Fluorescence Lyman-Alpha Stratospheric Hygrometer for Balloon

(www.flash-b.ru)

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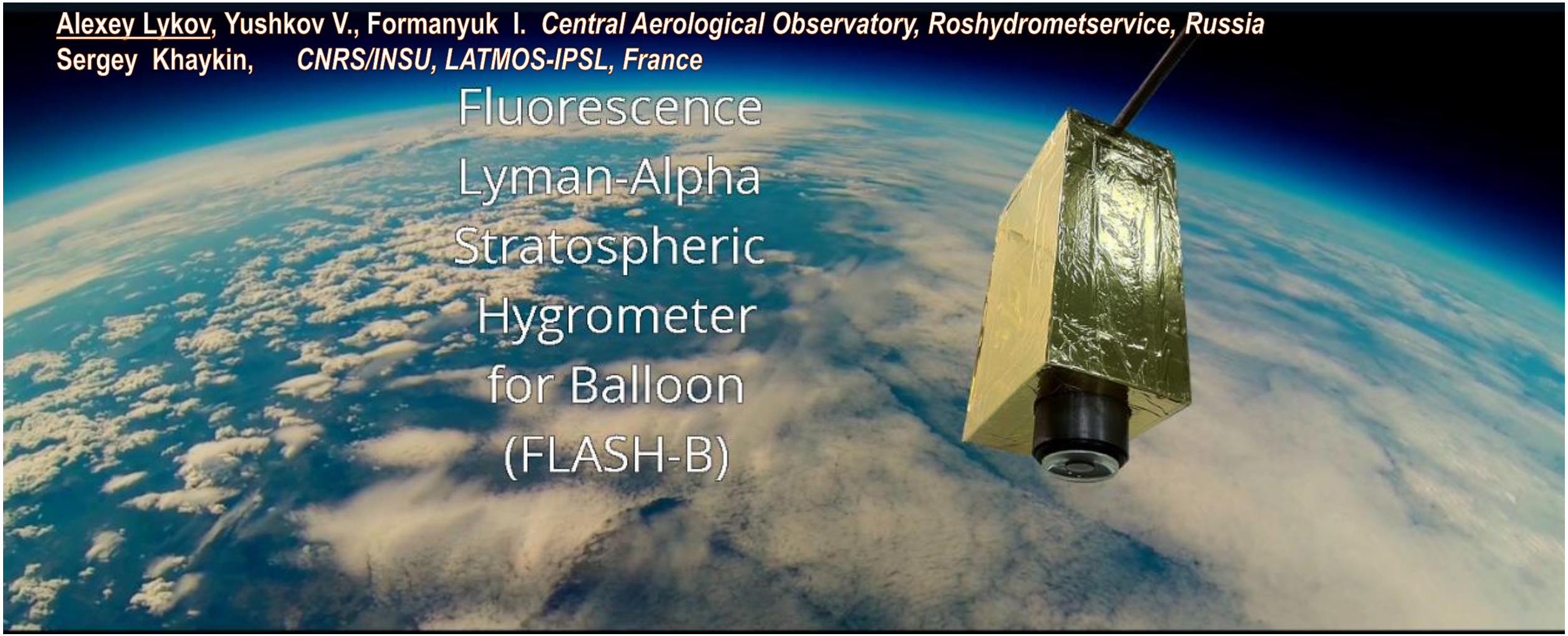
Sergey Khaykin, *CNRS/INSU, LATMOS-IPSL, France*



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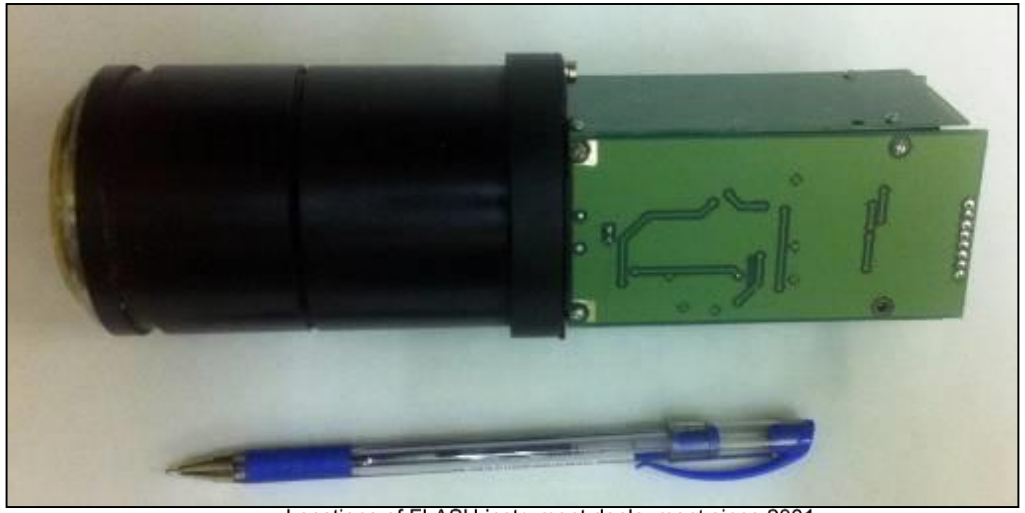
FLASH modification for different platform

- **Fast ultra-compact hygrometer applied in 18 international campaigns on all stratospheric platforms**
- **Reference for stratospheric H_2O**

Geophysica high-flying aircraft (FLASH-A);

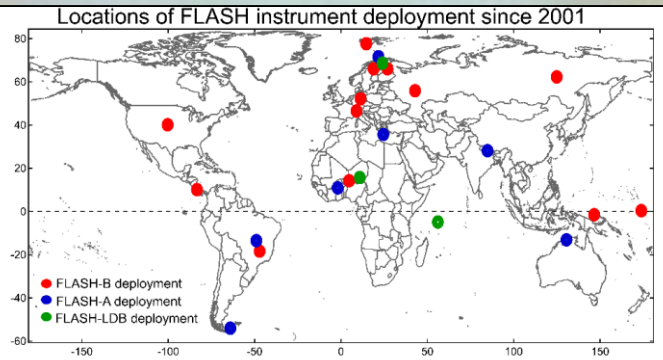
Yak-42 aircraft (VFG-1)



Range of measurement	*0.5...1000 ppmv*
Time resolution	*1 sec*
Detection limit	*0.1 ppmv*
Total uncertainty	*< 8 %*
Required power	*12 V, 1 W max*
Weight (w/o batteries)	*400 gr*

Small balloons (FLASH-B);

long-duration balloons (FLASH-LDB)



FLASH-B is lightweight optical hygrometer gives a fast response measures in UTLS

30+ publications

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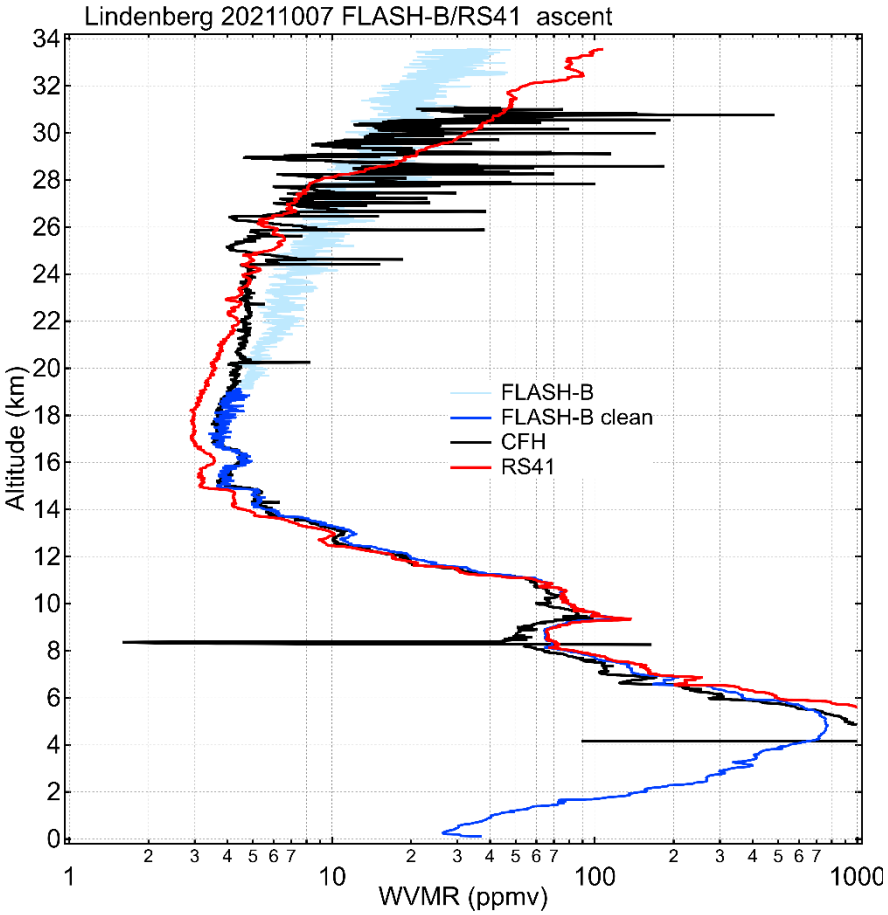
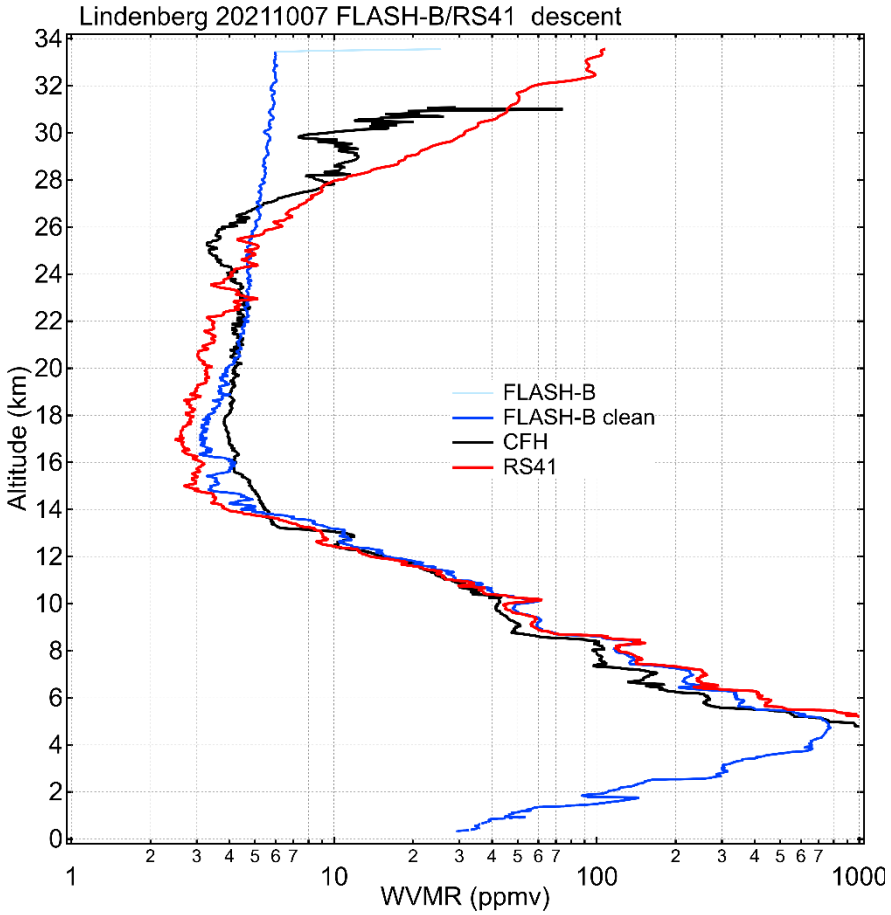
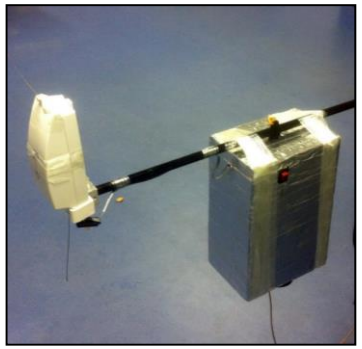
Flight in Lindenberg in October 2021 with RS41 and CFH.





Plug-and-play concept:

1. **Connect to radiosonde;**
2. **Switch on;**
3. **Open cap;**
4. **Fly.**



Calibrated in MOL and used this cal K for flight data. Finalized full xdata connection for combined flight with other instruments

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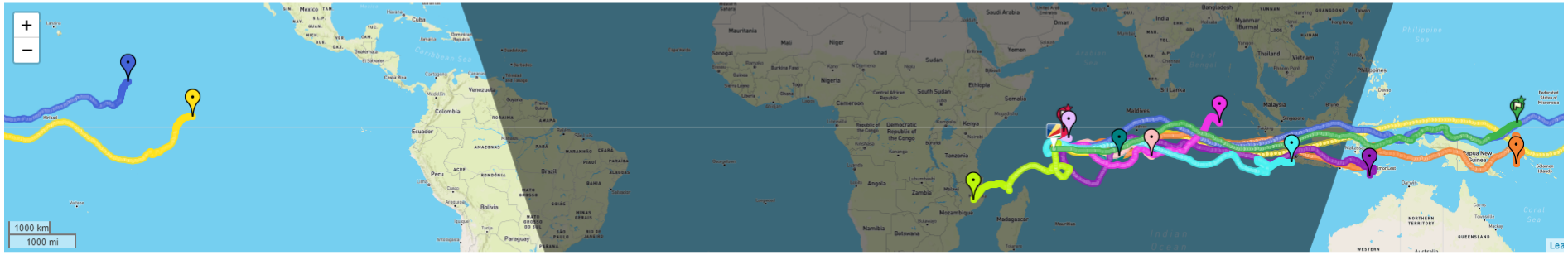
Strateole2 is a French-US project aimed at study of **small-scale processes** in the tropical LS using a fleet of **long-duration balloons. First Science Flight Campaign (**Oct-Dec2021) **(**https://webstr2.ipsl.polytechnique.fr/#/**)**

Strateole2

Long-duration balloon flights across the tropics to study atmospheric dynamics and composition

Select a campaign C1 - 2021

Zephyr Operations Manager
Call Albert: +33 6 03 91 58 34
If no answer, call Karim: +33 6 26 09 96 86
Email: str2ccmz@ipsl.polytechnique.fr



STRATEOLE 2 FLIGHTS

Flight	Type	Phase	Lat	Lon	Alt	Launch (UT)	Termination (UT)	Duration	Gondola	Latest Iridium Call (UT) Date	Duration	Status
ST2_C1_01_TTL5	TTL5	Terminated	-0.815	57.776	18425	2021-10-19 22:07	2021-10-21 06:22	1 days, 6 hours, 15 mins	ST2_C1_TTL5_51	2021-10-21 13:16	0:03:09	OK
ST2_C1_02_STR1	STR1	Terminated	0.850	153.965	6	2021-10-20 00:35	2021-11-01 13:08	12 days, 11 hours, 33 mins	ST2_C1_STR1_52	2021-11-01 13:09	0:02:31	OK
ST2_C1_03_TTL4	TTL4	In Flight	2.225	-127.166	18657	2021-10-20 21:40		23 days, 0 hours, 10 mins	ST2_C1_TTL4_51	2021-11-12 21:43		OK
ST2_C1_04_STR2	STR2	In Flight	9.651	-140.766	20212	2021-10-20 23:54		22 days, 21 hours, 56 mins				OK
ST2_C1_05_TTL3	TTL3	In Flight	-7.700	153.564	18670	2021-10-27 22:21		15 days, 23 hours, 29 mins	ST2_C1_TTL3_51	2021-11-12 21:24	0:03:10	OK

S. Khaykin (LATMOS)

L. Kalnajs, S. Davis, T. Deshler (LASP)

Yushkov V., Formanyuk I. (CAO)

First Science Flight Campaign was performed 20 flights. The FLASH hygrometer flying on **TTL3** balloons as part of **RACHuTS** reeling system by Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado Boulder.

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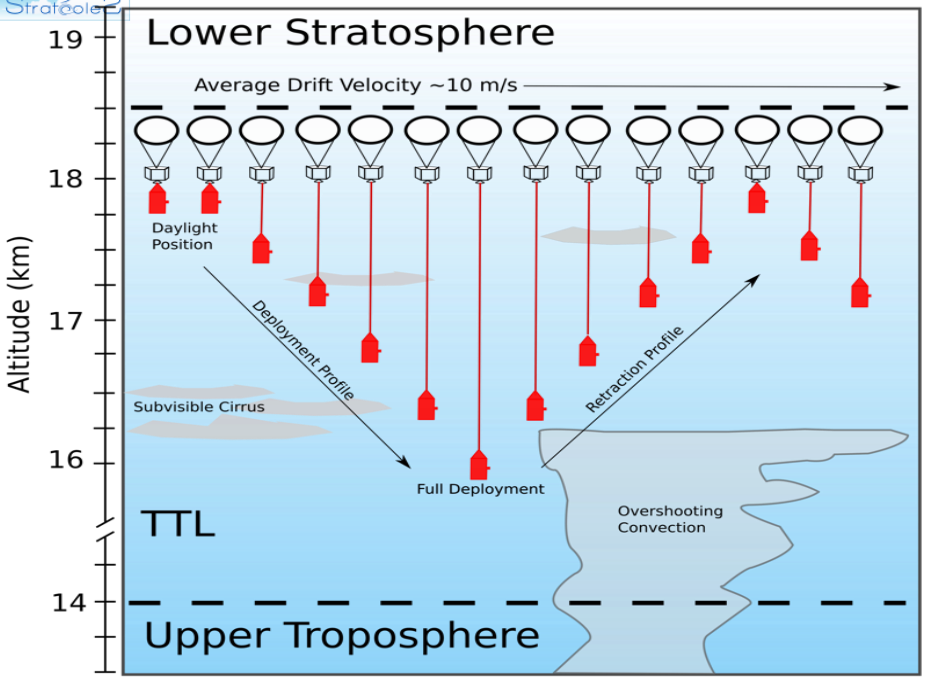
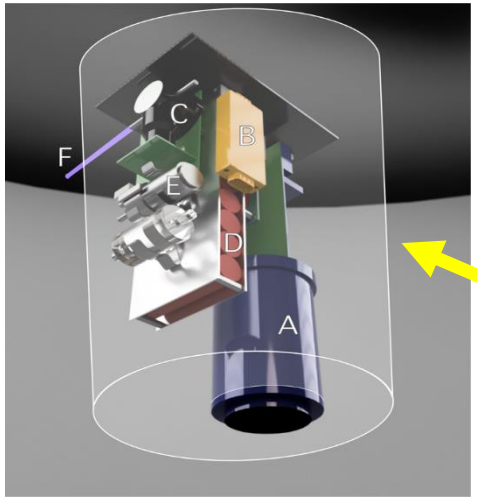
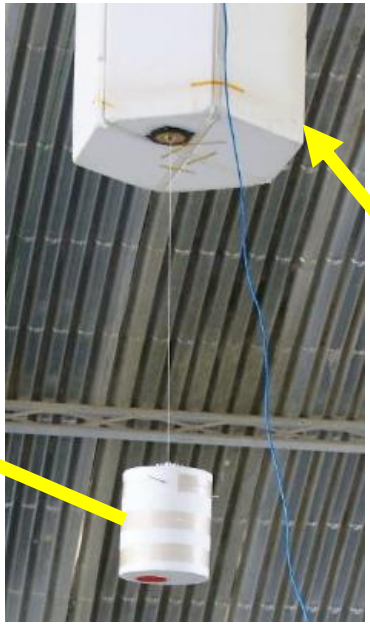
RACHuTS: Reeldown Aerosol Cloud Humidity and Temperature Sensor

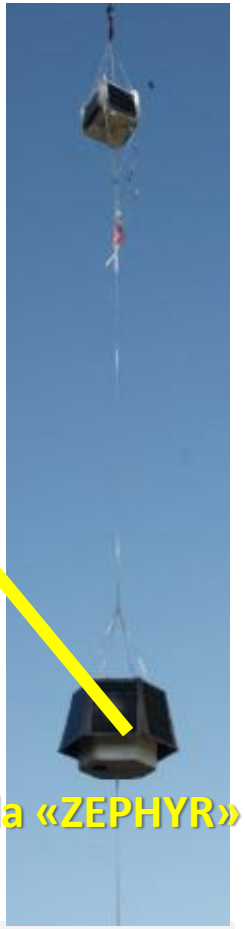


- Deployment of sensors 2 km below the gondola
- Up to 8 profiles during nighttime
- Now collected more than 51+21 profiles obtained during TTL3 flight

Deployable module







A: FLASH-B water vapor sensor;
B: TSEN temperature and pressure sensor
C: ROPC aerosol and cloud particle detector

Payload gondola «ZEPHYR»

amt-2020-347 Submitted on 29 Aug 2020

A Reel-Down Instrument System for Profile Measurements of Water Vapor, Temperature, Clouds and Aerosol Beneath Constant Altitude Scientific Balloons

Lars E. Kalnajs, Sean M. Davis, J. Douglas Goetz, Terry Deshler, Sergey Khaykin, Alex St Clair, Albert Hertzog, Jerome Bordereau, and Alexey Lykov

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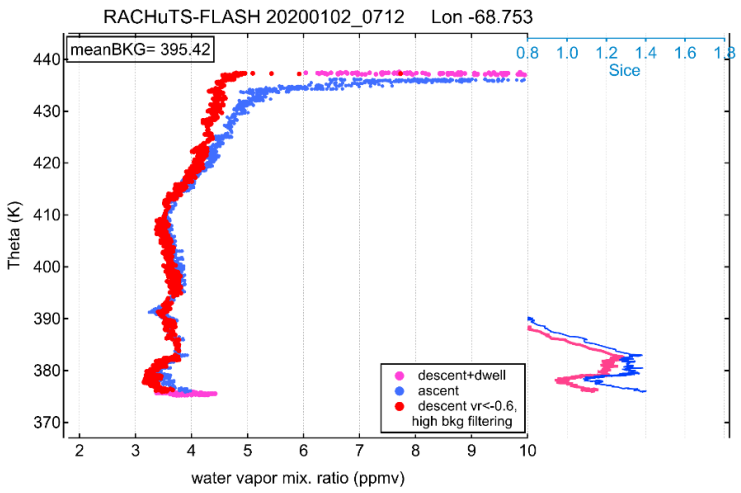
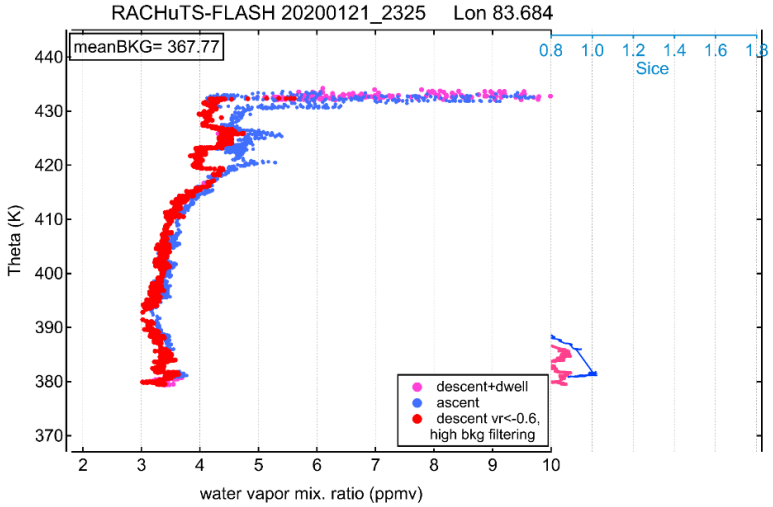
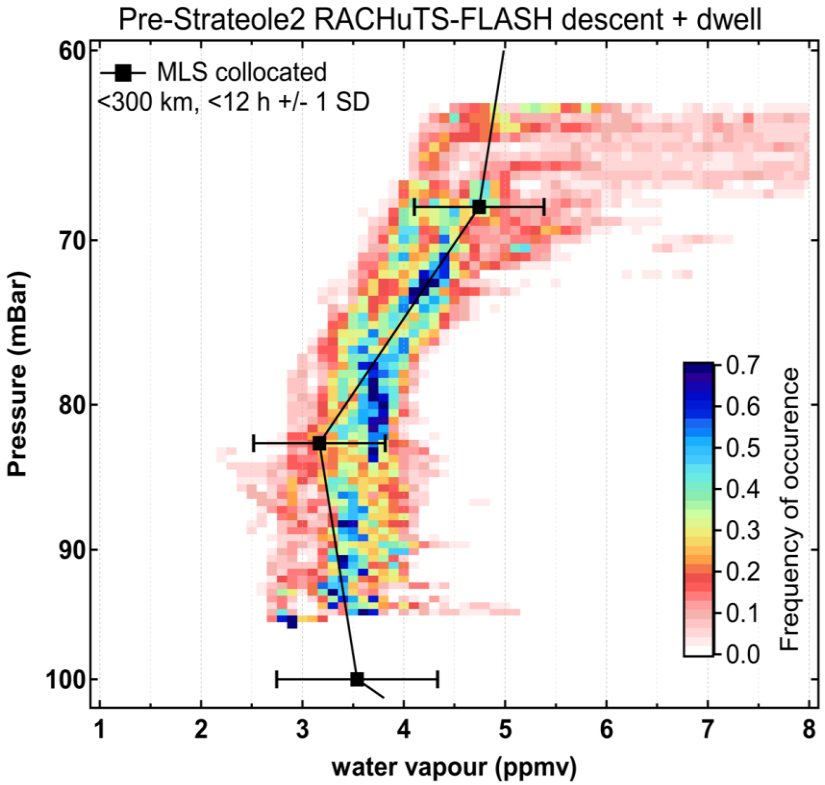
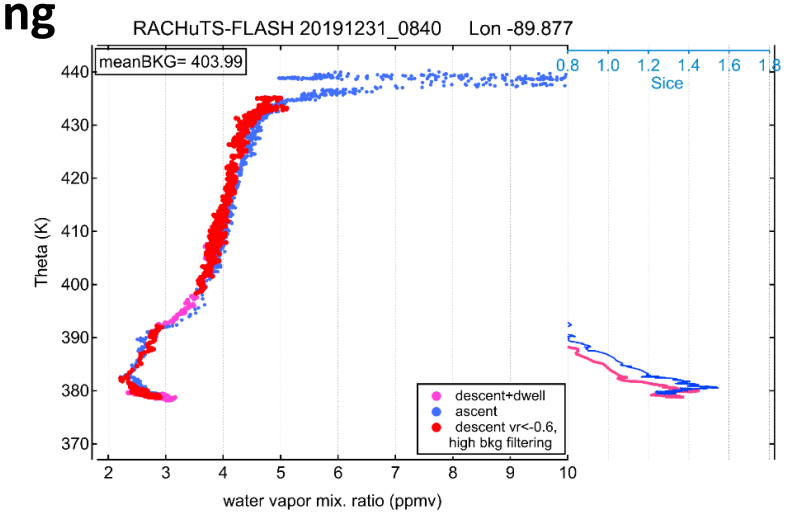
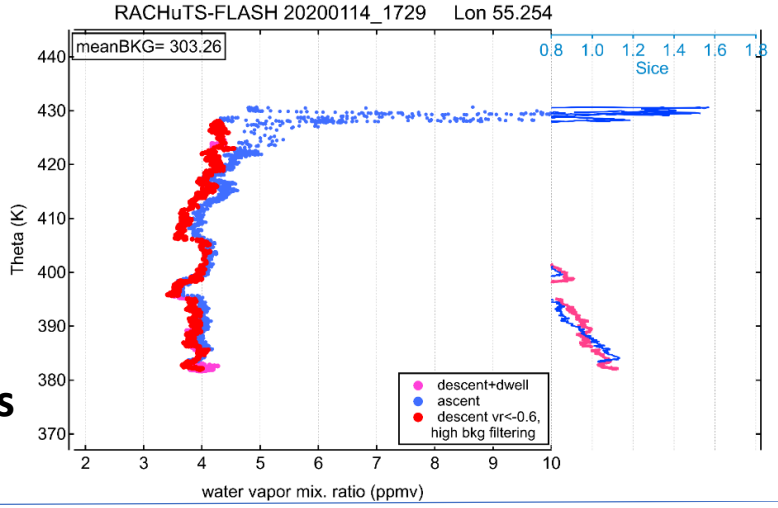
Examples of water vapour profiles during pre-Strateole2 (Dec 2019)











Excellent stability of the WV measurements by FLASH over 3 months!

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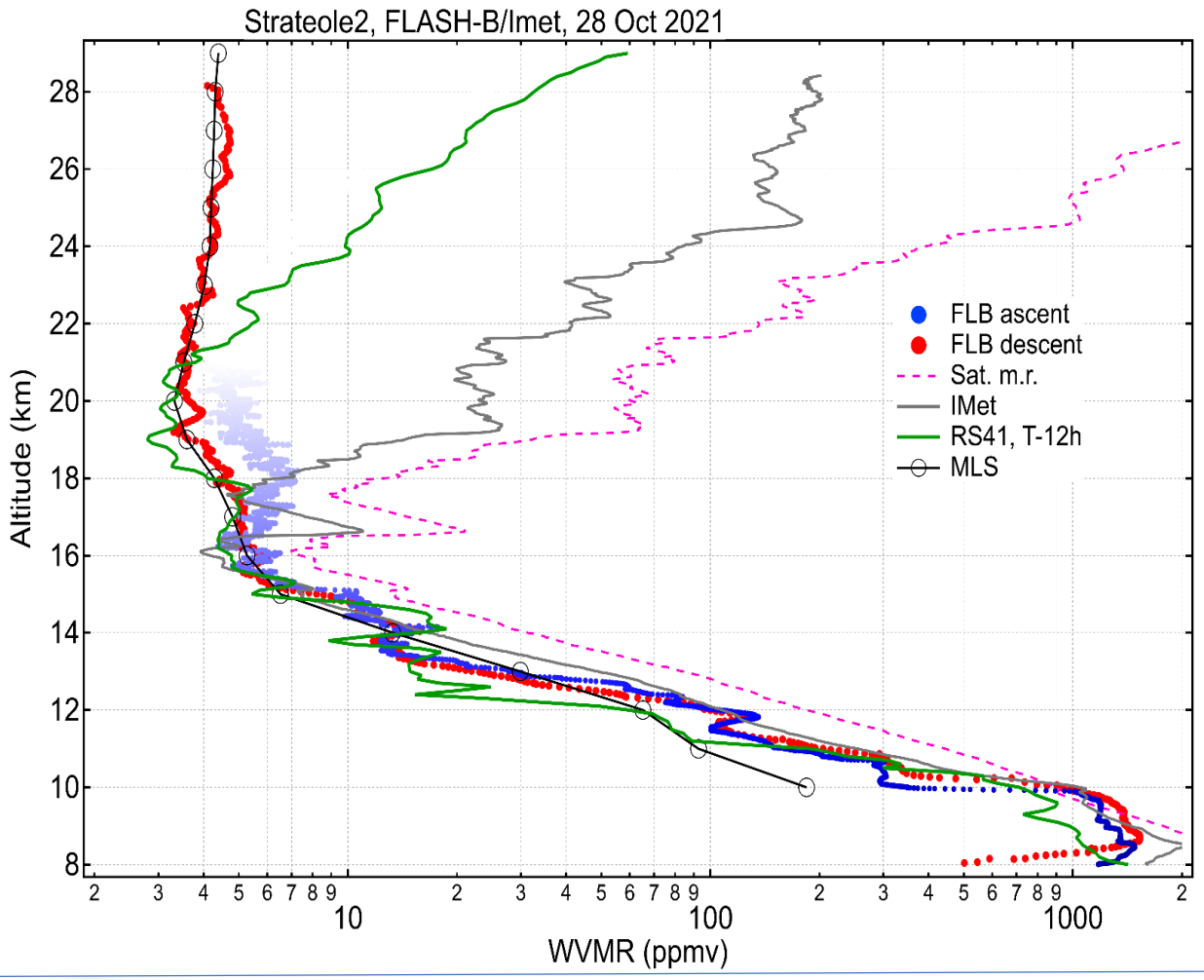
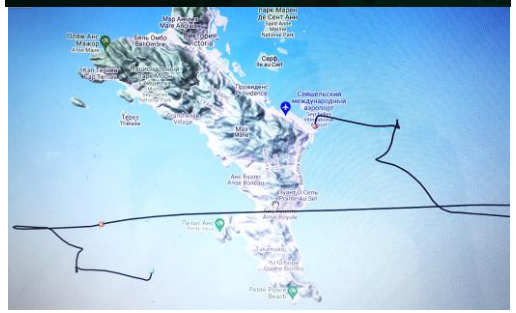
FLASH+AZOR (FLAZOR) flight in Seychelles and recovery on water



During Strateole2 a combined flight FLASH-B and AZOR backscatter sondewas performed on meteorological balloon with xdata stream to iMet-4 Radiosonde. Comparison ascend and descend data show very good agreement with local sonde RS41 and MLS satellite data.

18650 2,5 Ah rechargeable LiPol batteries were used. After landing in the ocean successfully recovered, and ready to be flown again



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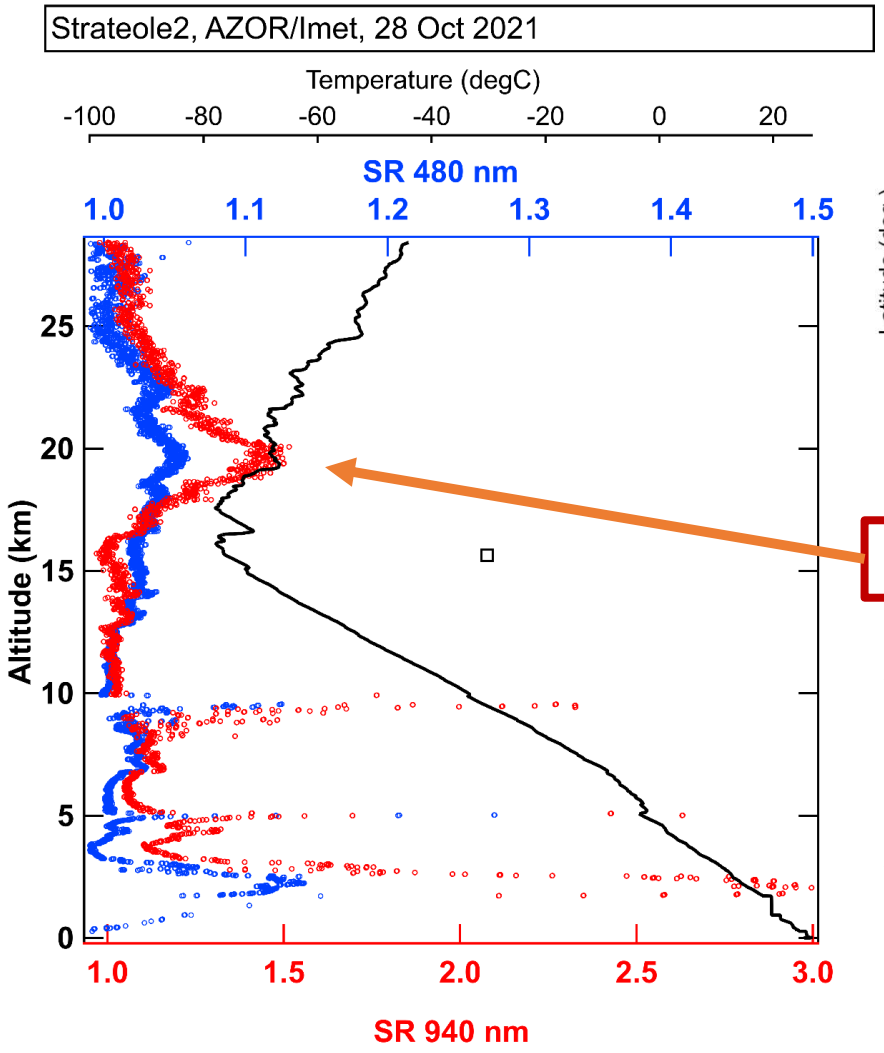
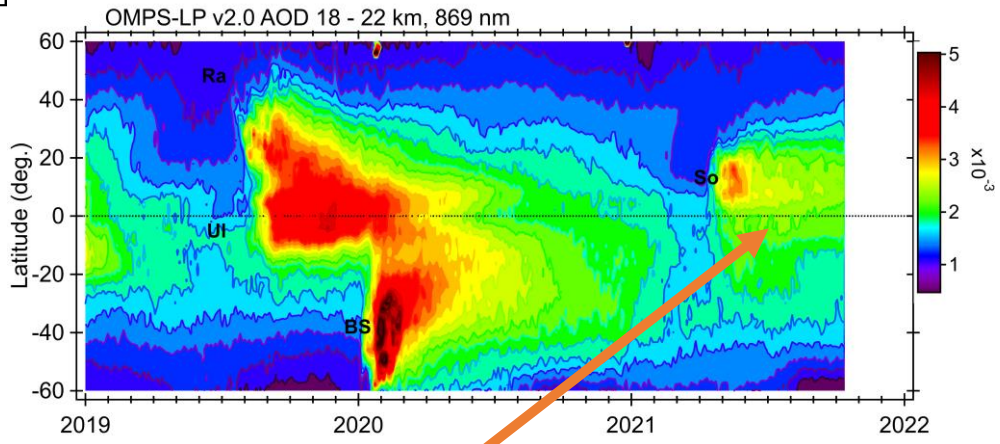
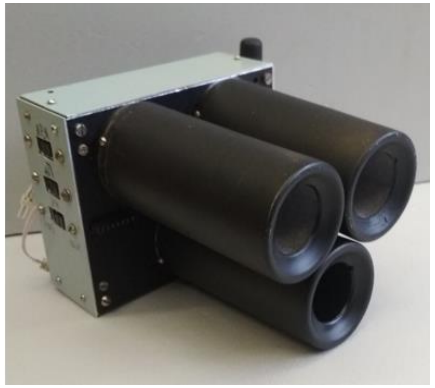


Aerosol backscatter sonde AZOR





AZOR captures aged volcanic aerosol from Soufriere Hills eruption in April 2021

AZOR is optical probe for in-situ studies of the vertical distribution of the aerosol component in UTLS. The principle of operation is based on the measurement of backscattering from a sequence of powerful light pulses. LEDs at 470 nm and 940 nm are used as light sources. The analyzed air volume is located at a close (0.5 m) distance from the light sources. Weight less than 1 kg. Price less than 1k $

Used for study PSC in north of Russia (2019) and participate in Strateole2 for study equatorial stratospheric aerosol distribution (2021).

Fluorescence Lyman-Alpha Stratospheric Hygrometer for Balloon

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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)

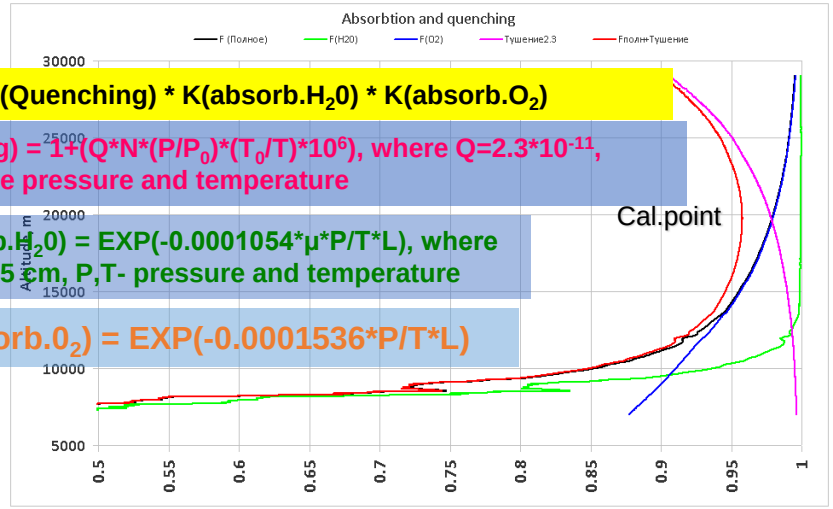
Total relative error of calibration is estimated at 4% (1 σ)

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.

- TD prepared to be provided to GRUAN lead center, but needs revisions regarding last changes of FLASH instrument
- Error budget provided in PhD thesis by S. Khaykin, 2005.
- A lot of publications with results of comparisons



WVMR = J*K(cal) * K(Quenching) * K(absorb.$H_2$0) * 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_2$0) = 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)

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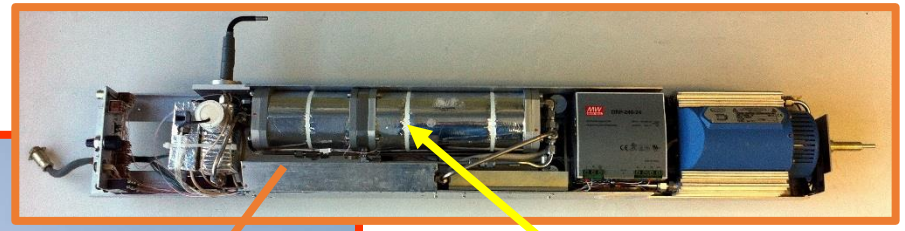

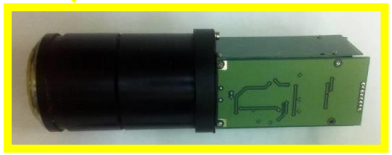

FLASH-B

The Flash hygrometer was used on board stratospheric aircraft "Geophisica" M55 during StratoClim campaign

Parameter	Geophysica
Water vapour	FLASH-A
Ice water content	FISH/FLASH
HDO/H_2O	ChiWIS
Carbon monoxide	COLD, AMICA
Temperature	TDC UCSE
Cloud backscatter and depolarization	MAS (in situ) MAL (remote)
Cloud tops	MAL (remote)

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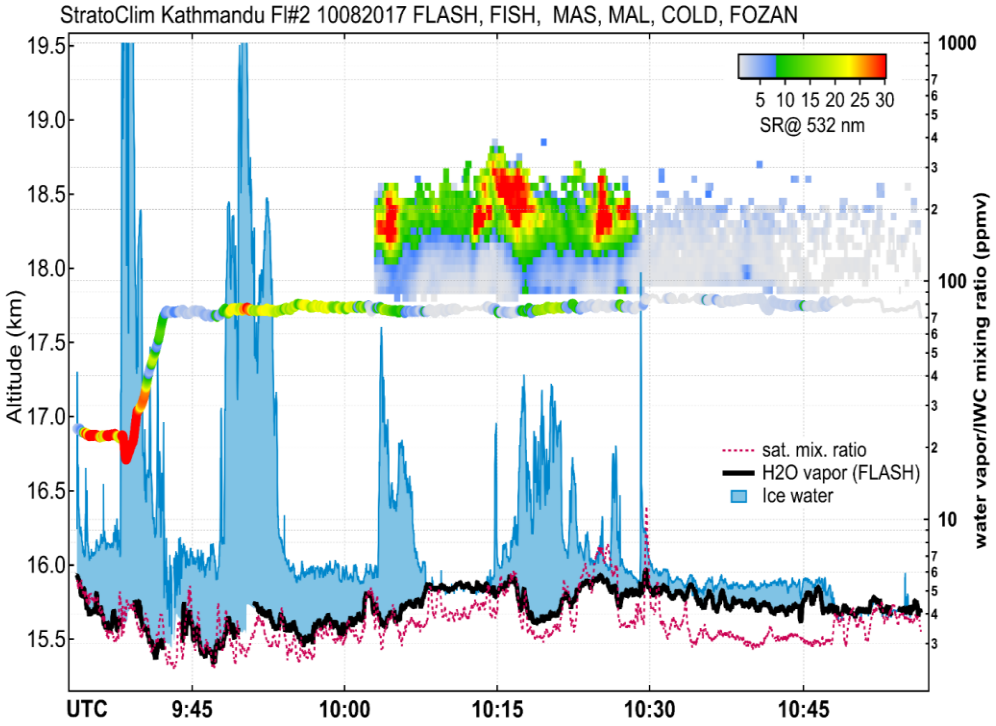

- Flight through active overshoots and fresh outflow (**IWC up to 2500 ppmv, 600 µm crystals at 385 K !!!**)

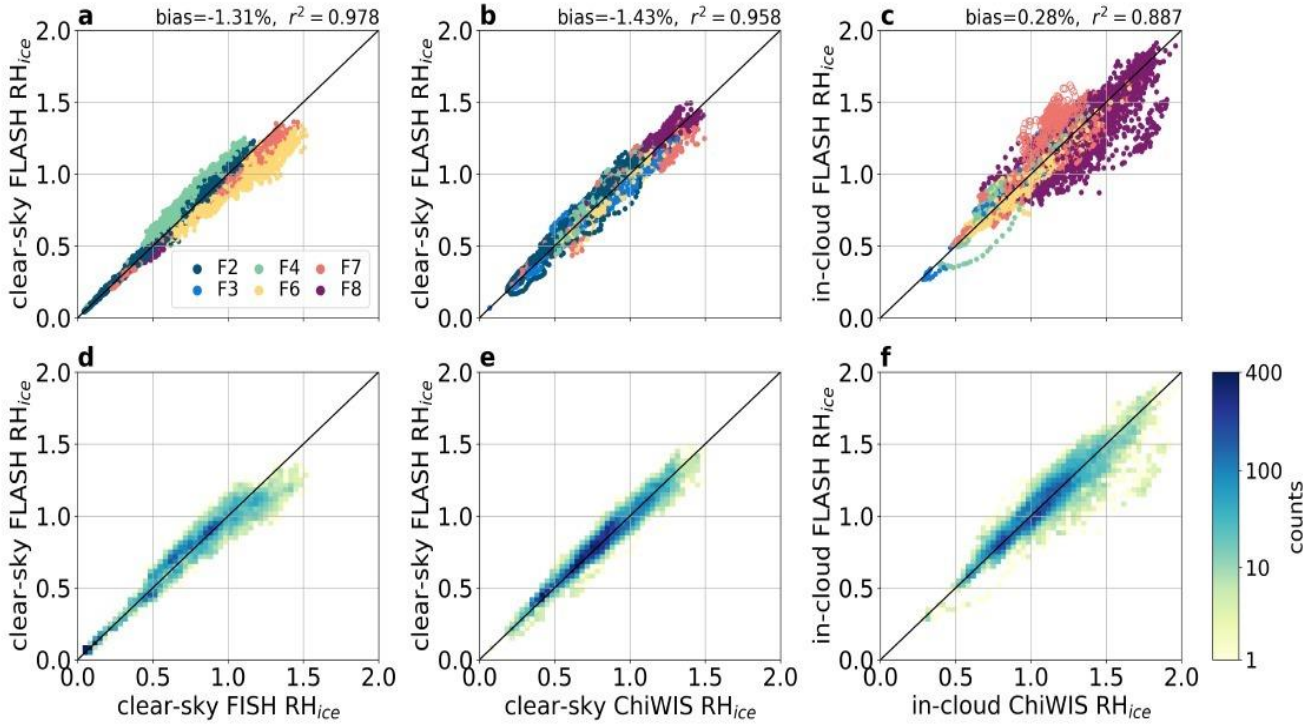

Figure 7. RH_{ice} correlations between the three in situ hygrometers: a) clear-sky FISH vs. clear-sky FLASH, b) clear-sky ChiWIS vs. clea sky FLASH, c) in-cloud ChiWIS vs. in-cloud FLASH. Points are colored by flight number and plotted in random order. The open circles panel c) on F7 mark the time period of disagreement between ChiWIS and FLASH as the airplane was ascending out of a deep dive. Pane d)-f) show the same information as a)-c) but as the frequency of observations over all the flights in each 0.3 by 0.3 bin. The one-to-one lir is plotted in black. The percentage difference and r^2 coefficients are shown above each panel.

Summary

- **FLASH is the smallest stratospheric hygrometer adapted for every existing airborne platform**
- **Excellent performance and remarkable stability during Strateole2 test campaign throughout the entire TTL3 flight**
- **Participation in Strateole2 campaign 2021-2022: 3 flights under TTL3 and 2 flights on rubber balloon**
- **Lesson learnt: imprecise tuning of lamp duty cycle may cause temperature-dependent offset in fluorescense signal**
- **Future FLASH experiments:**
  - Joints flights in 2021 with GSMA Pico and LPC2E micro within HEMERA WP11 in Aire-Sur-l'Adour
  - AQUAVIT-4 intercomparison campaign (AIDA facility, KIT)
  - Flights within ACCLIP campaign in South Korea