www.flash-b.ru

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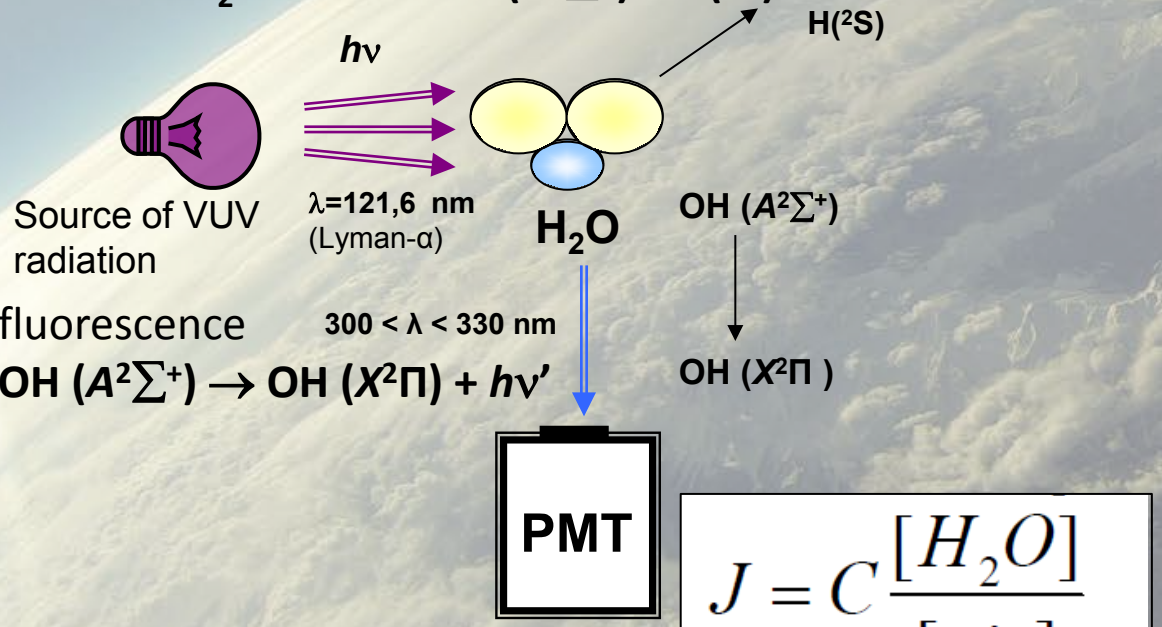
Fluorescence Lyman-Alfa Stratospheric Hygrometer for Balloon (FLASH-B)

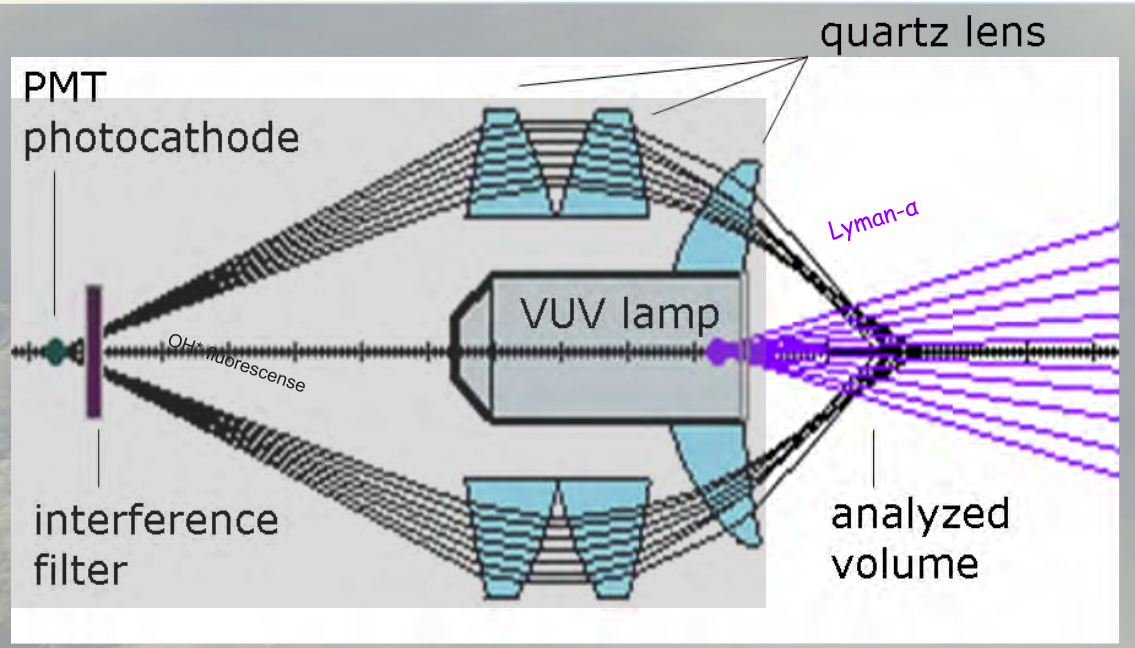
Method of measurement and optical layout

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.

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



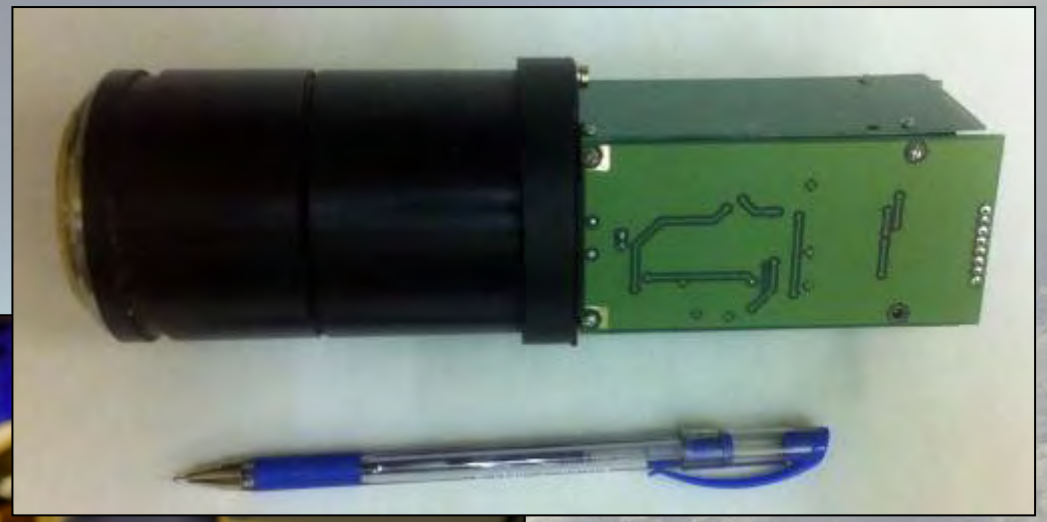
$$J = C\frac{[H_2O]}{[air]}$$

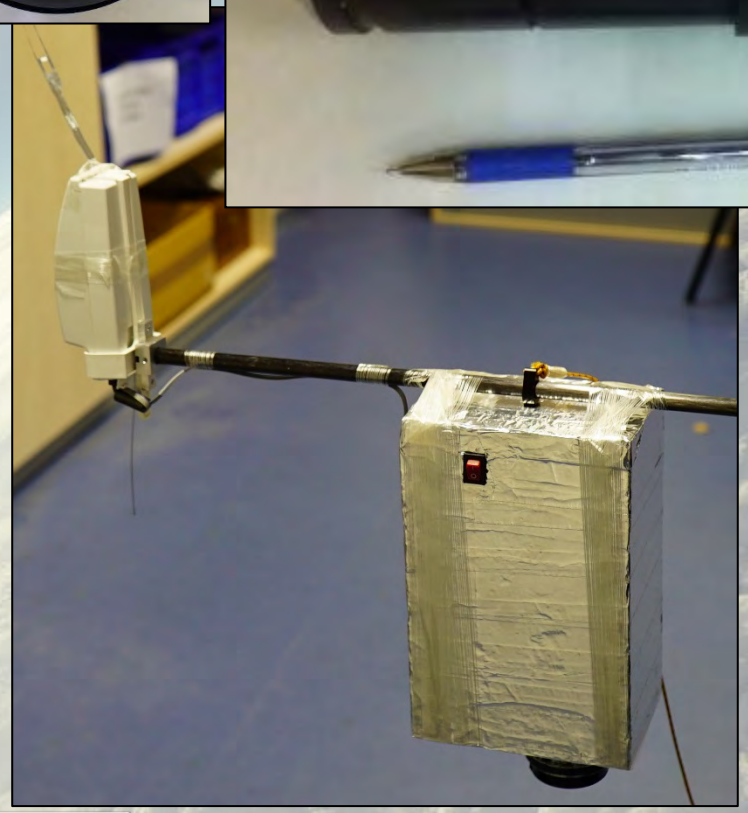


Optical layout of the fluorescent hygrometer (FLASH) for balloon

The instrument uses the open layout, where the optics is looking directly into the outside air. Therefore, measuring only at night.

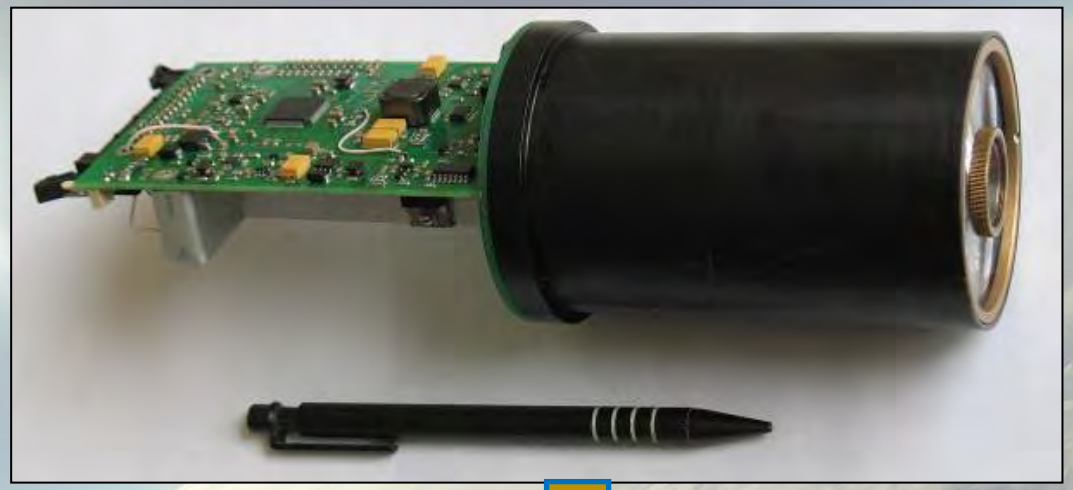
Specifications





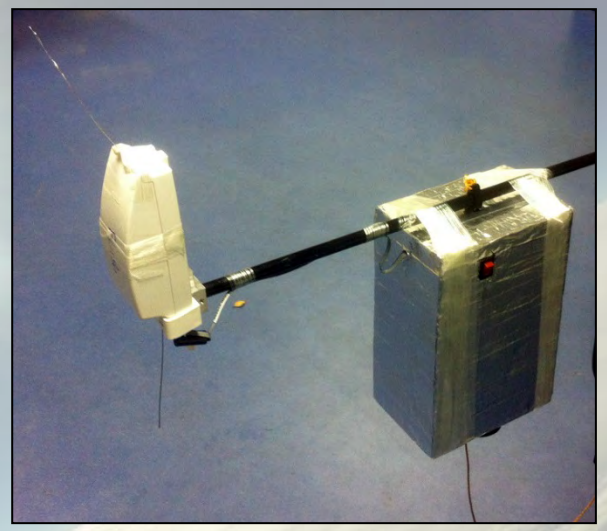
Range of measurement	*0.5...1000 ppmv*
Resolution time	*1 sec*
Integration time	*4 sec*
Precision	*5.5%*
Total uncertainty	*<10 % (1σ) at μ> 3 ppmv*
Vertical resolution	*~ 50 m (descent in UTLS)*
Temperature range	*-95^{0}C … +40^{0}C*
Pressure range	*300… 5 hPa*
Required power	*9-30V, 1 W max*
Weight (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*
	Meisei RS-06G,
	Meteolabor SRS34
Protocol XData	*20 byte/sec*

Construction



1. New PMT – Yamamatsu R12421;
2. Improve shielding PMT against radio interference;
3. Built-in temperature and pressure sensors for internal calculation
4. Switch on PMT and Lamp under 2 km by pressure sensor
5. Switch off all below 2 km by pressure sensor for safe batteries
6. Styrofoam box covered by film against contamination effect
7. Rechargeable batteries 4x18650 or 8xAA Lithium batteries
8. Micro SD flash card data logger

Flight preparation

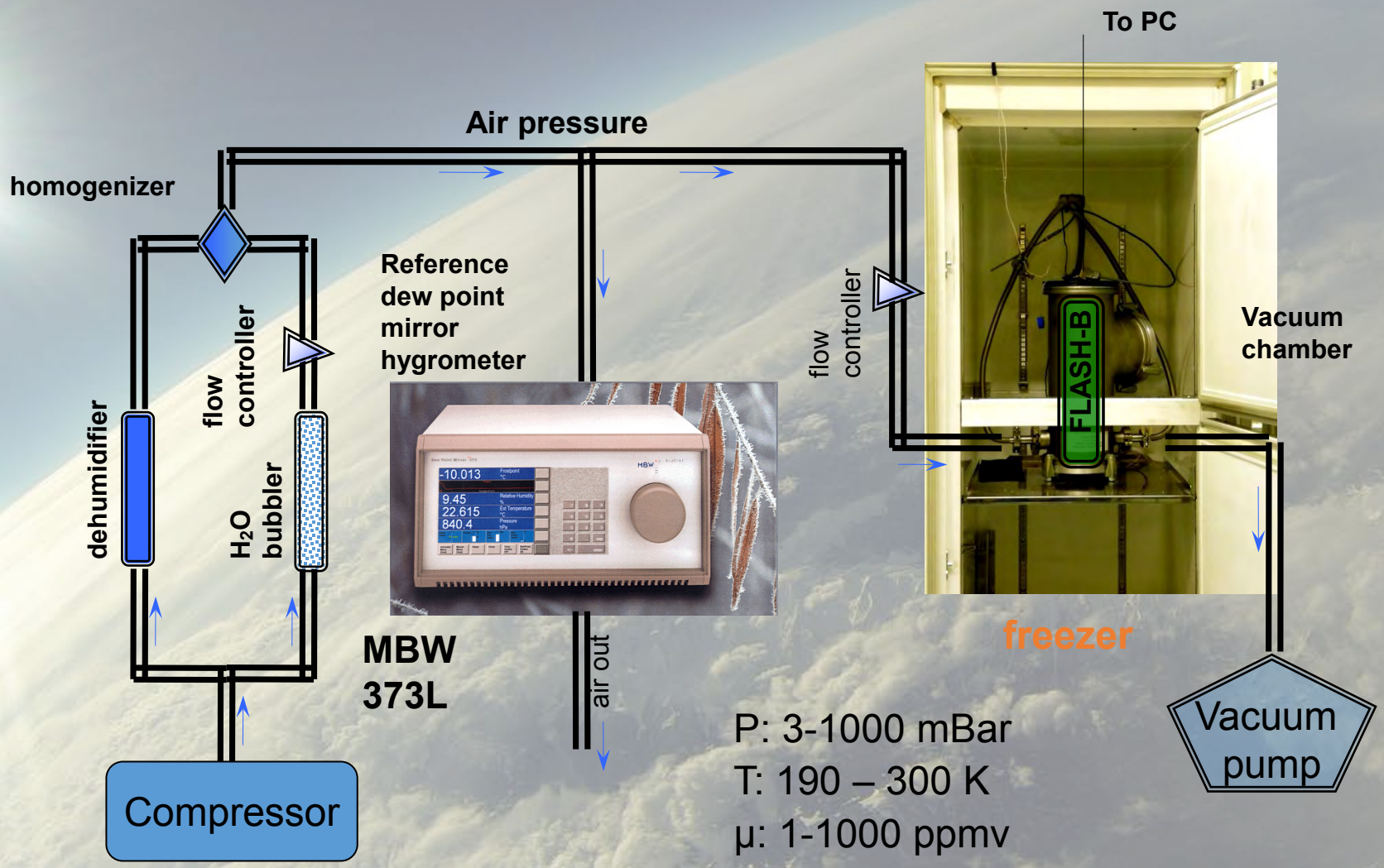


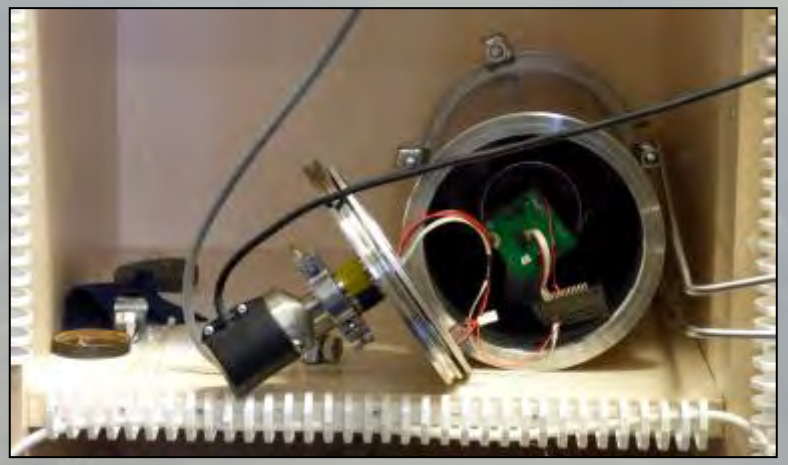
Sealant recommended against contamination in stratosphere

Plug-and-play concept

1. Clean optics;
2. Connect to radiosonde;
3. Switch on;
4. Check the data incoming;
5. Open cap;
6. Ready to fly!

Calibration facility

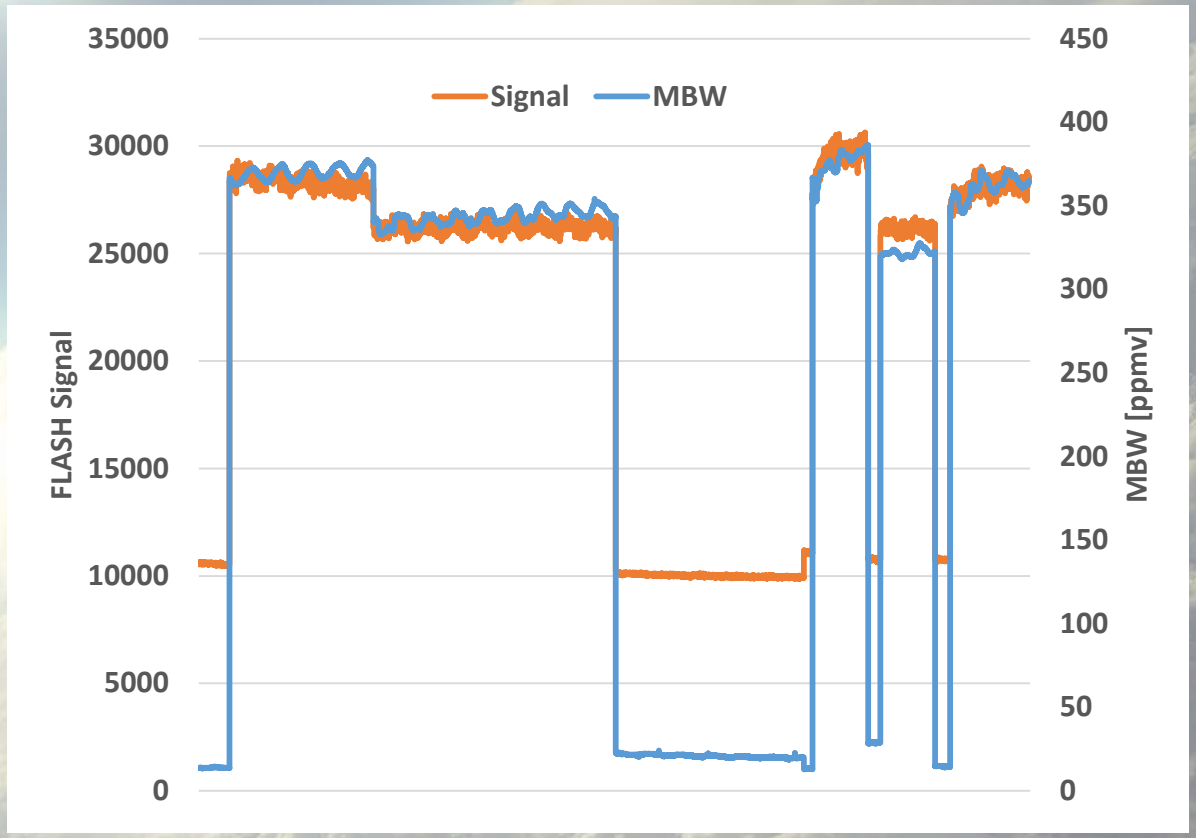


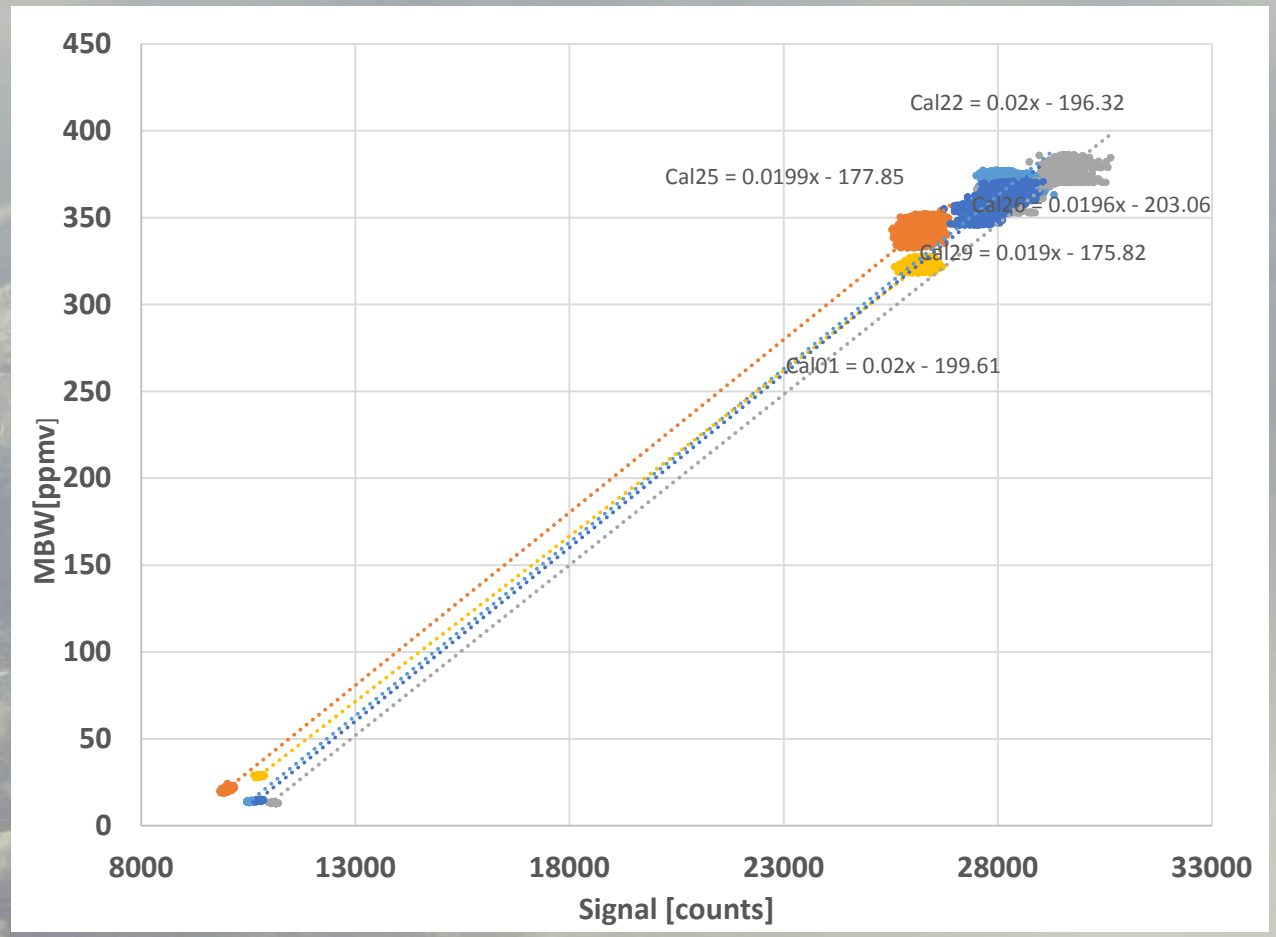


Calibration facility in Lindenberg

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. Repeated calibration data during some days for series Flash instruments for Japan in October 2016.





The total relative error of the calibration amounts to < 2%.

Calculation formula

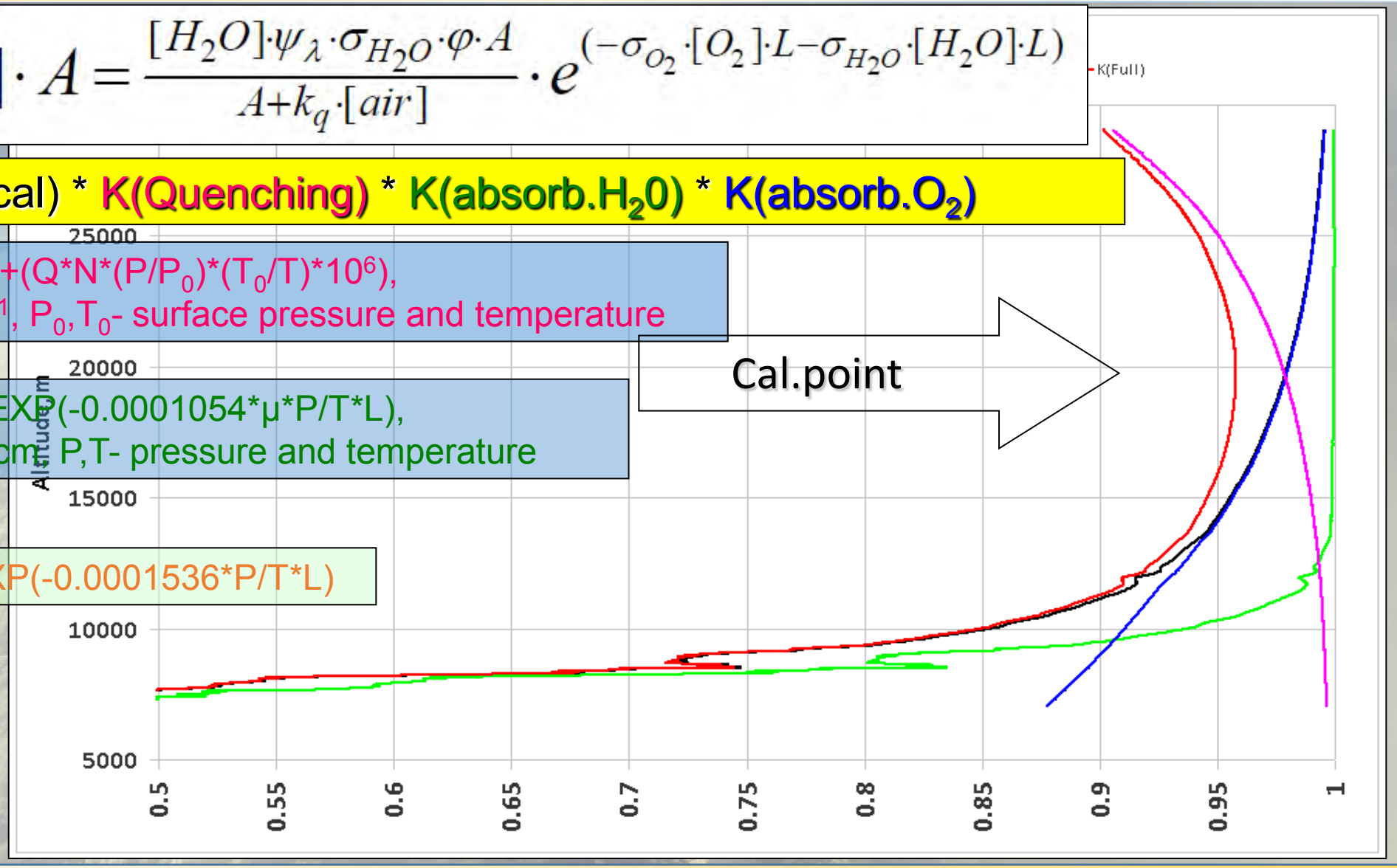
$$J = [OH^*] \cdot A = \frac{[H_2O] \cdot \psi_\lambda \cdot \sigma_{H_2O} \cdot \varphi \cdot A}{A + k_q \cdot [air]} \cdot e^{(-\sigma_{O_2} \cdot [O_2] \cdot L - \sigma_{H_2O} \cdot [H_2O] \cdot L)}$$

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)



FLASH-B error budget

Calibration error

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

Total relative error of calibration is estimated at 2% (1 σ)

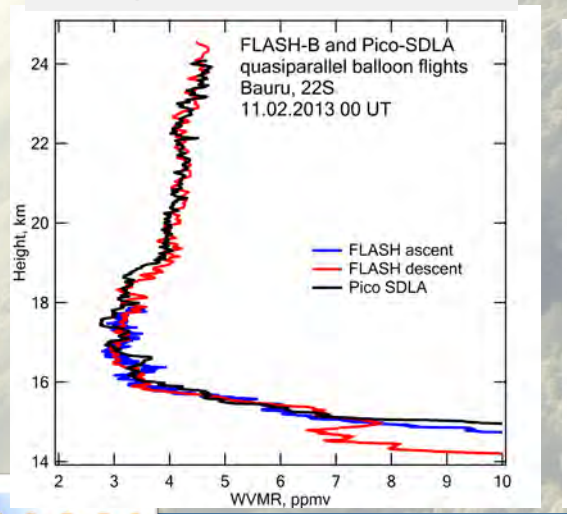
Measurement error

- Instability of Lyman-alpha emission, including temperature-related drifts (<3%)
- Random error (5% precision for 4 s integration)
- Detection limit 0.1 ppmv

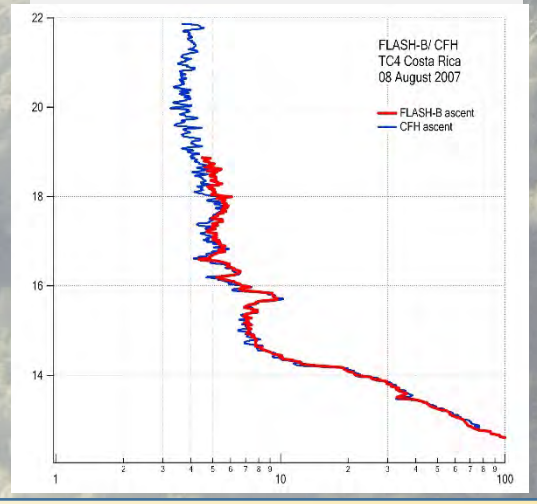
Total uncertainty (calibration error + 1σ precision) is below 10% at stratospheric conditions.

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

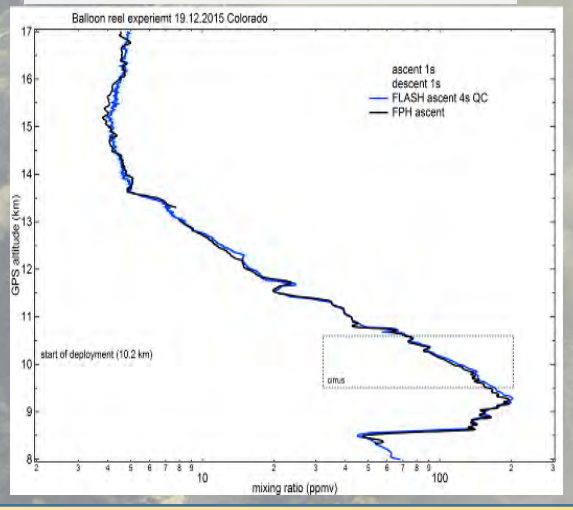
Comparison with Pico-SDLA



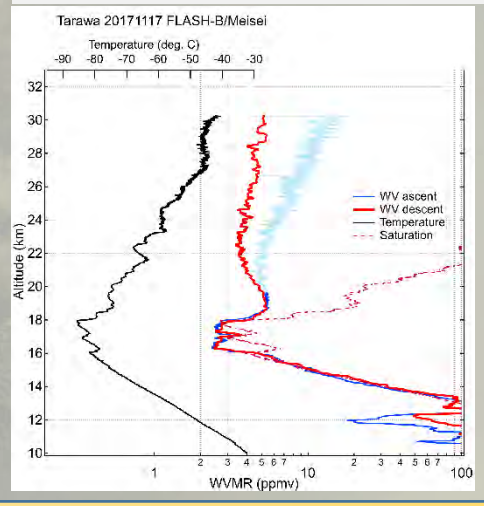
Comparison with CFH



Comparison with FPH

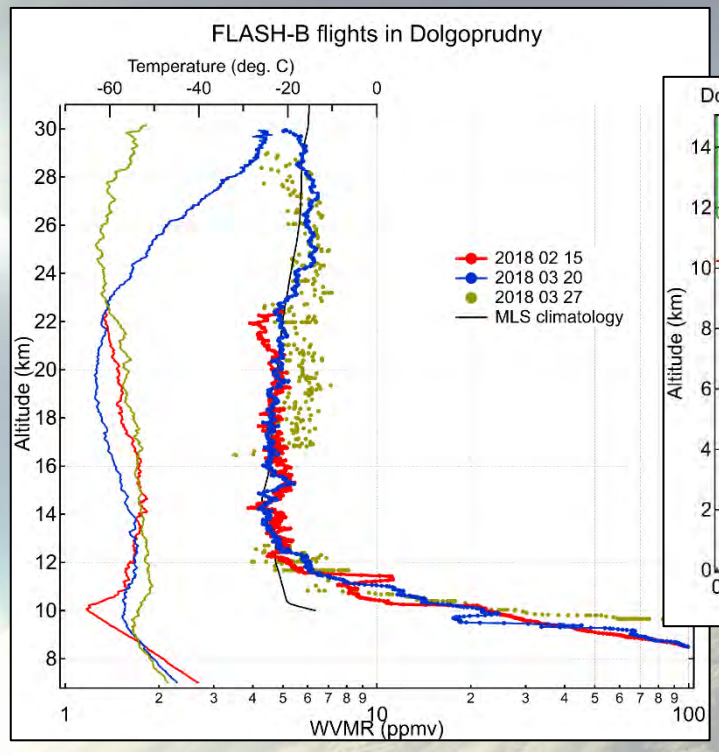


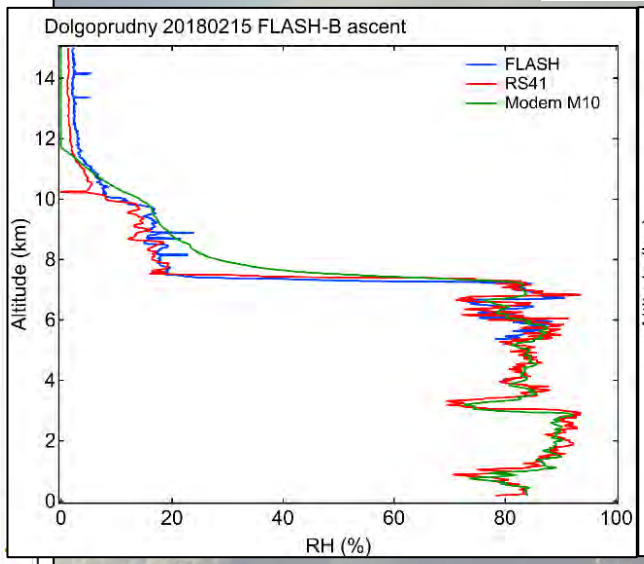
In-flight repeatability

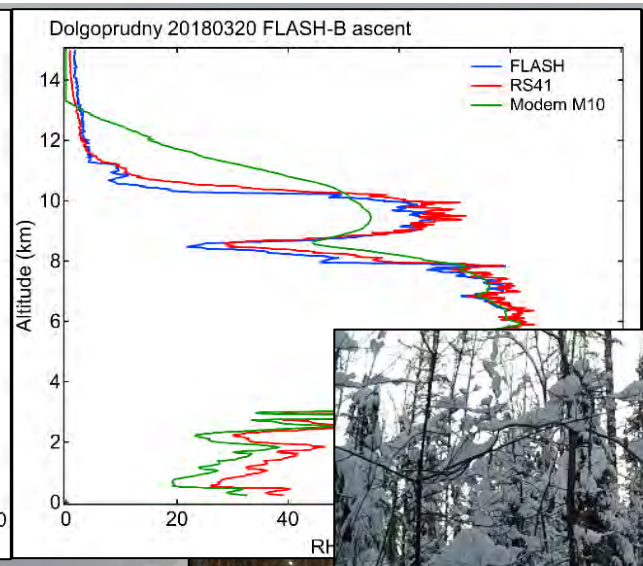


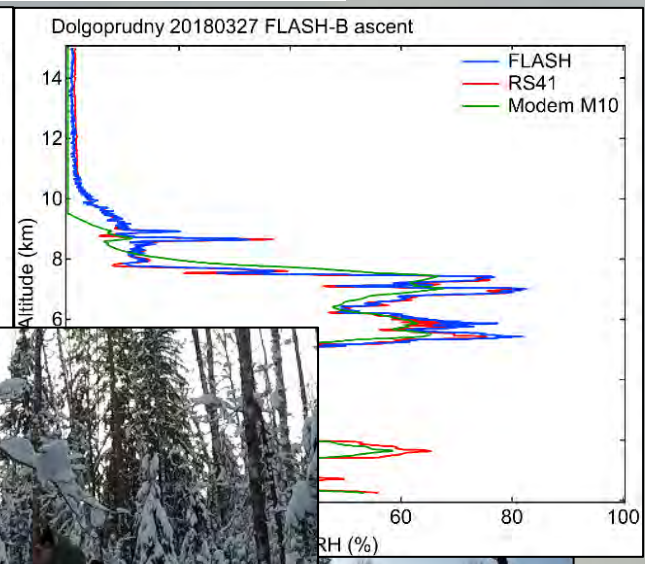
Flights in Dolgoprudny

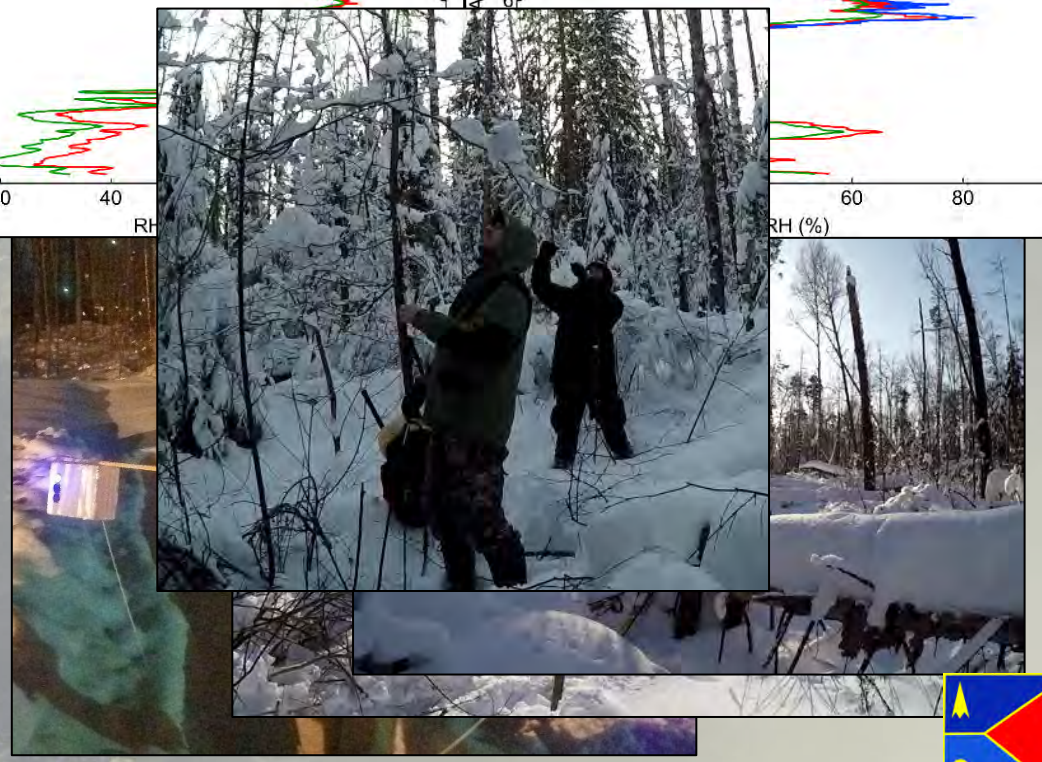
Tropospheric comparison with RS41 and M-10





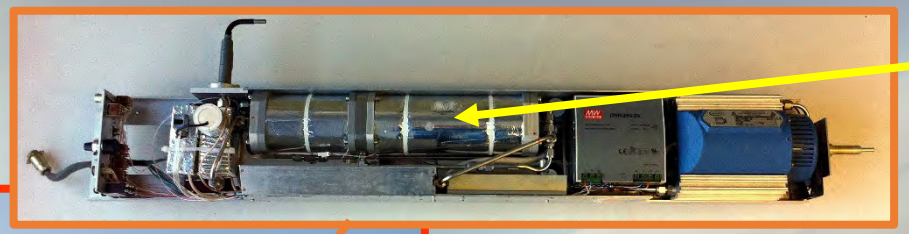


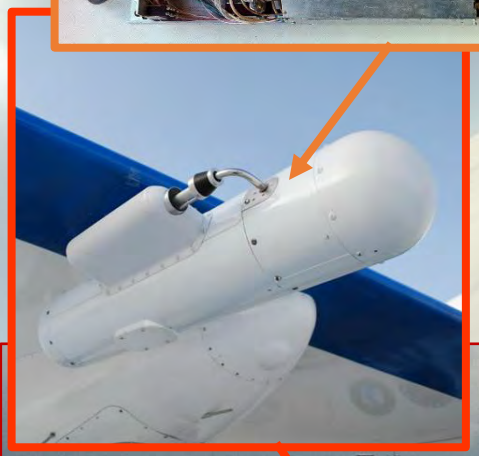




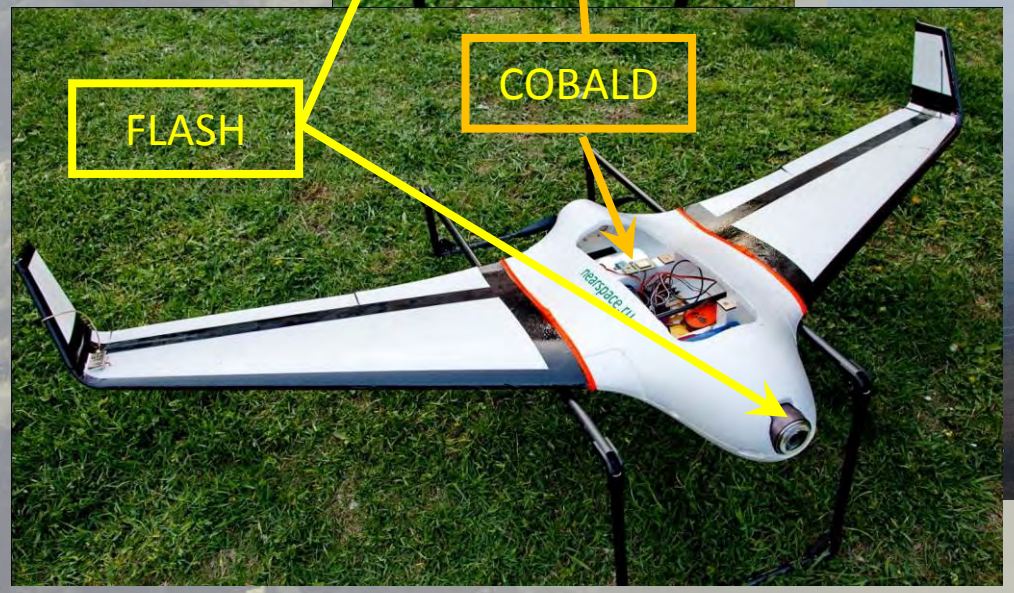
- made 3 consecutive flights of the same FLASH sonde in Dolgoprudny with a series of calibrations before and after each flight
- Consistent water vapour vertical profiles in the stratosphere and good agreement with M10 and RS41 in the free troposphere
- Small change of sensitivity factor (<10 %) in between the calibrations/flights

Application on different platforms





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



Summary

1. **FLASH-B sonde is a well established instrument capable of accurate water vapor measurements in the upper troposphere and stratosphere;**
2. **Fluorescence method ensures very fast response time and high capacity in resolving fine structures in vertical profile;**
3. **Calibration of the instruments is performed using reference MBW frost-point hygrometer, ensuring measurement traceability;**
4. **Basic documentation already provided to GRUAN, estimated error budget, total uncertainty <10 %;**
5. **FLASH-B performance and metrological characteristics have been validated in a large number of field intercomparisons (NOAA-CMDL, CFH, FPH, Pico-SDLA etc.);**
6. **FLASH-B is plug-and-play instrument allowing fast and easy flight preparation, interfaced with most of the existing radiosondes;**
7. **Possibility of multiple usage of FLASH sondes, provided access to calibration facility;**
8. **Made 3 consecutive flights of the same FLASH sonde in Dolgoprudny by GRUAN program, good agreement with RS41 and M10 in troposphere;**
9. **Application onboard aircraft and UAV;**