

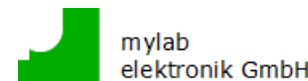
# PCFH – Peltier Cooled Frost point Hygrometer

ICM-12, Virtual meeting, 2020  
R23 replacements

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participation of other group members for the launch and recovery  
with support of DWD, MeteoSwiss and AWIPEV for launch and recovery

<sup>1</sup>. ETH Zürich, Switzerland

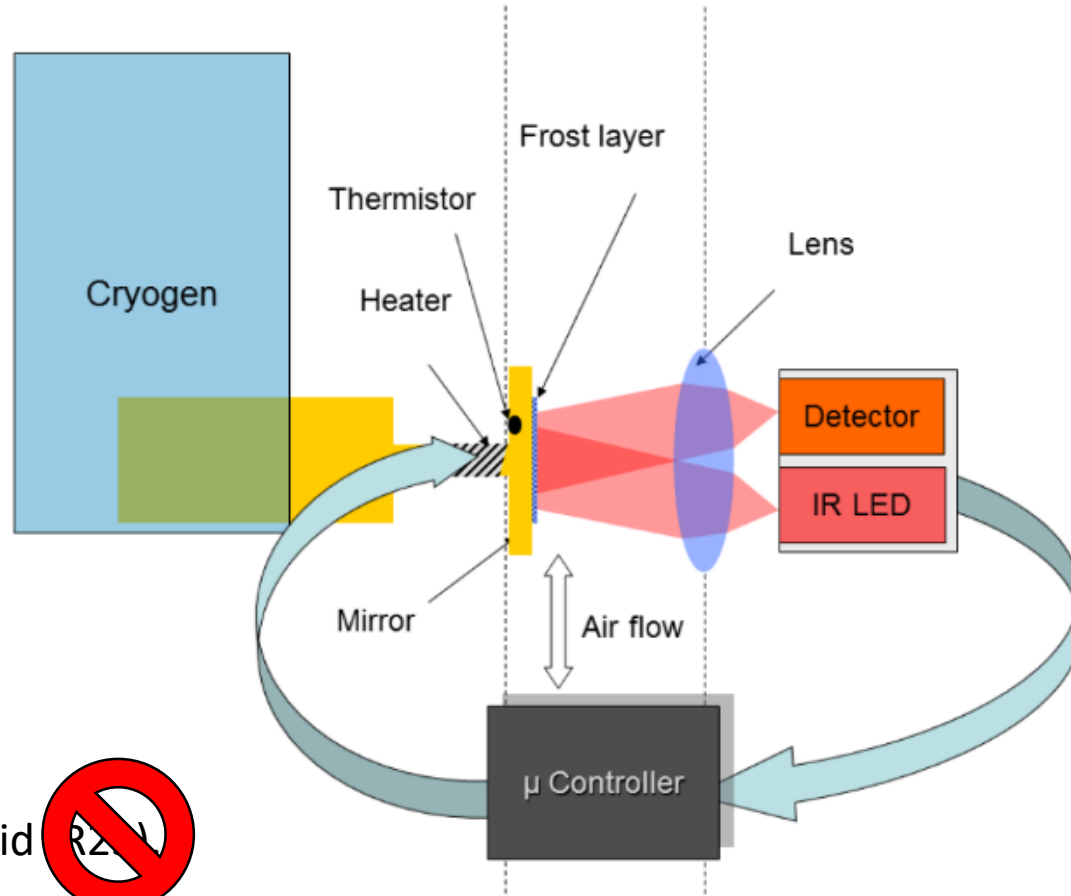
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# Water vapour

A dramatic sky scene with a sun partially obscured by clouds, casting a bright glow. The foreground shows dark silhouettes of mountains.

# CFH and FPH- Cryogenic Frost point Hygrometers



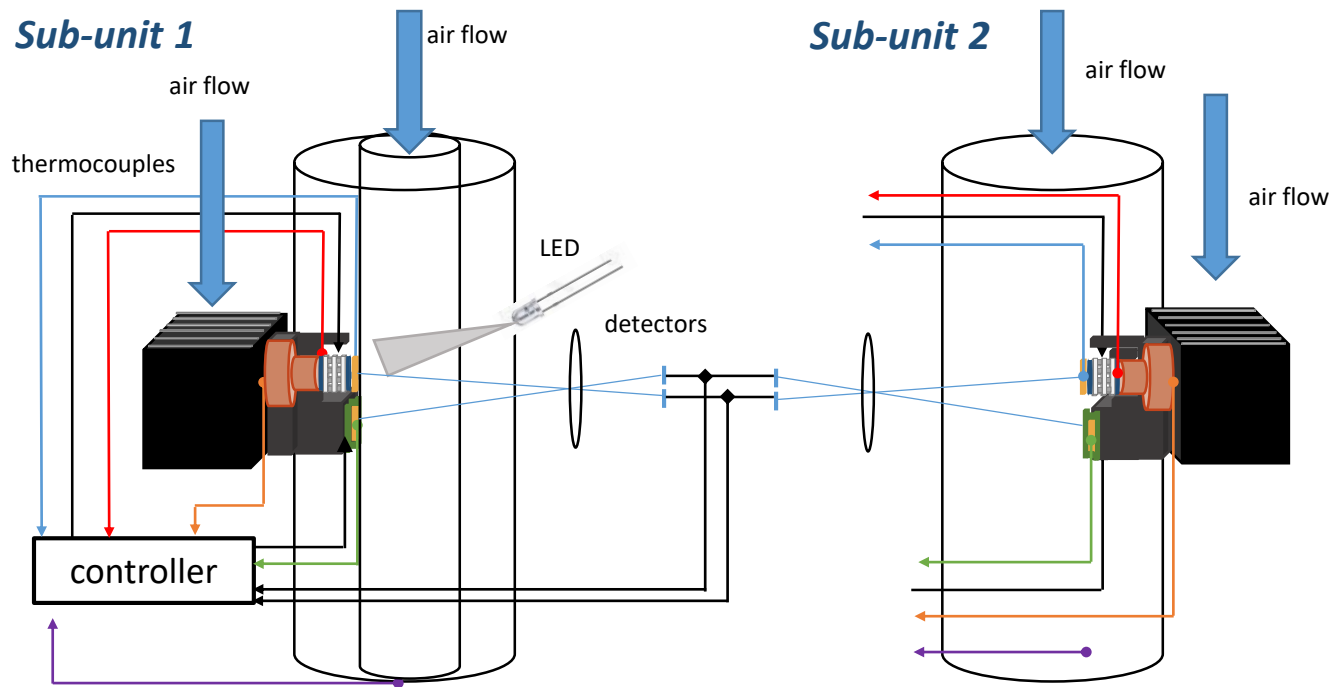
- Reference instrument;
- Cooling with cryogenic liquid



Vömel et al., 2007  
Fahey et al., 2014  
Hall et al., 2016  
Vömel et al., 2016

Due to cryogenic liquid phase-out, we need a new solution for water vapour monitoring.

# PCFH - Instrument description



$T_{mirror}$ ,  $T_{hot}$ ,  $T_{sink}$ ,  $T_{refsurf}$  &  $T_{air}$

Peltier-cooled Frost point Hygrometer (PCFH)

- In-house development since 2015
- Double stage Peltier element
- Ambient air as only cooling agent (heat sink)
- Detection scheme with reference surface
- Thermocouples for 5 different temperature measurements per sub-unit
- Twin instrument construction
- Shared electronics and communication

But the most important novelty is

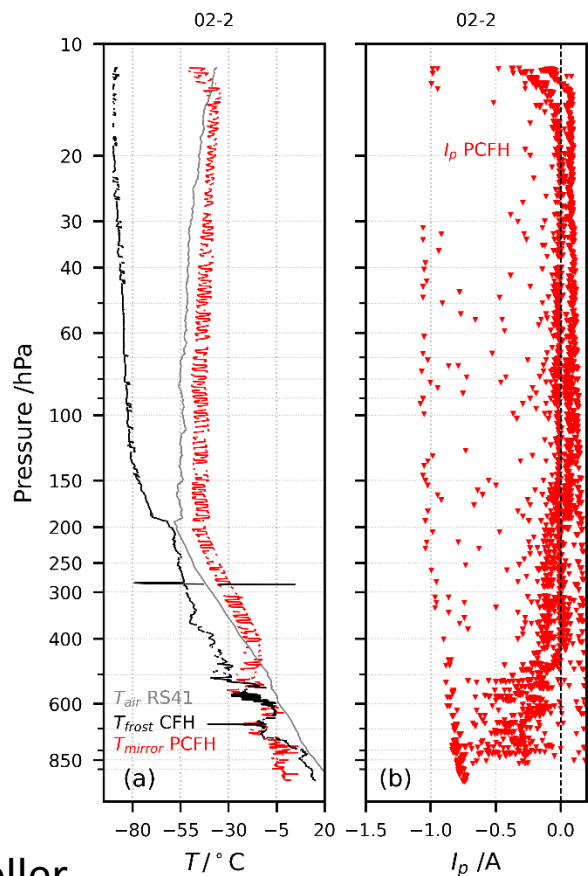
- **the possibility to program the instrument with different controller schemes**

Technical challenge:  
reach comparable cooling with double stage Peltier element and heat sink  
as the CFH and FPH do with cryogenic liquid

# Outline

- Introduction of some controller examples
  - Used for thermal and optical characterization
- Overview of PCFH flights
- Results of thermal characterization
- Results of optical characterization
  - PID controller flights from Ny-Ålesund
  - 'bias update' reflex relay controller flights from Zürich
- Summary and next steps

# Controller examples – thermal characterization

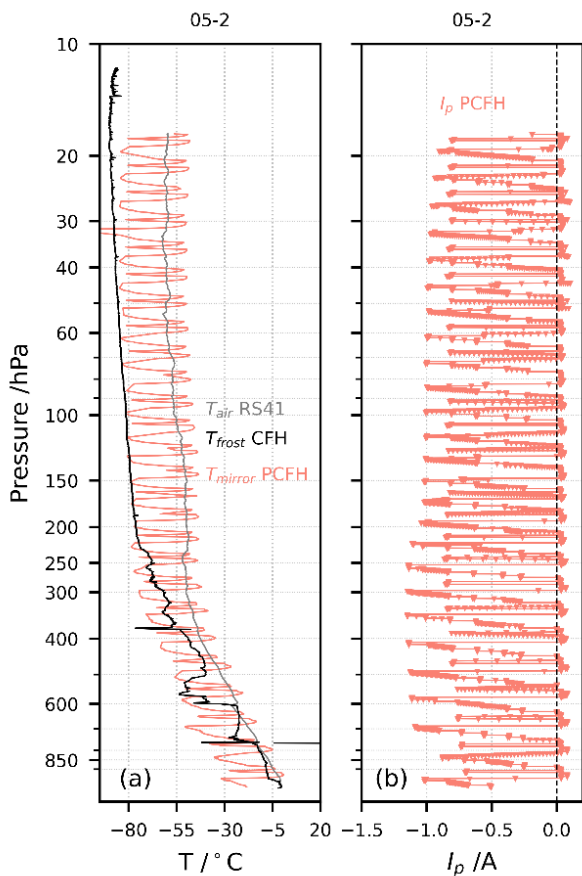


Controller  
types

initial PID trial

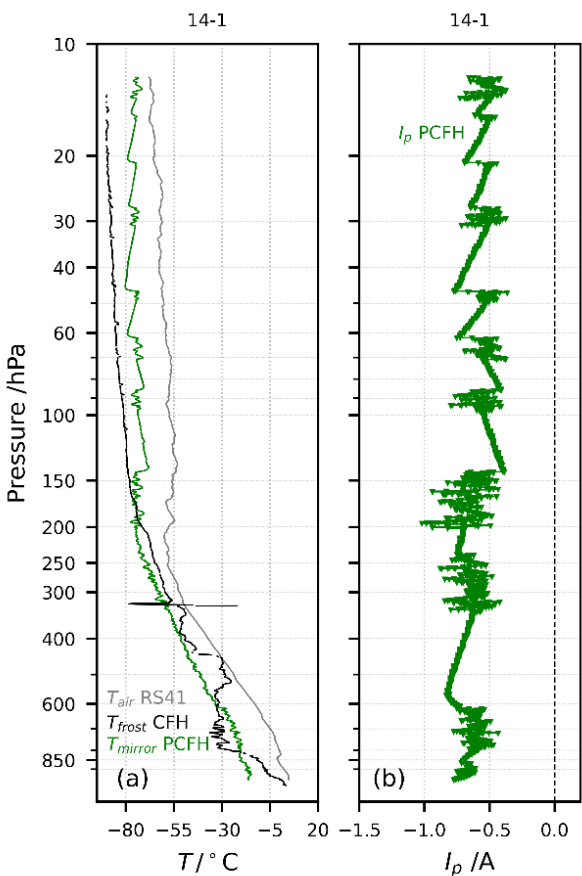
Heat load

low



characterization steps

low

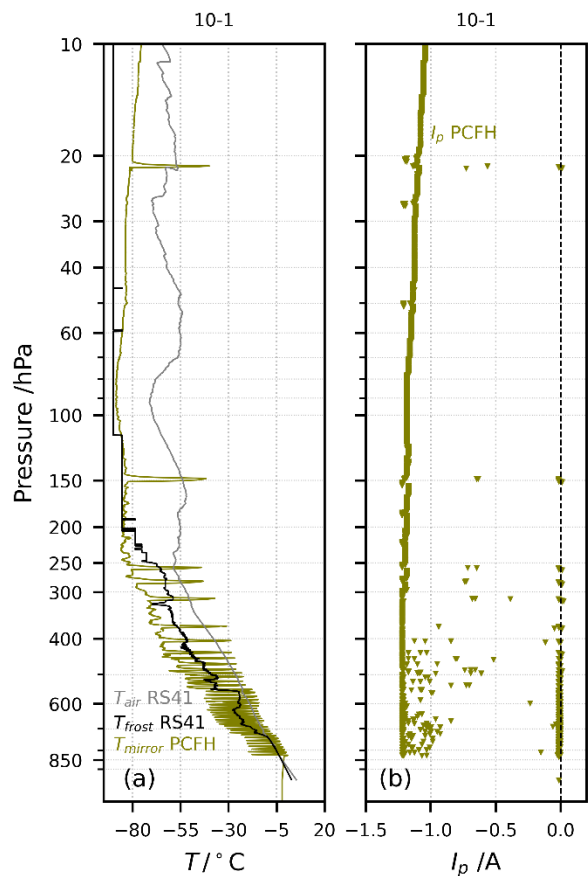


temperature relay controller

medium

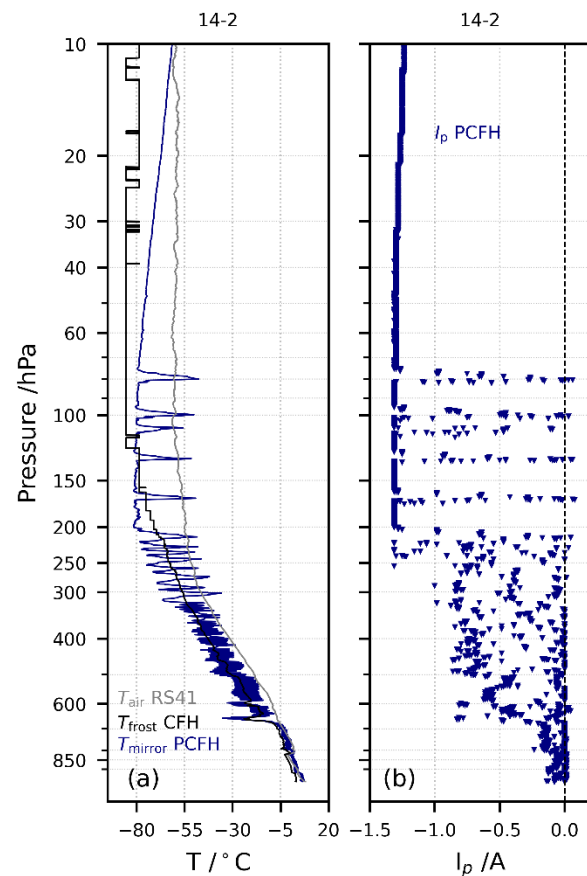


# Controller examples – optics characterization



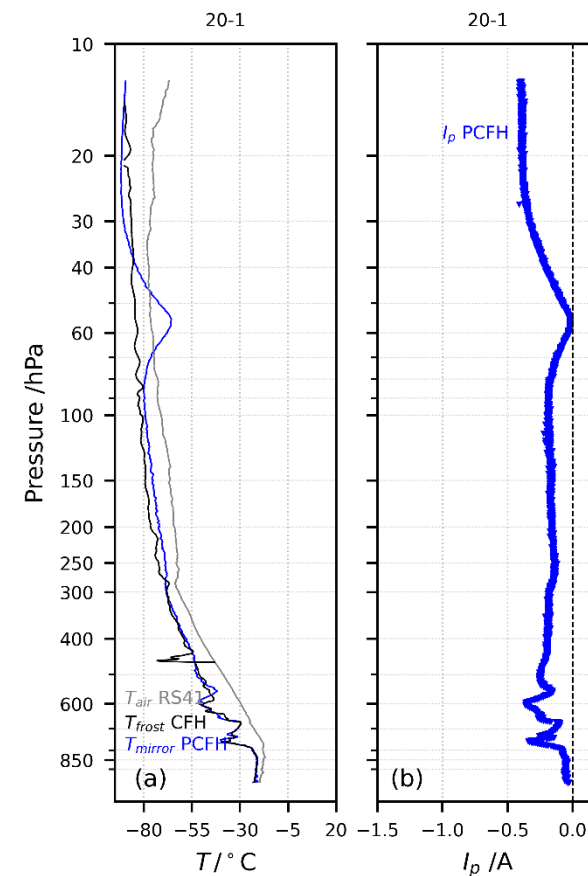
'bang-bang'  
reflex relay controller

high



'bias update'  
reflex relay controller

high



PID controller

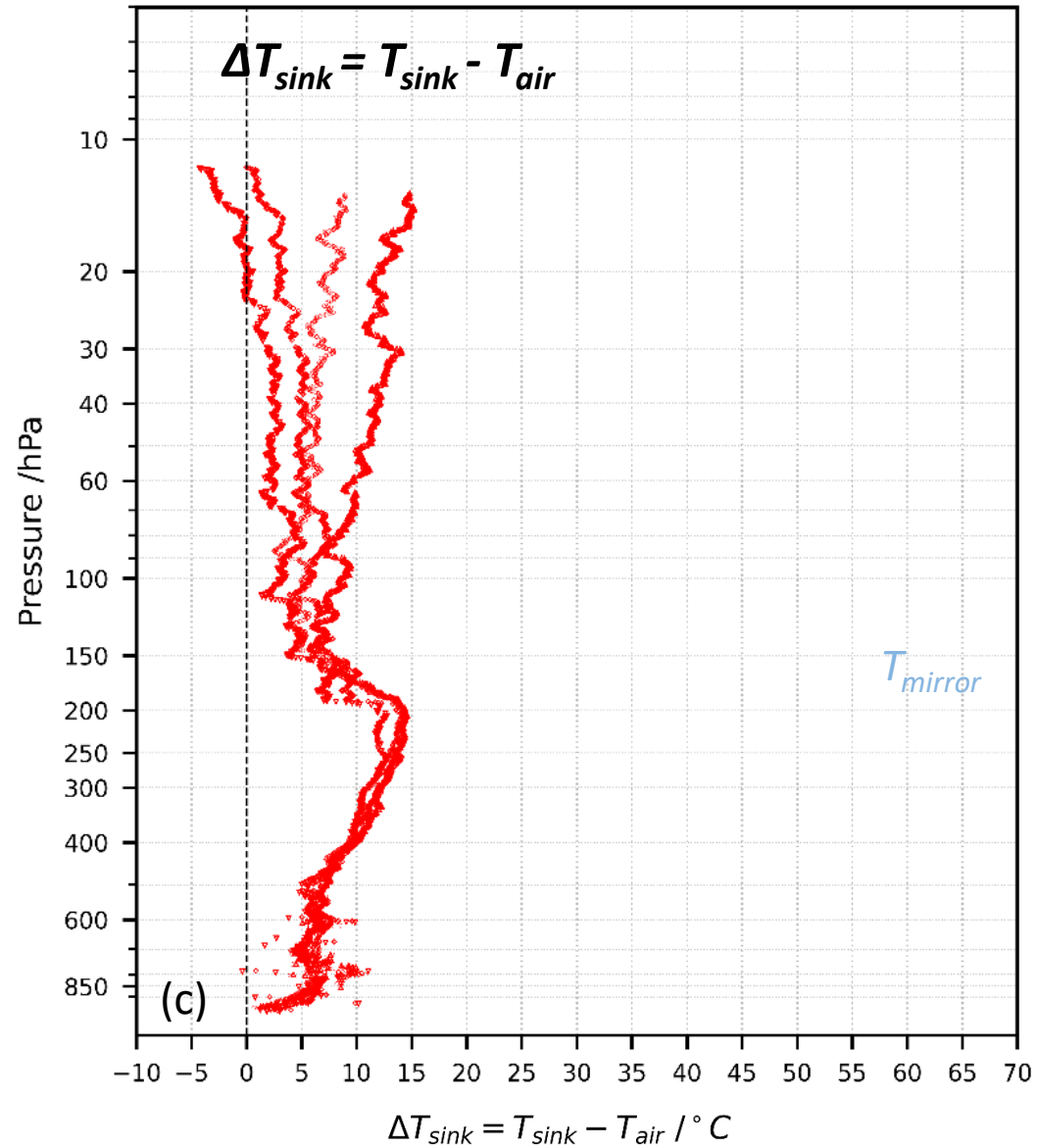
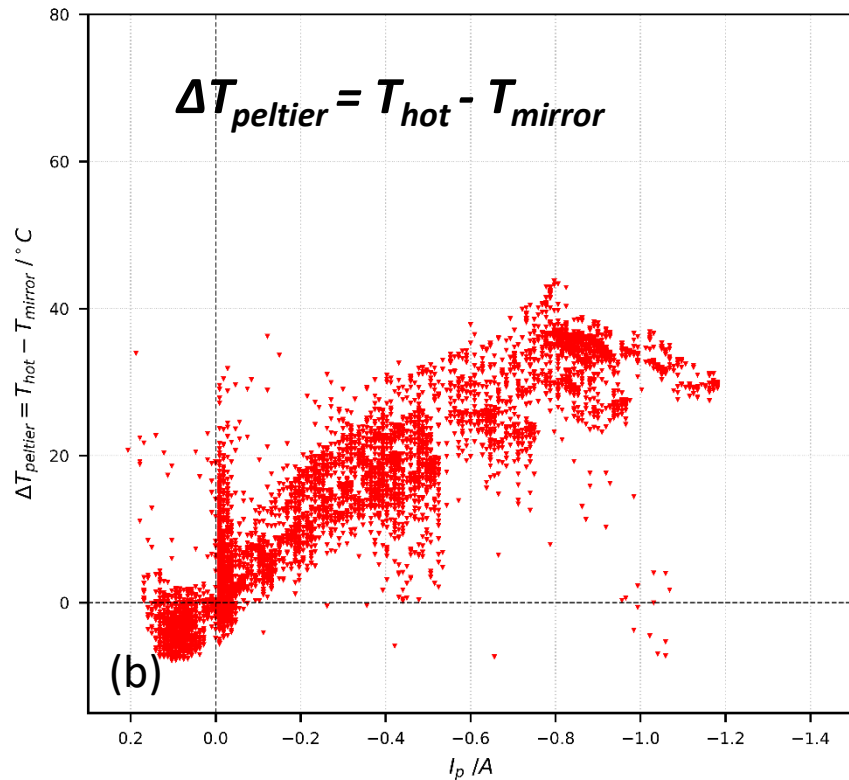
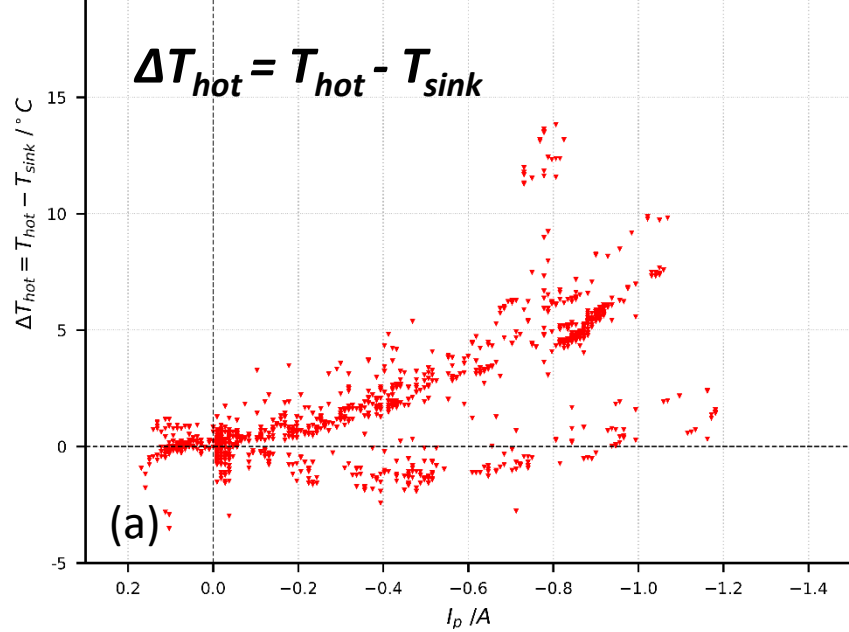
low

# PCFH flights - overview

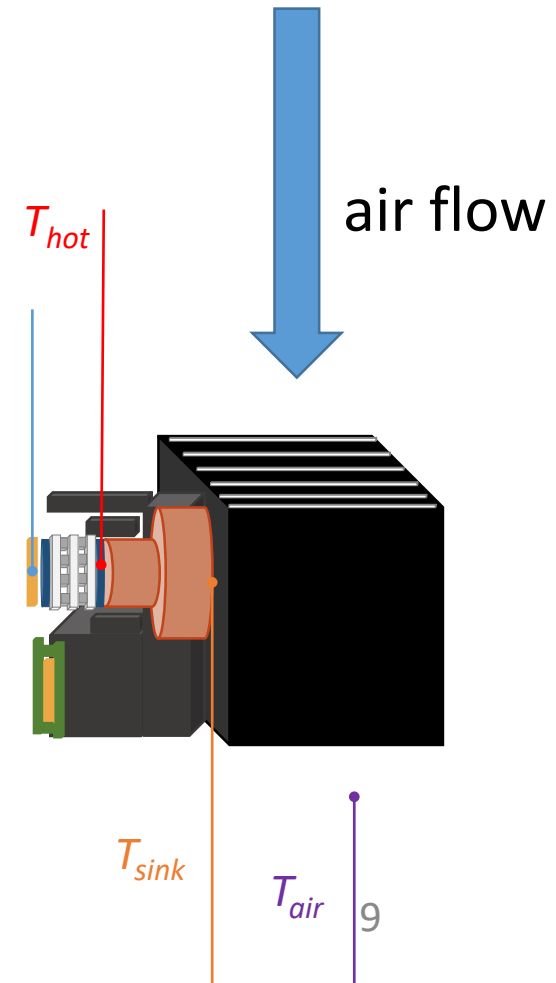
	date and time	SN	location	status	controller type	radiosonde	reference	add-on
1	2018-0725-02UT	01	Lindenberg	recovered – discontinued	characterization steps (SU1) + failed initial PID controller (SU2)	RS41	RS41	
2	2018-0725-20UT	02	Lindenberg	recovered – discontinued	characterization steps (SU1) + failed initial PID controller (SU2)	RS41	CFH	COBALD-CFH
3	2018-1212-16UT	04	Lindenberg	recovered – discontinued	characterization steps	RS41	CFH	O3-CFH
4	2018-1212-16UT	05	Lindenberg	recovered – discontinued	characterization steps	RS41	RS41	COBALD
5	2018-1213-22UT	06	Lindenberg	recovered – discontinued	characterization steps	RS41	CFH	O3-COBALD-CFH
6	2019-1111-19UT	10	Lindenberg	recovered	temperature relay controller (SU1)+ characterization steps (SU2)	RS41	CFH	COBALD-CFH
7	2019-1111-19UT	14	Lindenberg	recovered		RS41	RS41	
8	2019-1114-16UT	10	Lindenberg	recovered	temperature relay controller (SU1) + failed reflex relay controller (SU2)	RS41	CFH	COBALD-CFH
9	2019-1114-16UT	14	Lindenberg	recovered		RS41	RS41	
10	2020-0129-17UT	10	Payerne	lost	Reflex 'bang-bang' relay controller	RS41	RS41	
11	2020-0208-16UT	13	Ny-Ålesund	lost	Reflex 'bang-bang' relay controller	RS41	CFH	O3-COBALD-CFH
12	2020-0217-20UT	19	Ny-Ålesund	lost	PI controller	RS41	CFH	O3-COBALD-CFH
13	2020-0221-19UT	20	Ny-Ålesund	lost	PI controller	RS41	CFH	O3-COBALD-CFH
14	2020-0226-19UT	15	Ny-Ålesund	lost	PI controller	RS41	CFH	O3-COBALD-CFH
15	2020-0811-18UT	17	Zürich	recovered	Reflex 'bias update' relay controller	I-met	I-met	
16	2020-1013-09UT	17	Zürich	recovered	Reflex 'bias update' relay controller	I-met	I-met	day
17	2020-1105-08UT	14	Zürich	recovered	Reflex 'bias update' relay controller	I-met	I-met	day



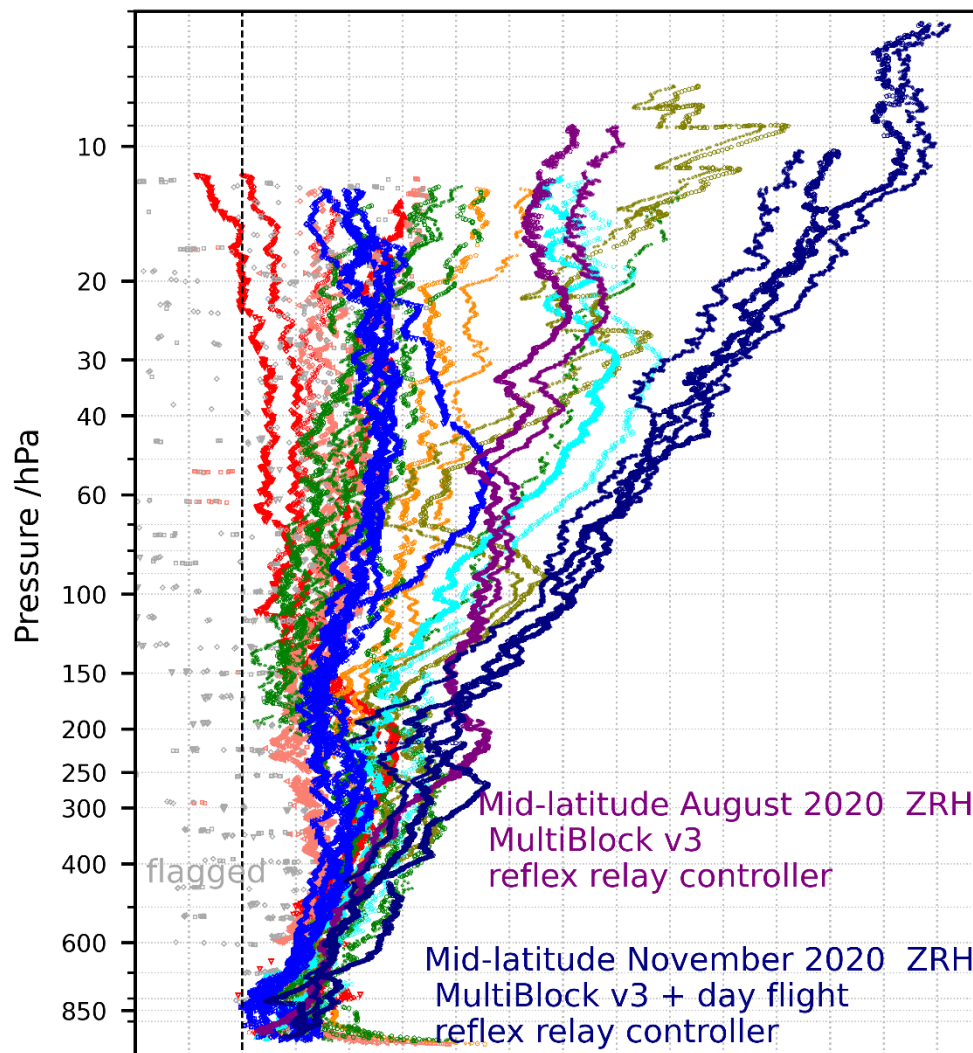
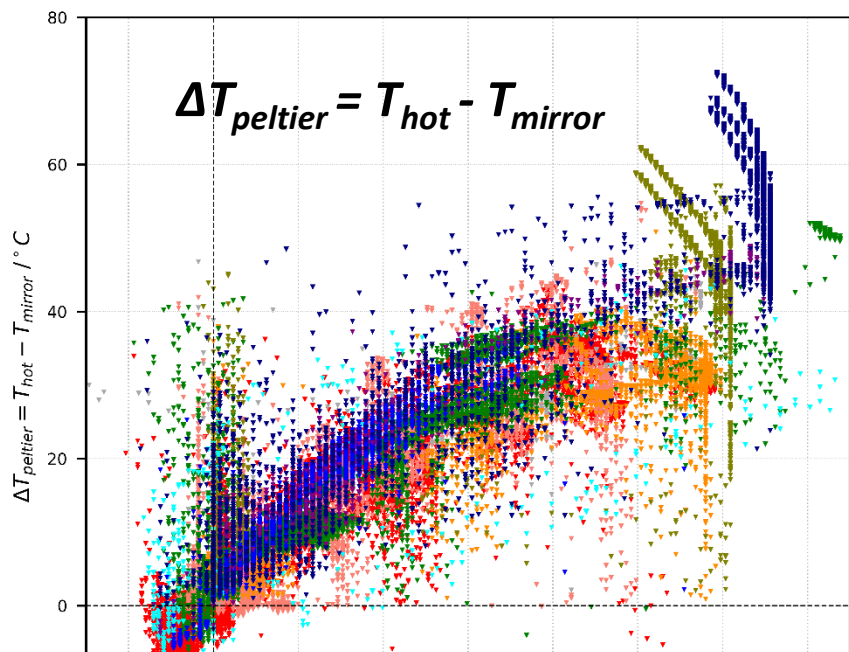
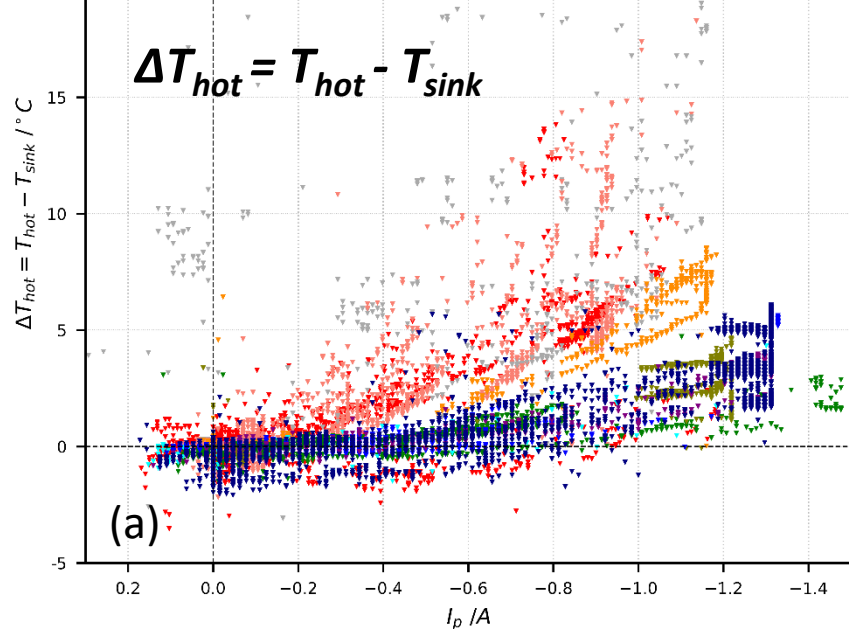
# PCFH— thermal characterization



Mid-latitudes July 2018 LI  
MultiBlock v1 + elect. v1  
PID + steps characterization



# PCFH– thermal characterization – all flights



Mid-latitudes July 2018 LI  
MultiBlock v1 + elect. v1  
PID + steps characterization

Mid-latitudes Dezember 2018 LI  
MultiBlock v2 + elect. v1  
steps characterization

Mid-latitudes Dezember 2018 LI  
MultiBlock v2  
steps characterization

Mid-latitudes November 2019 LI  
MultiBlock v3  
temperature relay controller

Mid-latitudes January 2020 PY  
MultiBlock v3  
reflex 'bang-bang' relay controller

Mid-latitude August 2020 ZRH  
MultiBlock v3  
reflex relay controller

Polar Night February 2020 NYA  
MultiBlock v3  
reflex 'bang-bang' relay controller

Mid-latitude November 2020 ZRH  
MultiBlock v3 + day flight  
reflex relay controller

Polar Night February 2020 NYA  
MultiBlock v3  
PI controller

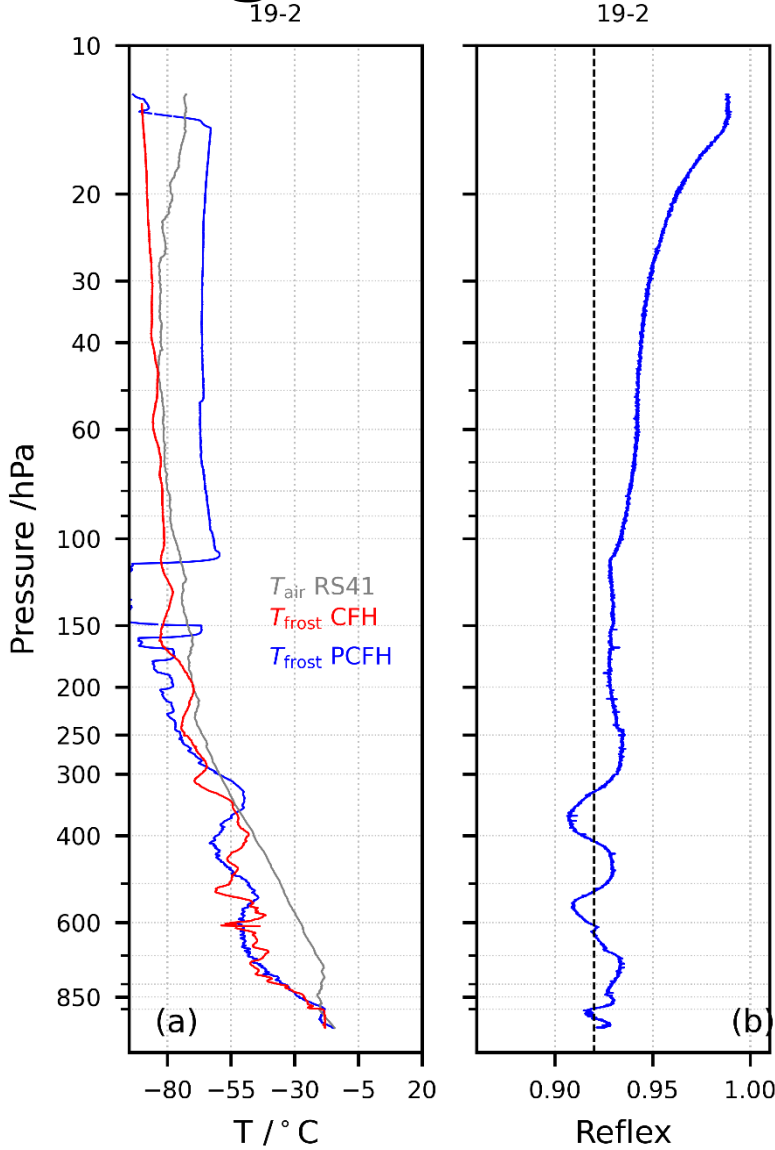
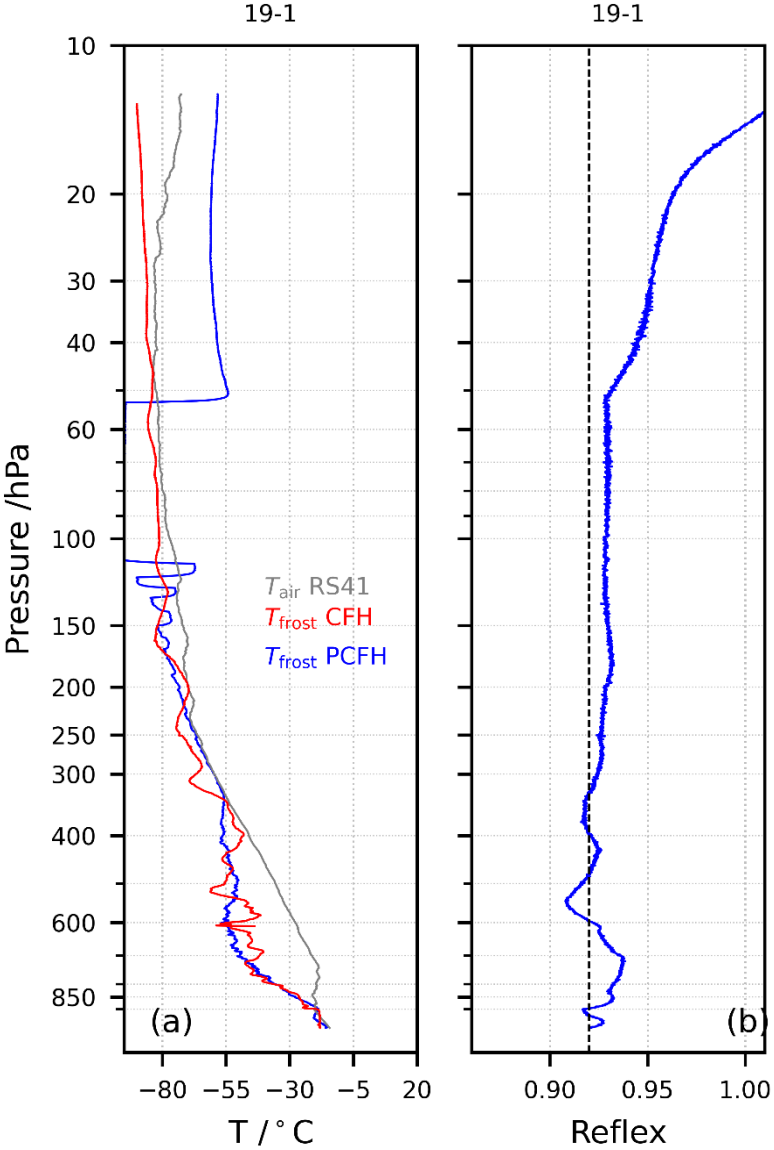
Established design for the double stage Peltier element, copper finger and heat sink:  
Reproducibility and understanding of the thermal behavior

# PCFH– optics characterization – 2020 flights

	date and time	SN	location
12	2020-0217-20UT	19	Ny-Ålesund

status	controller type
lost	PI controller

radiosonde	reference	add-on
RS41	CFH	O3-COBALD-CFH

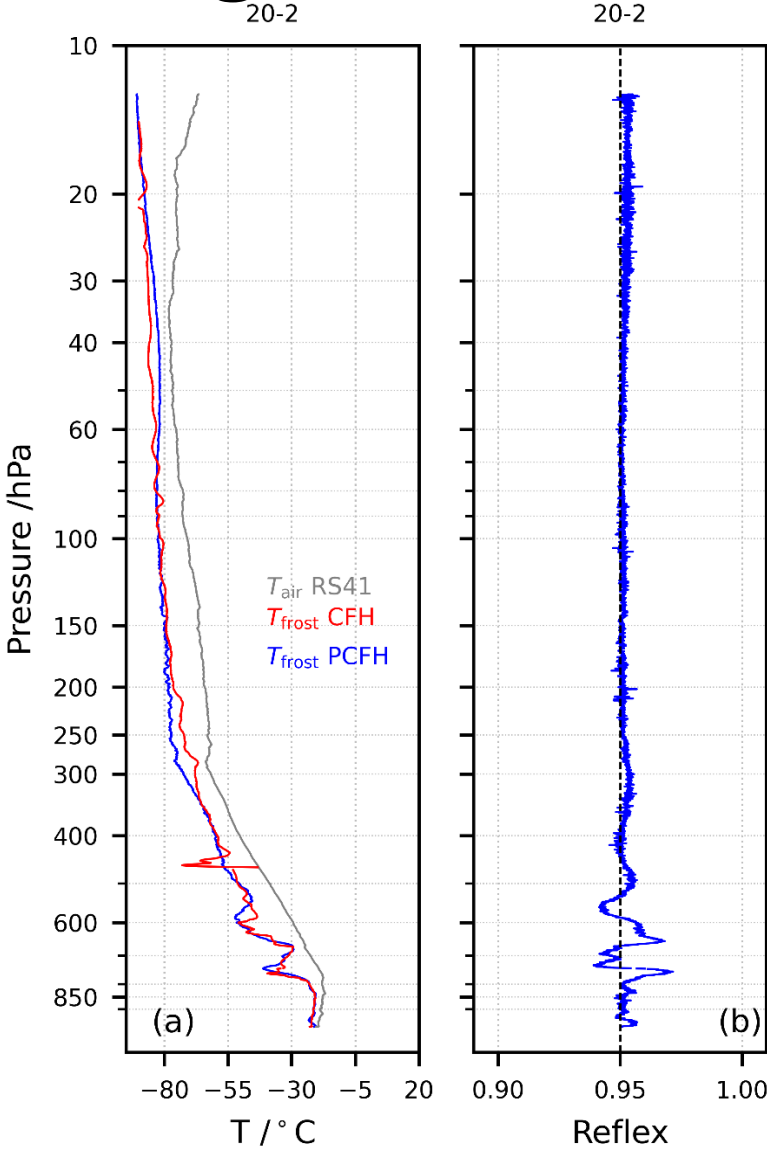
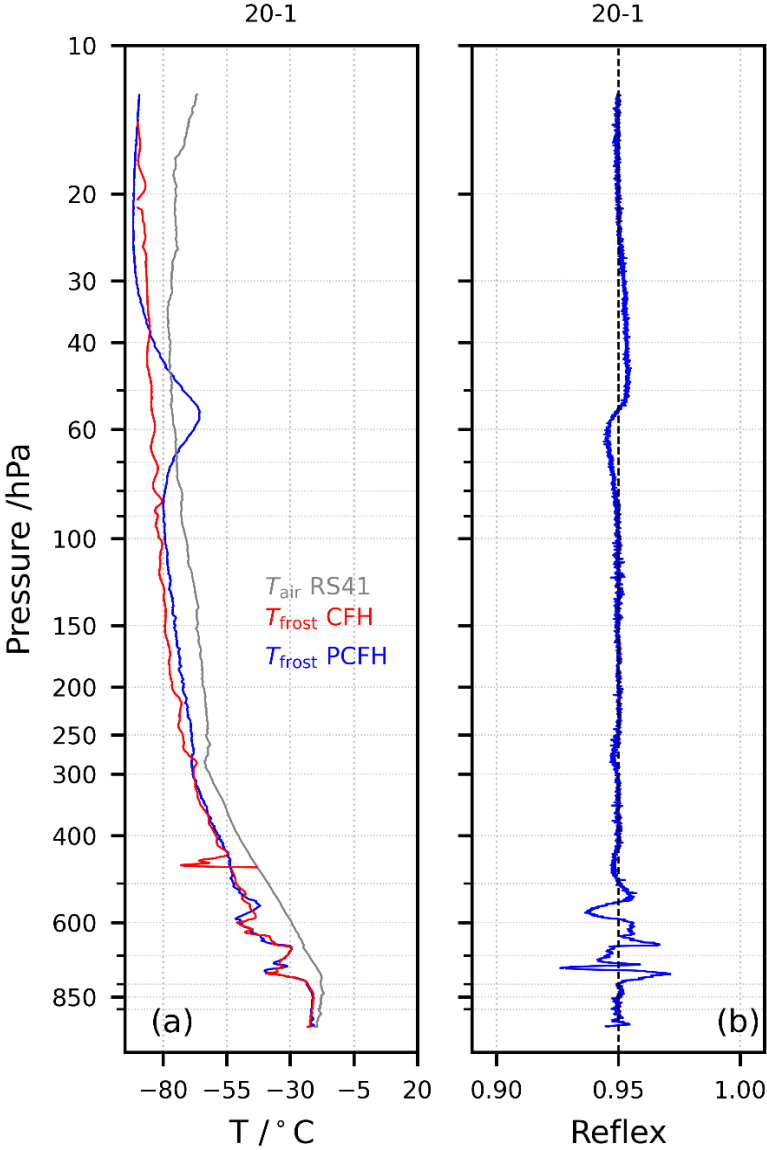


# PCFH– optics characterization – 2020 flights

	date and time	SN	location
13	2020-0221-19UT	20	Ny-Ålesund

status	controller type
lost	PI controller

radiosonde	reference	add-on
RS41	CFH	O3-COBALD-CFH

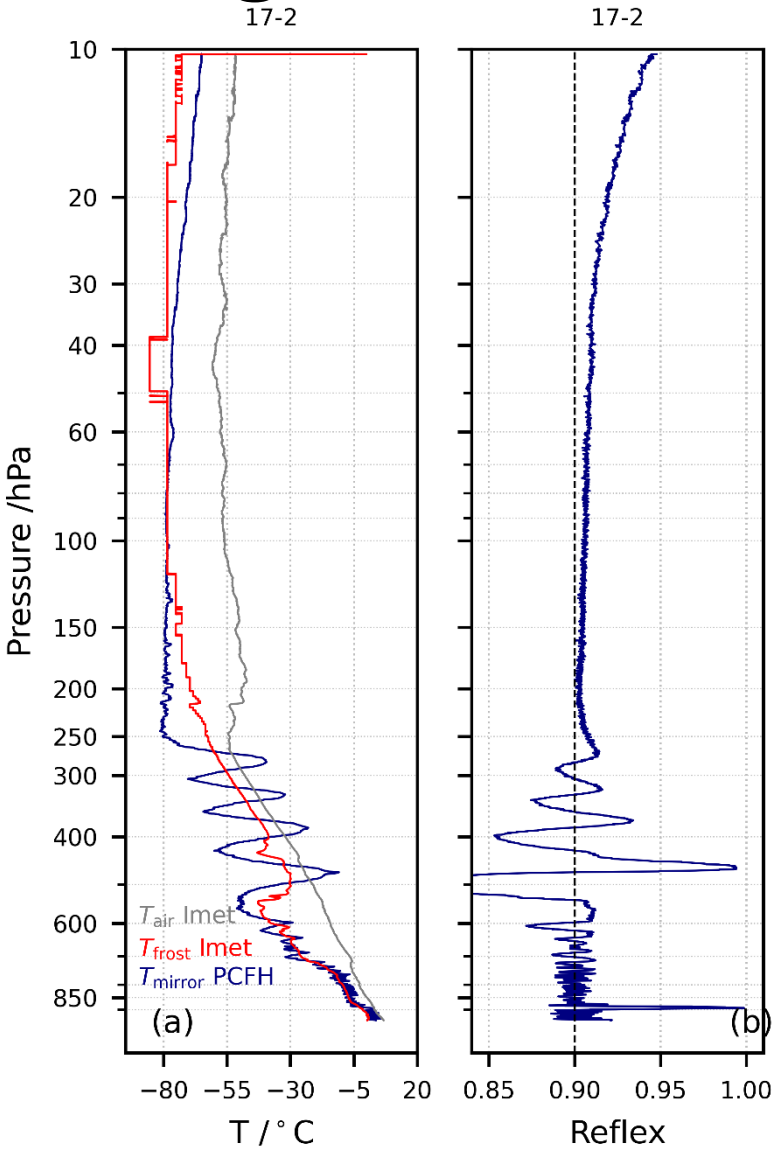
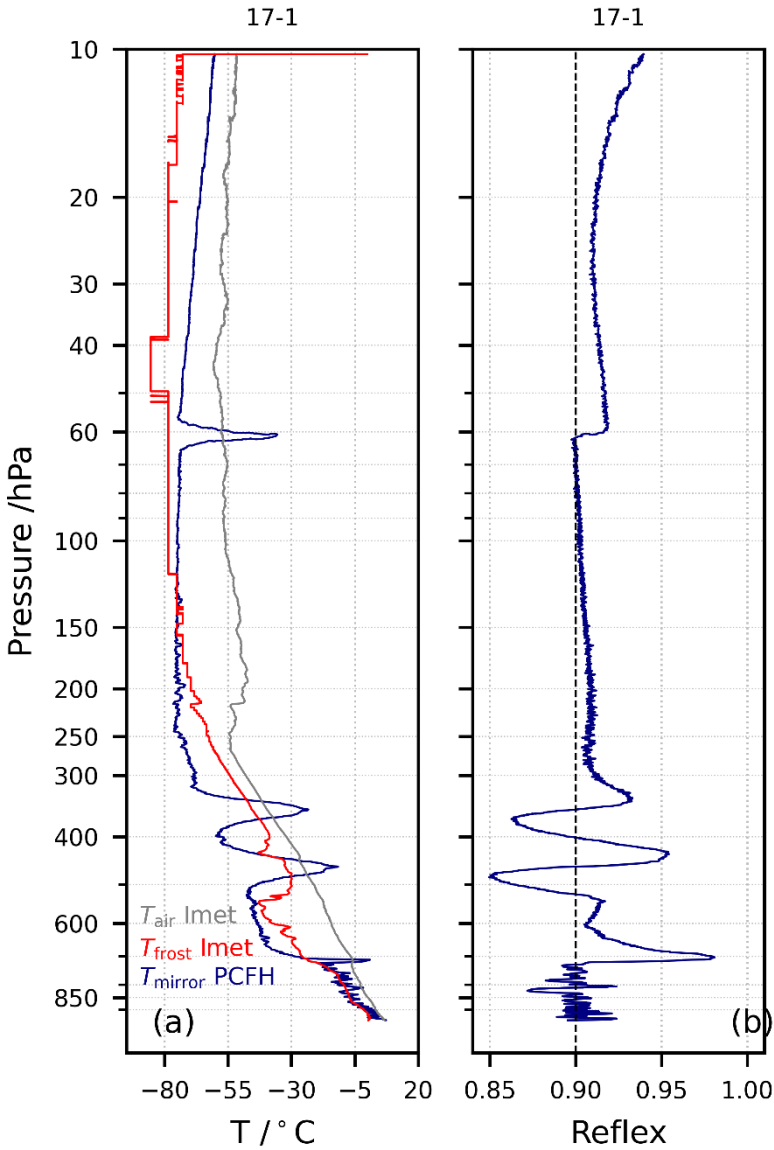


# PCFH– optics characterization – 2020 flights

	date and time	SN	location
16	2020-1013-09UT	17	Zürich

status	controller type
recovered	Reflex 'bias' relay controller

radiosonde	reference	add-on
I-met	I-met	day

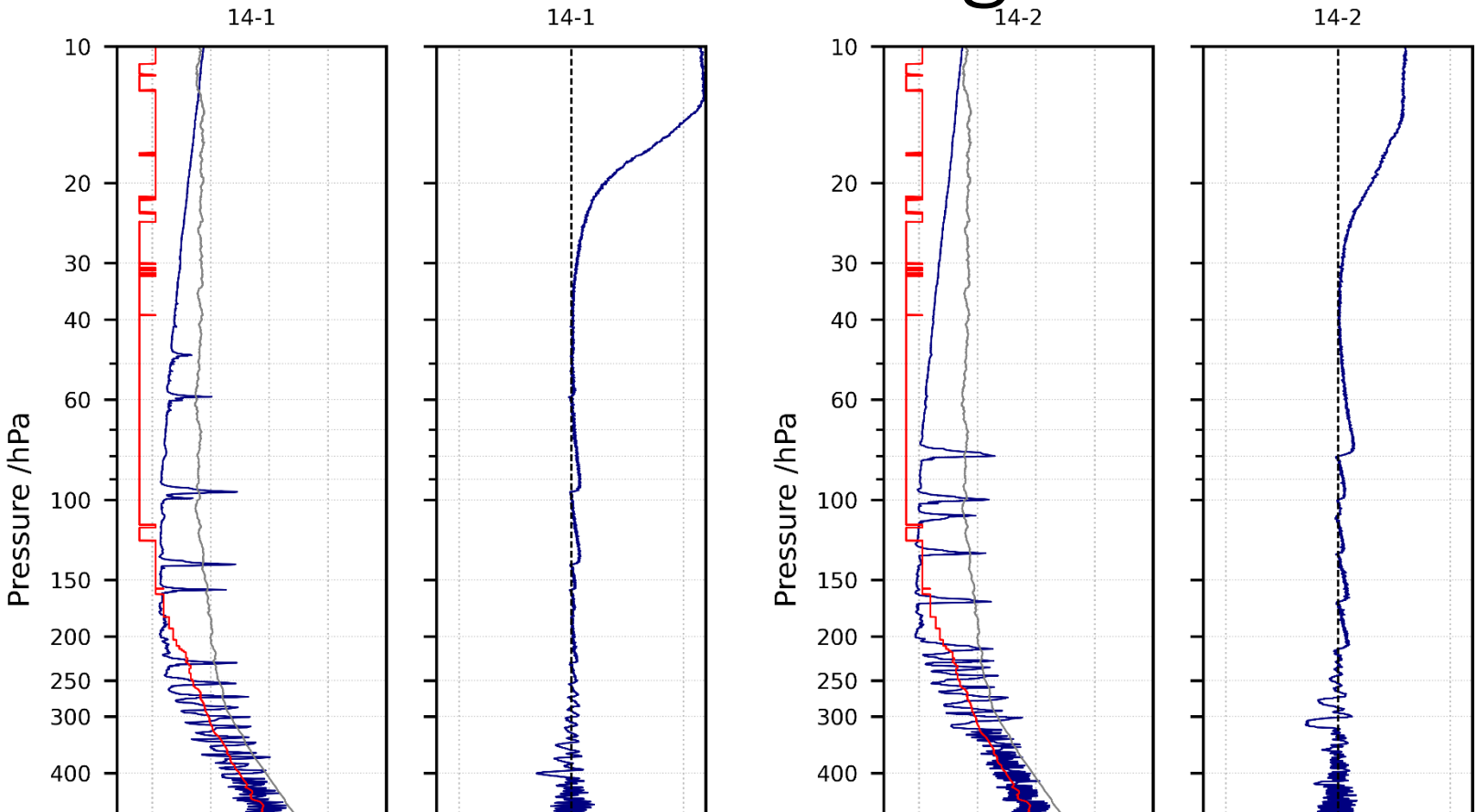


# PCFH– optics characterization – 2020 flights

	date and time	SN	location
17	2020-1105-08UT	14	Zürich

status	controller type
recovered	Reflex 'bias' relay controller

radiosonde	reference	add-on
I-met	I-met	day



Expected operating range: Polar night up to 10 hPa and mid latitudes night/day up to 40/100 hPa

Further investigation of the optical detection scheme:  
Search for a better operating point or re-design of the mirror

T / °C

Reflex

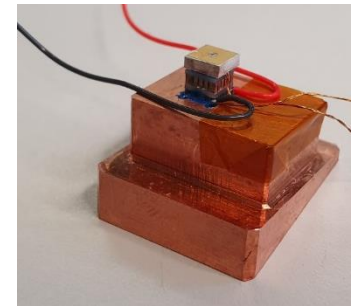
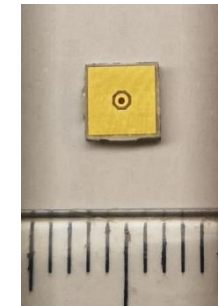
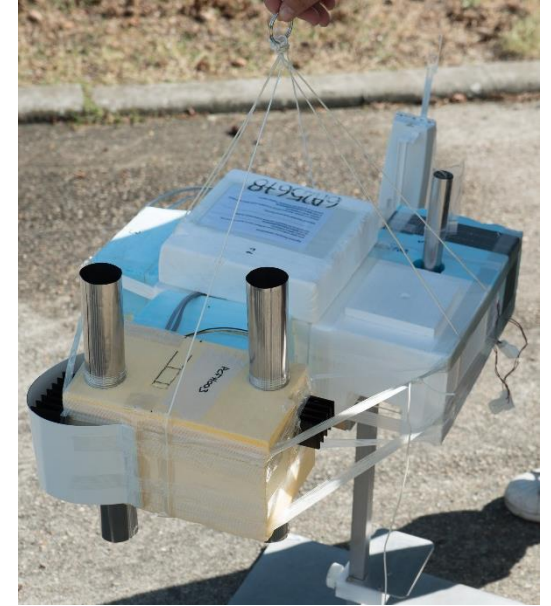
T / °C

Reflex



# PCFH– summary and next steps

- Total of 17 flights
  - Different locations: Lindenberg, Ny-Ålesund, Payerne, Zürich
  - Different radiosondes: RS41 and Imet
  - Add-on instrument on the RS41: ECC O3, COBALD, CFH
- Established design for the double stage Peltier element, copper finger and heat sink
  - Reproducibility and understanding of the thermal behavior
- Expected operating range:
  - Polar night up to 10 hPa and
  - Mid latitudes night up to 40/ 100 hPa
- Further investigation of the optical detection scheme
  - Search for a better operating point
  - Re-design of the mirror: brighter
- Further investigation of the system dynamics to optimize the controller
  - 'bias update' reflex relay controller
  - PID controller
  - Optimal controller



# Thank you!

## Questions?

