Lyman-alpha emission, including temperature-related drifts (<3%)
- Random error (5.5% precision for 4 s integration)
- Detection limit 0.1 ppmv

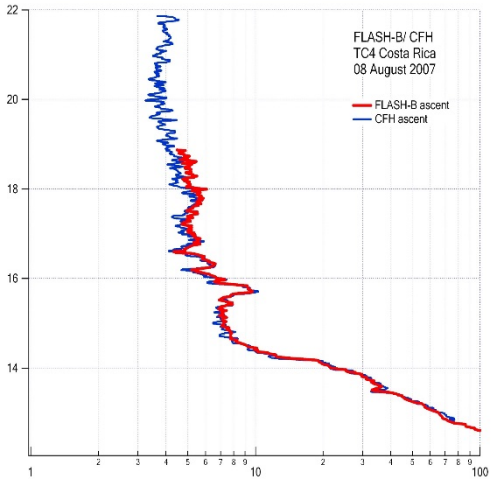
Total uncertainty (calibration error + 1σ precision) is below 10% at stratospheric conditions.

**Comparison against other hygrometers and in-flight repeatability fully confirms the estimated uncertainty**

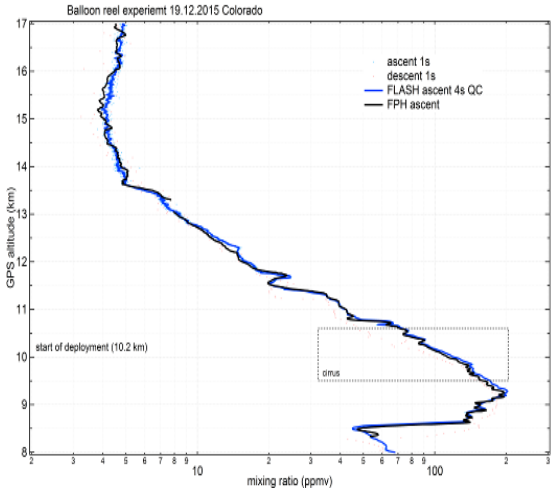
Comparison with Pico-SDLA




Comparison with CFH




Comparison with FPH




In-flight repeatability