Fluorescence Lyman-Alpha Stratospheric Hygrometer for Balloon (FLASH-B)
**Measurement method**

\[ \text{H}_2\text{O} + h\nu \rightarrow \text{OH} \left( A^2\Sigma^+ \right) + \text{H}(2S) \]

Fluorescence

\[ \text{OH} \left( A^2\Sigma^+ \right) 
\rightarrow \text{OH} \left( X^2\Pi \right) + h\nu' \]

Quenching

\[ \text{OH} \left( A^2\Sigma^+ \right) + \text{N}_2, \ \text{O}_2 \rightarrow \text{products} \]

**Source of VUV radiation**

\( \lambda = 121.6 \text{ nm (Lyman-}\alpha) \)

300 < \( \lambda < 330 \text{ nm} \)

**PMT**

\[ I_{fl} = \frac{[\text{H}_2\text{O}] \cdot J \cdot \varphi \cdot A}{k_q \cdot [\text{air}] + A} \]

at \( P > 7 \text{ hPa} \)

\( k_q \cdot [\text{air}] \ll A \)

**Fluorescence intensity**

\( I_{fl} \)

**Photodissociation rate**

\( J \)

**Quantum efficiency**

\( \varphi = 0.05 \)

**Excited OH production**

\( A = 1.26 \cdot 10^6 \text{ s}^{-1} \) – Einstein coefficient,

\( k_q^{\text{air.}} = 2.3 \cdot 10^{-11} \text{ sm}^3 \text{ s}^{-1} \) – quenching coefficient of the excited OH in air
The analyzed volume is located outside the instrument at about 5 cm distance from the lamp window.

The fluorescent light, collected by the system of 3 quartz or plastic lenses concentrically arranged around the lamp, is focused onto the PMT cathode.
Technical parameters

Range of measurements: 0.5...1000 ppmv
Detection limit: 0.1 ppmv
Measurement cycle length: 1 sec
Integration time: 1 - 4 sec
Vertical resolution: ~ 50 m (descent in UTLS)
Uncertainty and detection limit: ±(10% + 0.1 ppm) @ 10 hPa < P < 30hPa, H2O > 3 ppm
Height range: 7 .. 35 km
Size, with ins. box: 250mm x 150mm x 70mm
Weight: 0.4 kg w/out batteries
Power, max: 12V, 0.6A

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Calibration

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

To PC

Vacuum pump

Vacuum chamber 50 mBar

freezer

MBW 373L

Compressor

flow controller

H$_2$O bubbler

dehumidifier

Reference dew point mirror hygrometer

Air pressure

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Calibration facility was created in Lindenberg include the dry air generator, calibration chamber, reference FPH MBW373 and software.

All recovered FLASH-B storing on shelf in LC was renew and recalibrated.
The total uncertainty of the calibration is determined by the following factors: uncertainty of the frost point measurement (0.1 K), uncertainty of the temperature dependence of the water vapor partial pressure, error in pressure determination, error accounting for inconsistency of the air sampled by the reference dew point hygrometer and the air inside the chamber, instability of the lamp emission. The total relative error of the calibration amounts to 4%. 
Calculation formula

\[ WVMR = J \times K(\text{cal}) \times K(\text{Quenching}) \times K(\text{absorb.H}_2\text{O}) \times K(\text{absorb.O}_2) \]

Absorption and quenching coefficients

\[ K(\text{Quenching}) = 1 + (Q \times N \times (P/P_0) \times (T/T_0) \times 10^6), \]

where \( Q = 2.3 \times 10^{-11} \), \( P_0, T_0 \) - surface pressure and temperature

\[ K(\text{absorb.H}_2\text{O}) = \exp(-0.0001054 \times \mu \times P/T \times L), \]

where focus \( L = 5 \text{ cm} \), \( P, T \) - pressure and temperature

\[ K(\text{absorb.O}_2) = \exp(-0.0001536 \times P/T \times L) \]

If \( P < 36 \mu = J \times K(\text{cal}) \times 0.956 \times (1 + 0.000781 \times (t + 273.16)/P) \)

If \( 36 < P < 300 \mu = J \times K(\text{cal}) \times (1 + 0.00031 \times P + 0.00033 \times K(\text{cal})^2 \times P \times J) \)
Preparation for flight

1. Fixing face down
2. Connect to radiosonde
3. Switch on
4. Check the data incoming
5. Open cap
6. Ready to fly!

Sealant recommended against contamination in stratosphere

Plug-and-play concept
Results

Contamination during ascent in downward-looking position of FLASH

The measurement precision is 5.5% calculated for 4 s integration time at stratospheric conditions.

Total uncertainty (calibration error + $1\sigma$ precision) is less than 10% at stratospheric conditions.
Comparisons vs RS41

Winter 2017 in Lindenberg 4 FLASH-B was calibrate, have flights, data processed and made comparison by LC staff according with provided technical documentation.
### Comparisons vs CFH

**NASA TC4, Costa-Rica**

![Graph showing temperature comparison](image)

**LUAMI UPPER-AIR intercomparison campaign, Lindenberg**

![Graph showing temperature comparison](image)

**LAPBIAT, Sodankyla**

![Graph showing temperature comparison](image)

**SOWER-2009, Biak, Indonesia**

![Graph showing temperature comparison](image)

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LUAMI campaign

FLASH-B / SRS / Snow White
LUAMI 06.11.2008 ascent

Temperature, deg. C

Height, km

RH, %

Temperature

FLASH-B
Snow White
CFH
COBALD

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AQUAVit chamber intercomparison campaign

Difference FLASH-B - reference

Experimental precision

Fahey et al., 2014

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Intercomparison of FLASH-B and Pico-SDLA

TRO-Pico, Bauru Brazil, February 10-11, 2013

- Water vapor profiles
  - Ascent FLASH-B
  - Descent FLASH-B
  - Descent Pico-SDLA
- Temperature profiles
  - Pico-SDLA
  - FLASH-B

TTL upper limit (Fueglistaler, 2009)

mean difference 0.5 % ((0.02 ± 0.21) ppmv)

TRO-Pico, Bauru Brazil, March 13, 2012

- Mixing ratio profiles
  - Ascent FLASH-B
  - Descent FLASH-B
  - Descent Pico-SDLA H2O
- Temperature profiles
  - FLASH-B
  - Pico-SDLA

mean difference 1.9 % ((0.08 ± 0.39) ppmv)

Ghysels et al., 2015, AMT
FLASH vs FPH intercomparison

Test of FLASH-B on a reeled device, Wiggins, CO

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Clouds and dehydration

FLASH and COBALD flight sampling the same air mass at CPT twice

Cirrus with extreme supersaturation (165%) and low backscatter

Subsaturated cirrus with high backscatter

Balloon ascent

Balloon descent

\( T_{\text{min}} = 187.8 \, \text{K} \)
Interface and features

• integration with:
  Swiss Meteolabor radiosonde SRS-34
  Vaisala RS-80, RS-92, RS-41
  MESEI RS-6G, RS-11
  Internet radiosonde by XDATA protocol
  MODEM M10 (in process)

• Low power electronics (less 6 Watts)

• Built-in pressure sensor for safety switch on/off on altitude

• 1 month capacity data logger

• Use 4xC or 8xAA size Lithium batteries or 18650 rechargeable LiPol batteries

• Reusable

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FLASH-B sonde is a well established instrument capable of accurate water vapour measurements in the upper troposphere and stratosphere. Fluorescence method ensures very fast response time and high capacity in resolving fine structures in vertical profile. Calibration of the instruments is performed using MBW frost-point hygrometer, ensuring measurement traceability. FLASH-B performance and metrological characteristics have been validated in a large number of field intercomparisons (NOAA-CMDL, CFH, FPH, Pico-SDL etc.). FLASH-B is plug-and-play instrument allowing fast and easy flight preparation. Existing interfaced with most of the existing radiosondes. Possibility of multiple usage of FLASH sondes, provided access to calibration facility. Basic documentation already provided to GRUAN, detailed error budget description in preparation.