

# Peltier Cooled Frost Point Hygrometer (PCFH)

Frank G. Wienhold, Yann Poltera, Thomas Peter  
ETH Zurich, Zurich, Switzerland

**Steven Brossi**, Thomas Brossi  
mylab elektronik, Bubikon, Switzerland

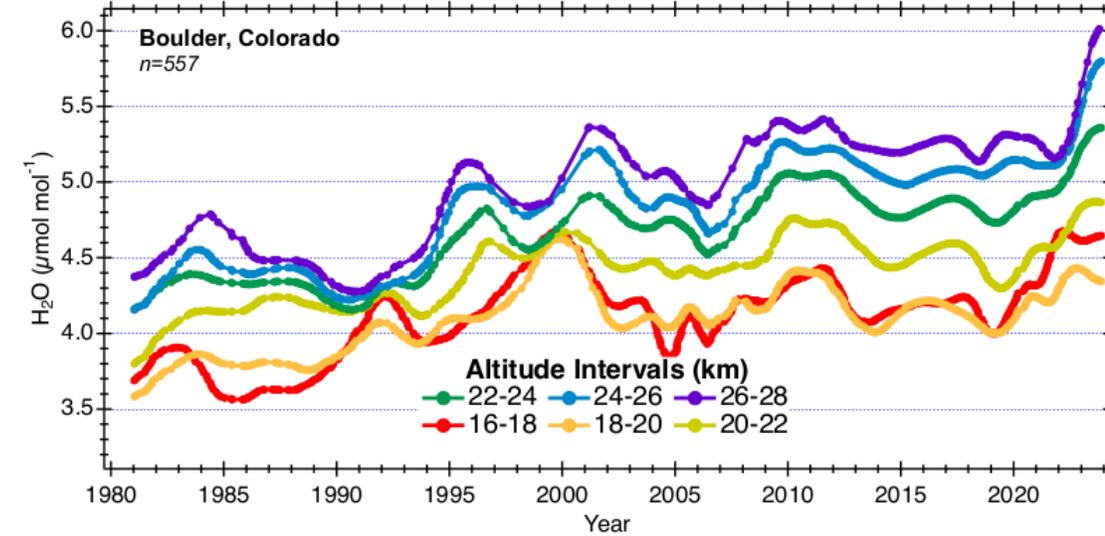
GRUAN ICM-15, Berne, 12 March 2024

# Water Vapor in the UT/LS

- **High-quality and long-term water vapor measurements** are needed in the UT/LS
- Present chilled mirror instruments, such as CFH and FPH, use the **refrigerant R23** (precooled by dry ice)
- Equilibrium between frost layer and surrounding air
  - minima and maxima of the mirror reflectivity
  - **'Golden Points'**
  - better than 0.2 K in FP or 3-4 % in H<sub>2</sub>O mixing ratio
- We develop the **Peltier-cooled Frost point Hygro-meter (PCFH)**, a novel chilled mirror instrument that
  - avoids using the strong greenhouse gas **R23** (**≈ 7 t CO<sub>2</sub> per sounding**)
  - facilitates the handling by avoiding the use of any liquids (**plug 'n play**)
  - makes full use of the **Golden Point approach**

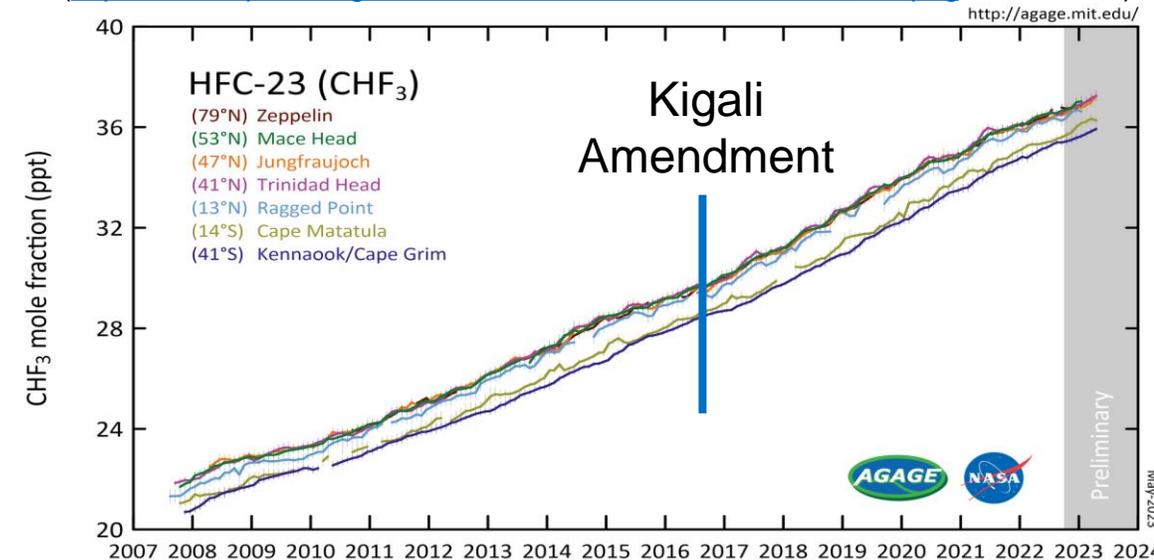
## NOAA FPH data

(<https://gml.noaa.gov/ozww/wvap>, Dale Hurst)



## AGAGE R23 measurements

([https://en.wikipedia.org/wiki/Fluoroform#/media/File:HFC-23\\_mm.png](https://en.wikipedia.org/wiki/Fluoroform#/media/File:HFC-23_mm.png), Jens Mühle)



# PCFH Setup



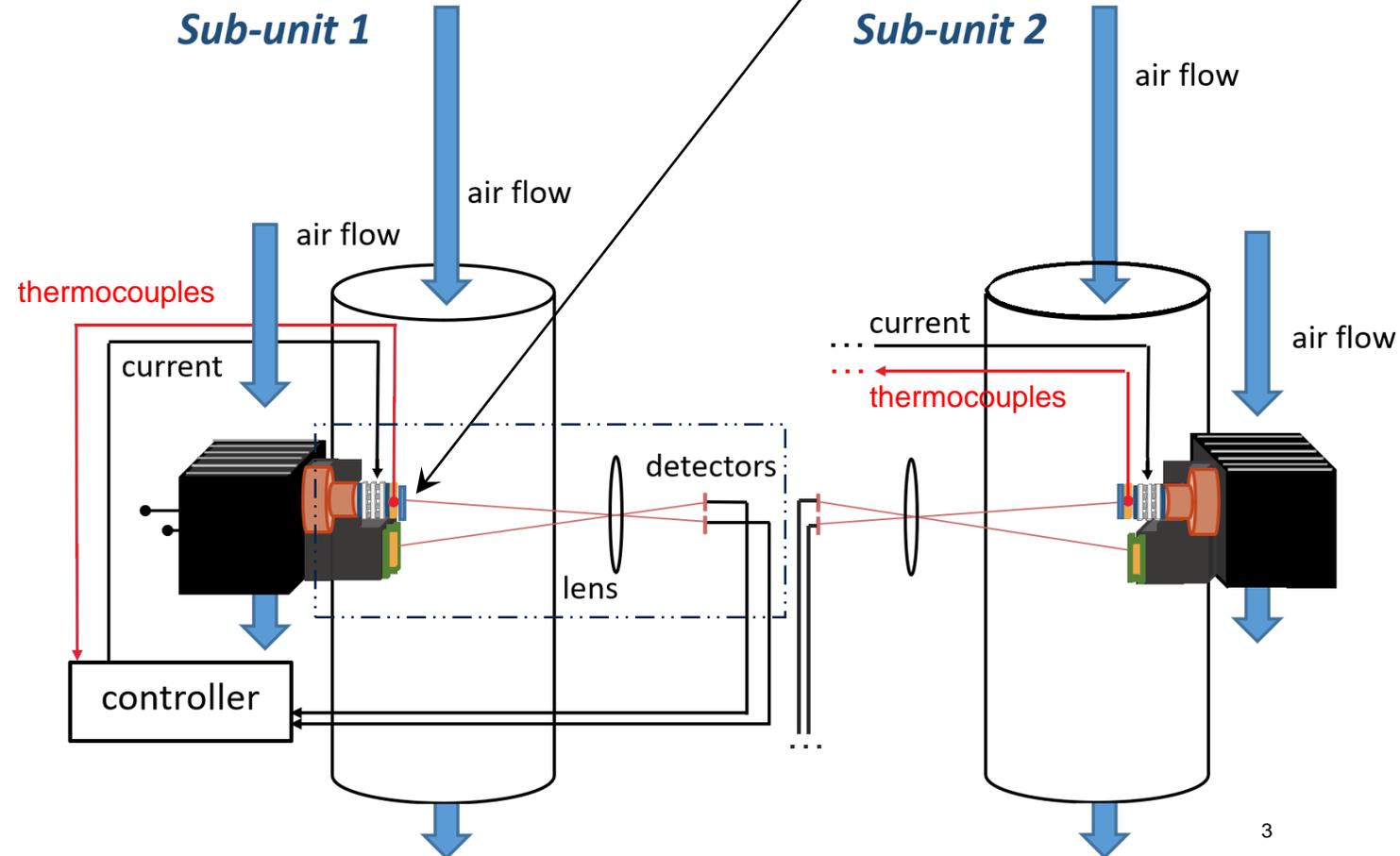
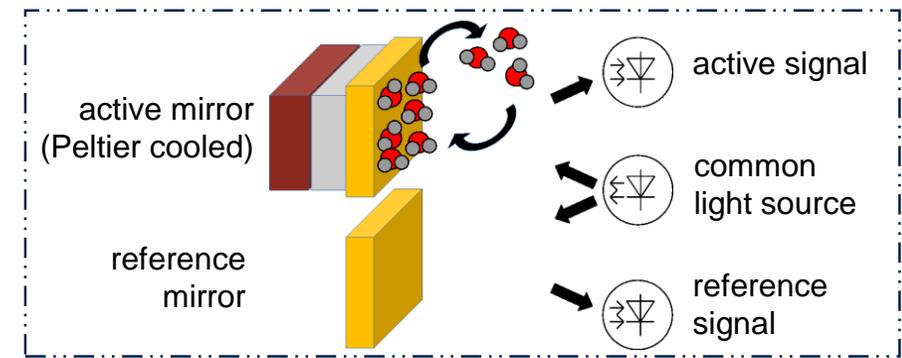
- balloon-borne frost point hygrometers
  - high accuracy and vertical resolution
  - easily measure in the tropopause region and in the lower stratosphere

## Goals

- replace coolant liquids by **Peltier elements**
- **reduced logistic and preparation efforts**
- **identify artifacts** and contamination
- eventually be **on par with FPH and CFH** at least up to 23 km

## Realization

- cooling by solid state thermoelectric device (single-stage Peltier)
- **two fully independent sub-units**
- easy handling



# PCFH development is part of the project “Swiss H<sub>2</sub>O-Hub”

(funded by MeteoSwiss/GAW+)

## 1. Uni Bern: **MIAWARA**

microwave radiometer, *remote sensing*



## 2. MeteoSwiss: **RALMO**

Raman lidar, *remote sensing*



## 3. Empa: **ALBATROSS**

mid-IR laser spectroscopy, *in-situ*



## 4. ETH Zürich: **PCFH**

Peltier-cooled frost point hygrometer, *in-situ*



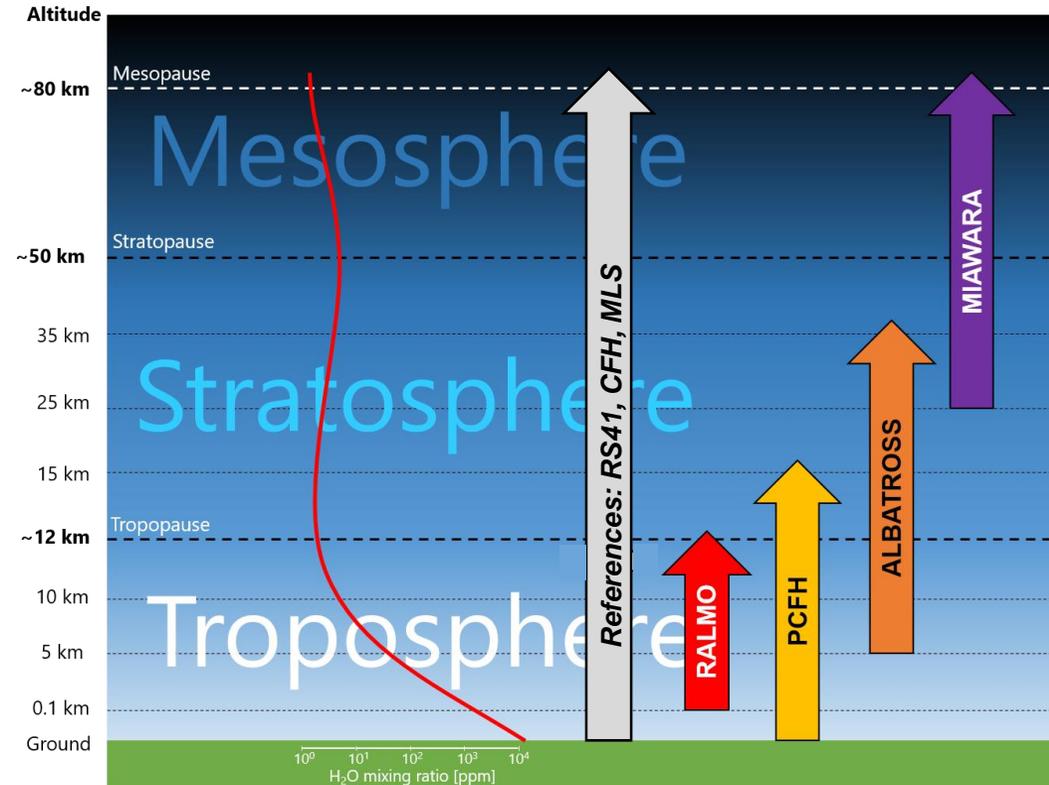
## 5. References: **CFH, RS41, MLS**

### Target Objectives

- combine in-situ and remote H<sub>2</sub>O sensing from ground to 80 km
- from development/testing towards monitoring
- towards SI traceability, low drift, high accuracy



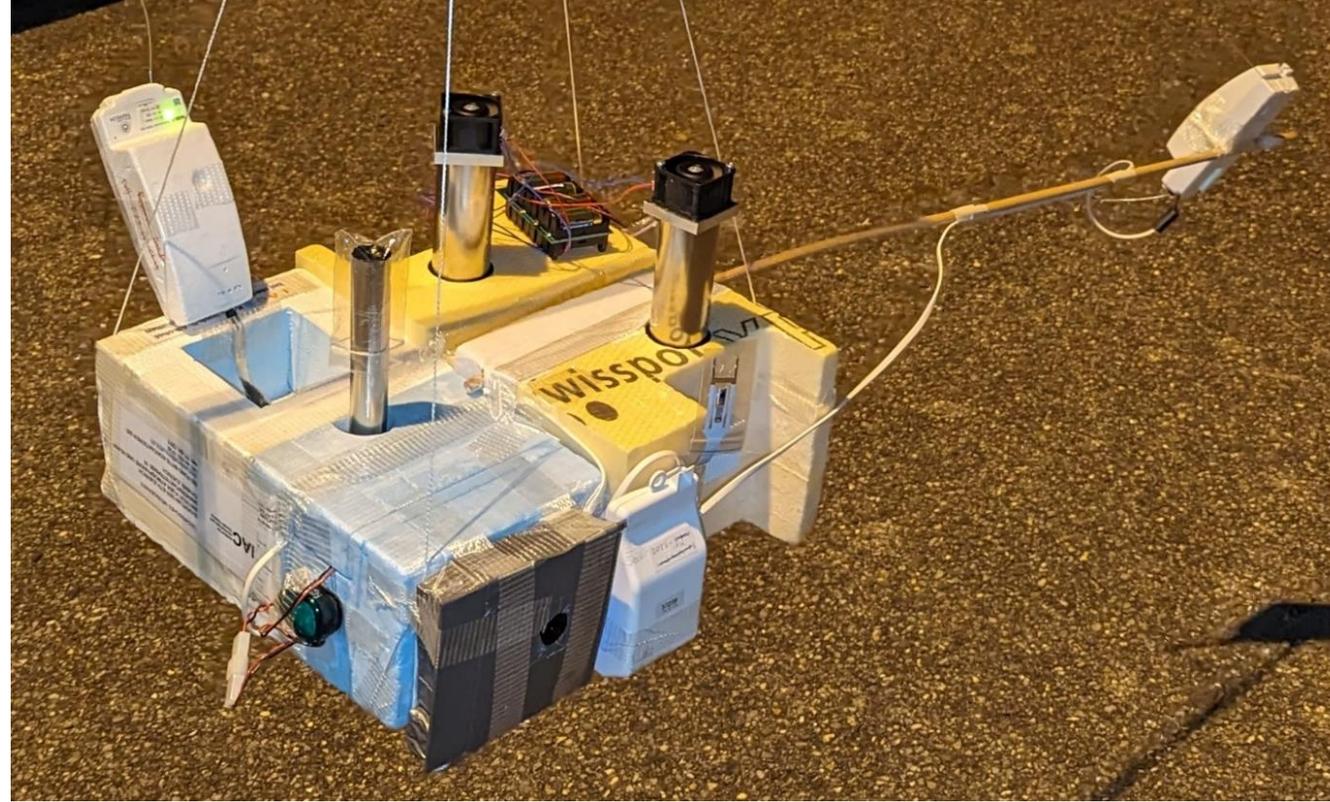
also funded by the Federal Office for the Environment



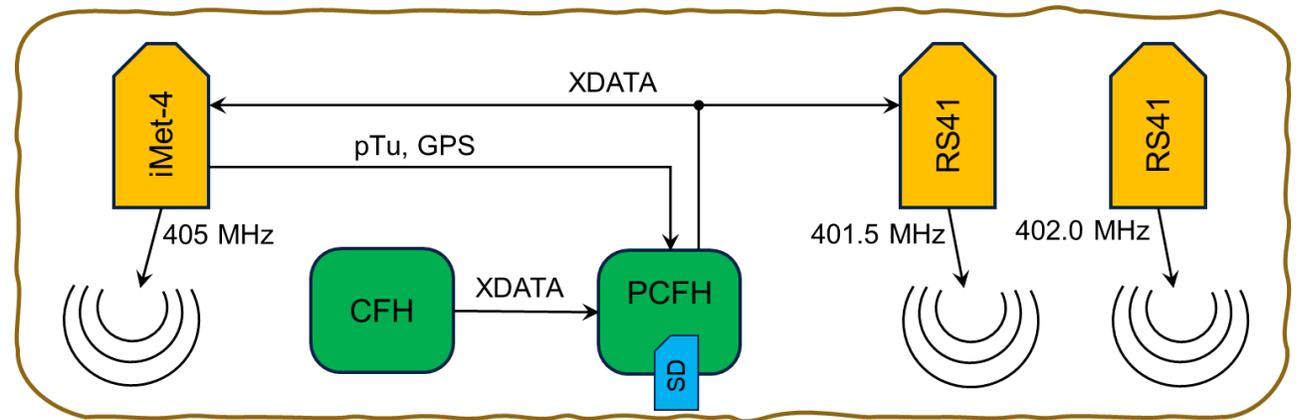
# Summer 2023 Payerne Campaign: Overview of Flights

Flight		Instrumentation						Telemetry		Remarks
No.	Date	PCFH	CFH	ALBATROSS	RS41	RS41 (special tasks)	iMet-4	MW41	SkySonde	
1	2023-0815-20UT	no SD logging	R23		403.5 MHz		405.0 MHz			TA3000 (H2), 30 m, SkySonde: antenna trouble
2a	2023-0817-21UT		R23		403.5 MHz		405.0 MHz			TA3000 (H2) ~50 m
2b	2023-0817-21UT				401.0 MHz					TA3000 (H2) ~50 m
3	2023-0822-20UT		R23		403.5 MHz		405.0 MHz			TA1200 (H2) ~60 m interferences
4	2023-0824-13UT		ethanol, dry ice		402.5 MHz					TA2000 (H2) ~60 m
→ 5	2023-0829-21UT		ethanol, dry ice		401.5 MHz	402.0 MHz, telemetry ref.	405.0 MHz			TA1200 (H2) ~60 m, MW41: improved
6	2023-0904-13UT		ethanol, dry ice, LN2		402.0 MHz	401.5 MHz, T cryo				TA2000 (H2) ~60 m
→ 7	2023-0906-22UT		ethanol, dry ice, LN2		402.0 MHz	401.5 MHz, T cryo	405.0 MHz			TA2000 (H2) ~60 m

# Balloon sonde arrangement for Flight 7



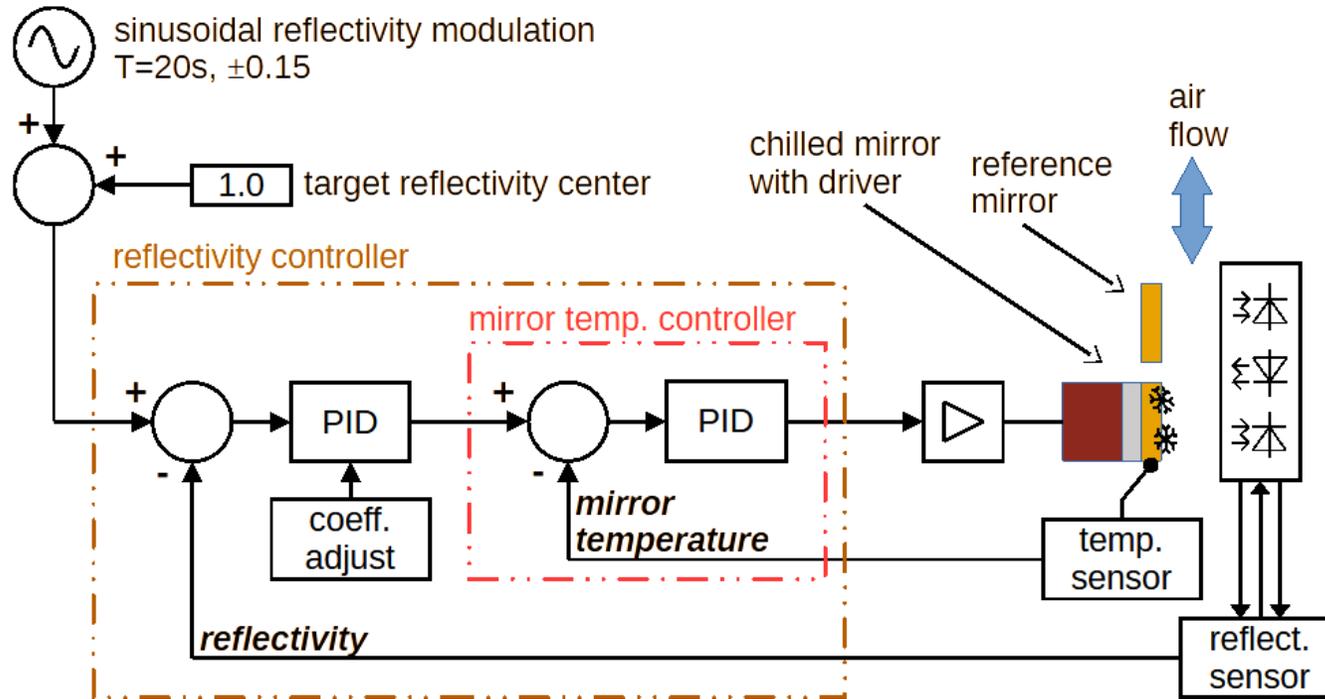
- Dual telemetry and data logging for CFH & PCFH
- iMet-4 + RS41 (+ RS41 as Tcryo without connection)
- PCFH logs its internal data along with XDATA from CFH and iMet-4 on SD card (high resolution, no telemetry gaps)



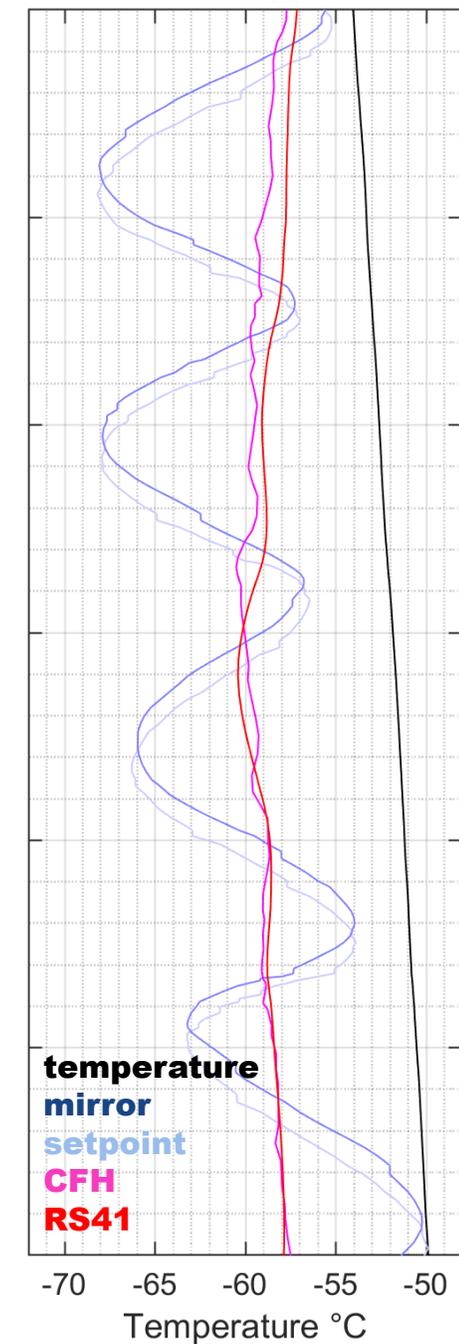
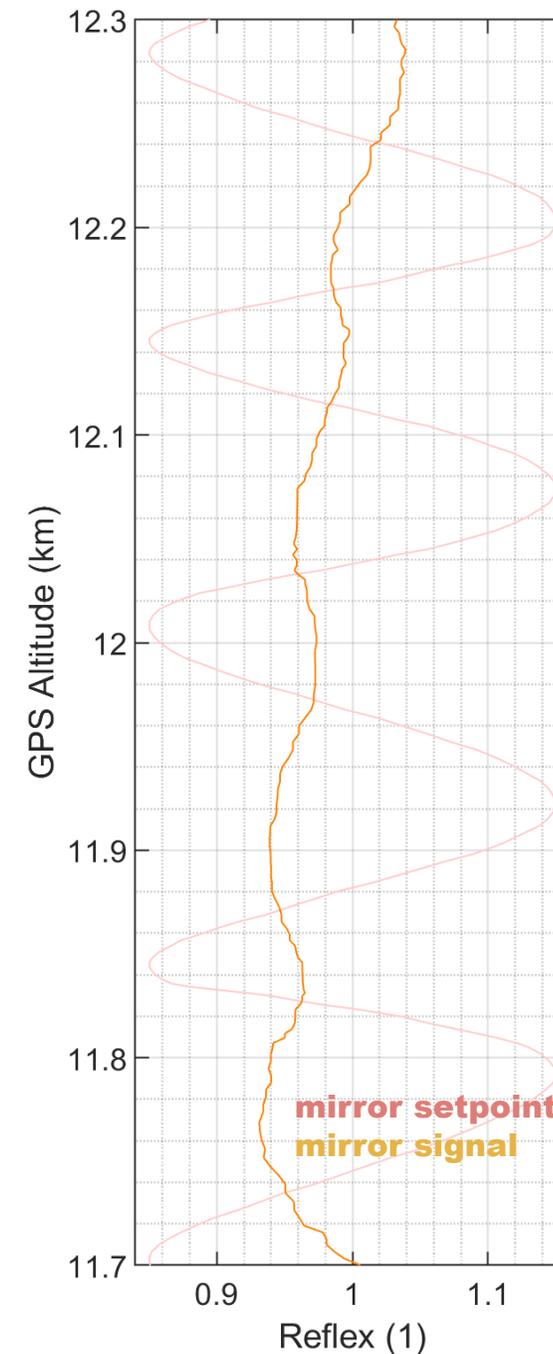


**100%  
RECOVERED**

# PCFH Golden Point generation



- cascaded PID controller: mirror temperature tracks frost point
- prescribed sinusoidal modulation of the target reflection  
→ enforce Golden Points
- mirror temperature oscillates around frost point



# PCFH Golden Point evaluation

## PCFH

1. identify minima & maxima in reflectivity



2. assign Golden Points on mirror temperature



3. separate traces for minima & maxima mirror signal



4. mean value: frost point temperature

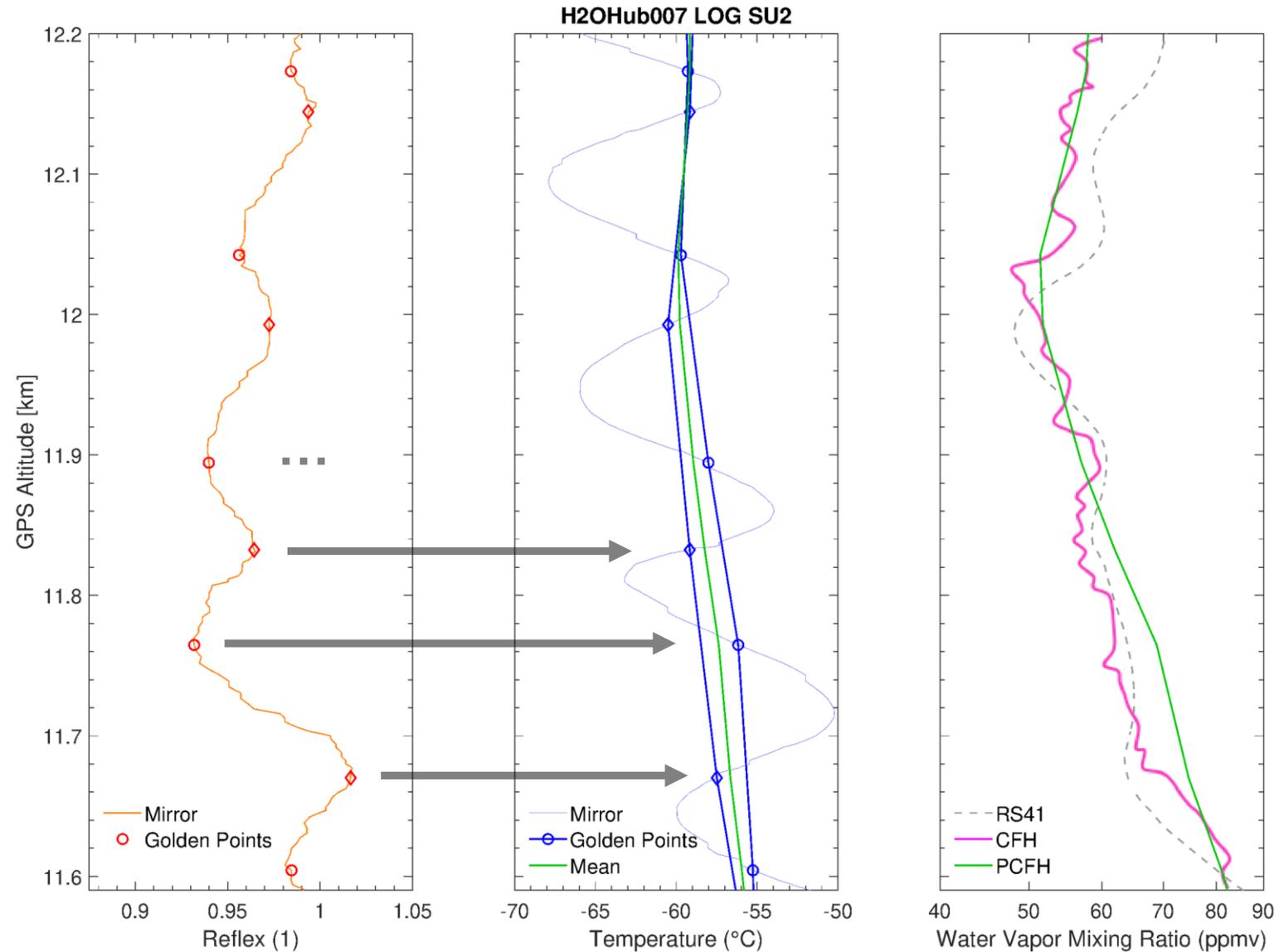


5. convert temperature to water vapor mixing ratio



## CFH

original data



# PCFH Golden Point evaluation

## PCFH

1. identify minima & maxima in reflectivity



2. assign Golden Points on mirror temperature



3. separate traces for minima & maxima mirror signal



4. mean value: frost point temperature

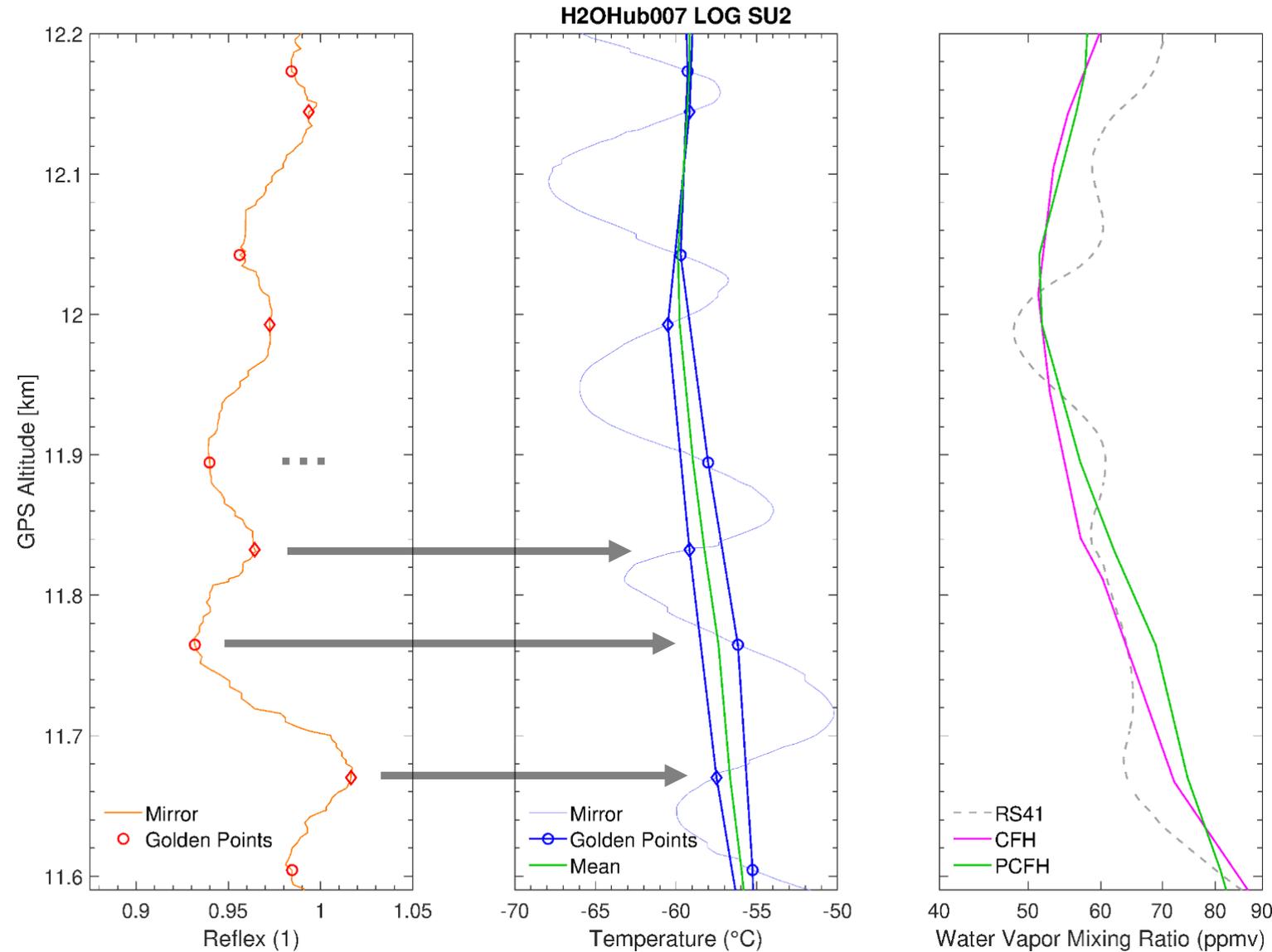


5. convert temperature to water vapor mixing ratio



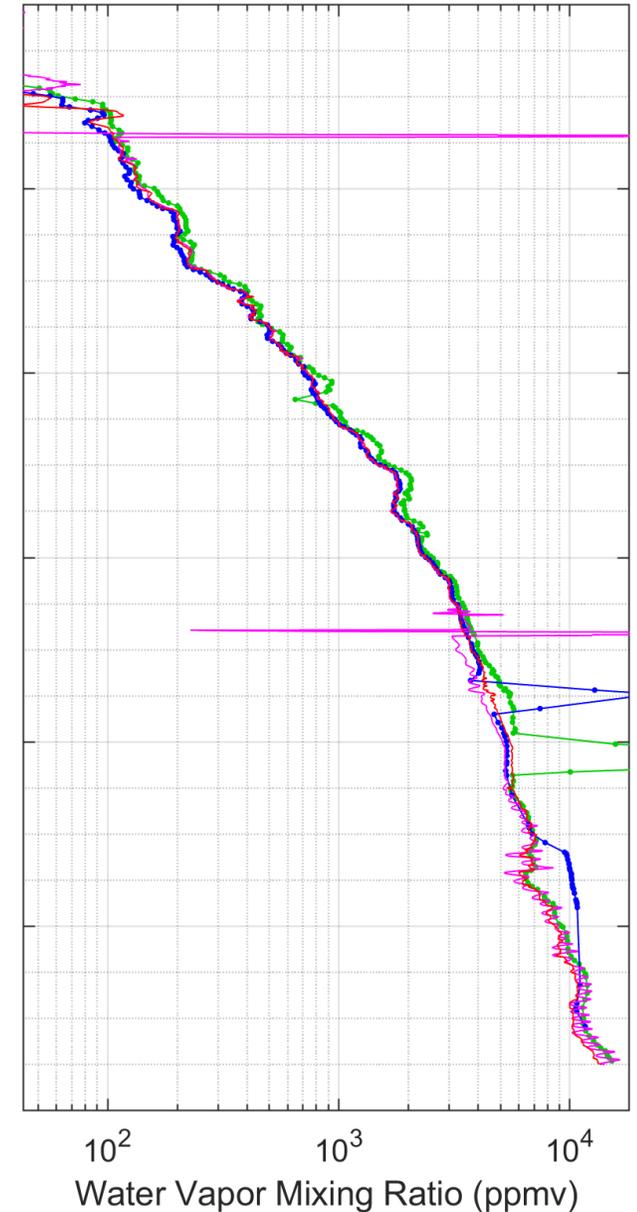
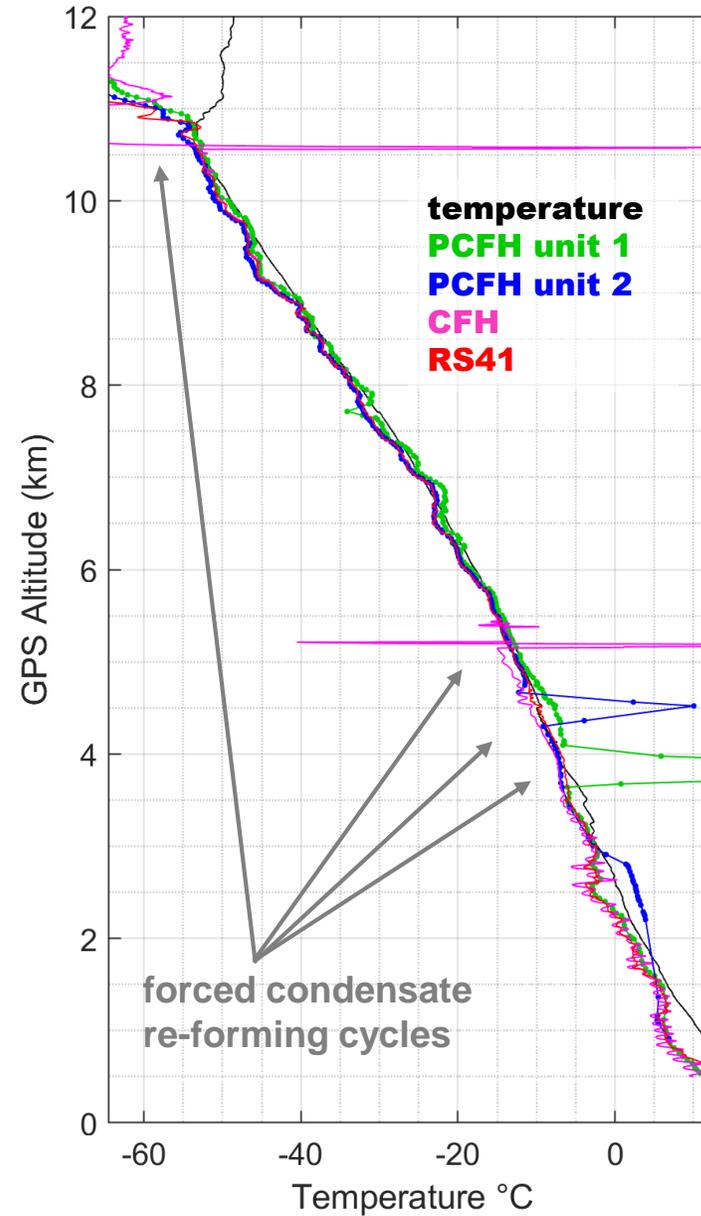
## CFH

same **Golden Point** treatment as for PCFH



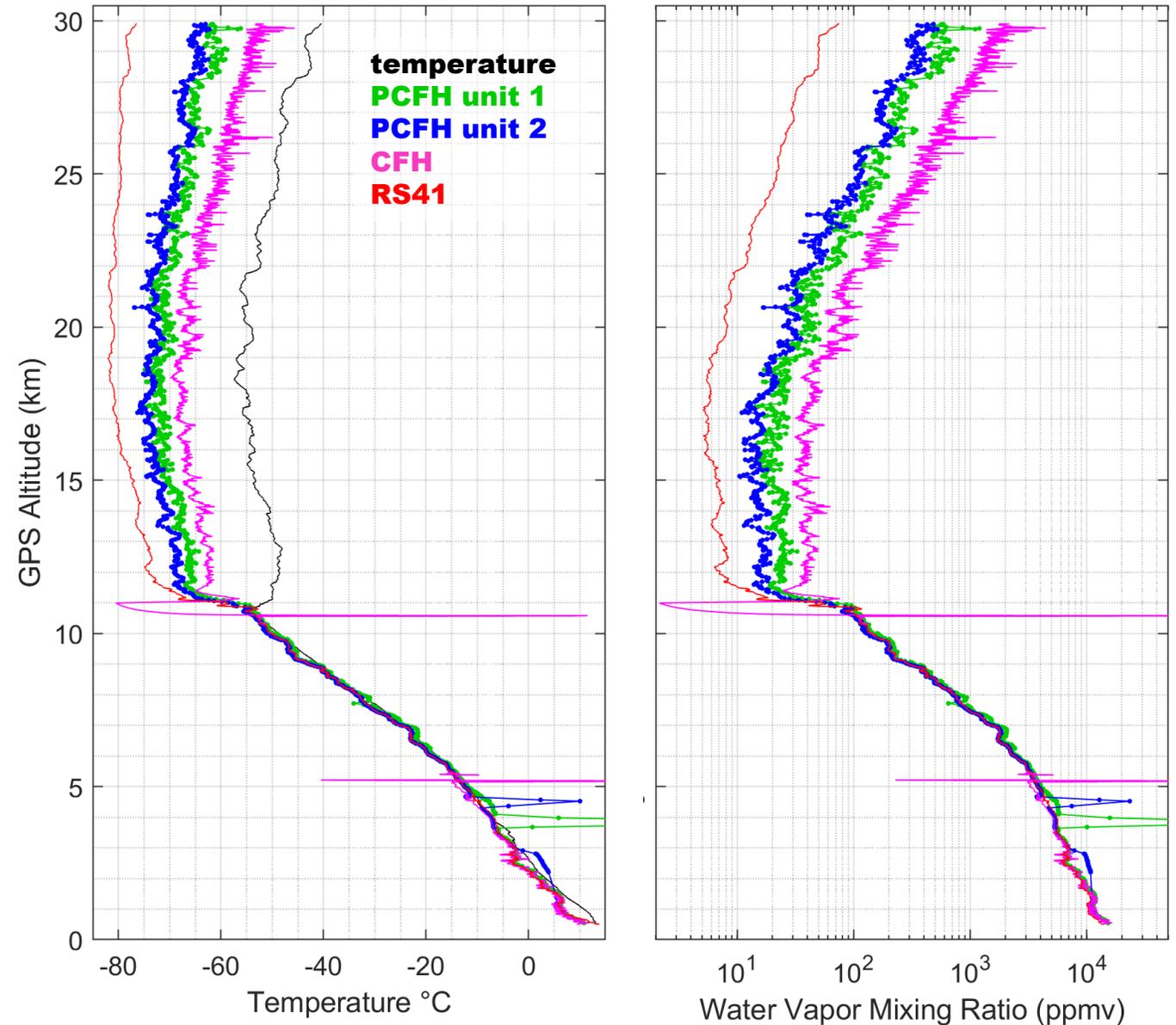
# Flight 2023-0829, H2O-Hub005

- Good instrument agreement with CFH and RS41 below the tropopause



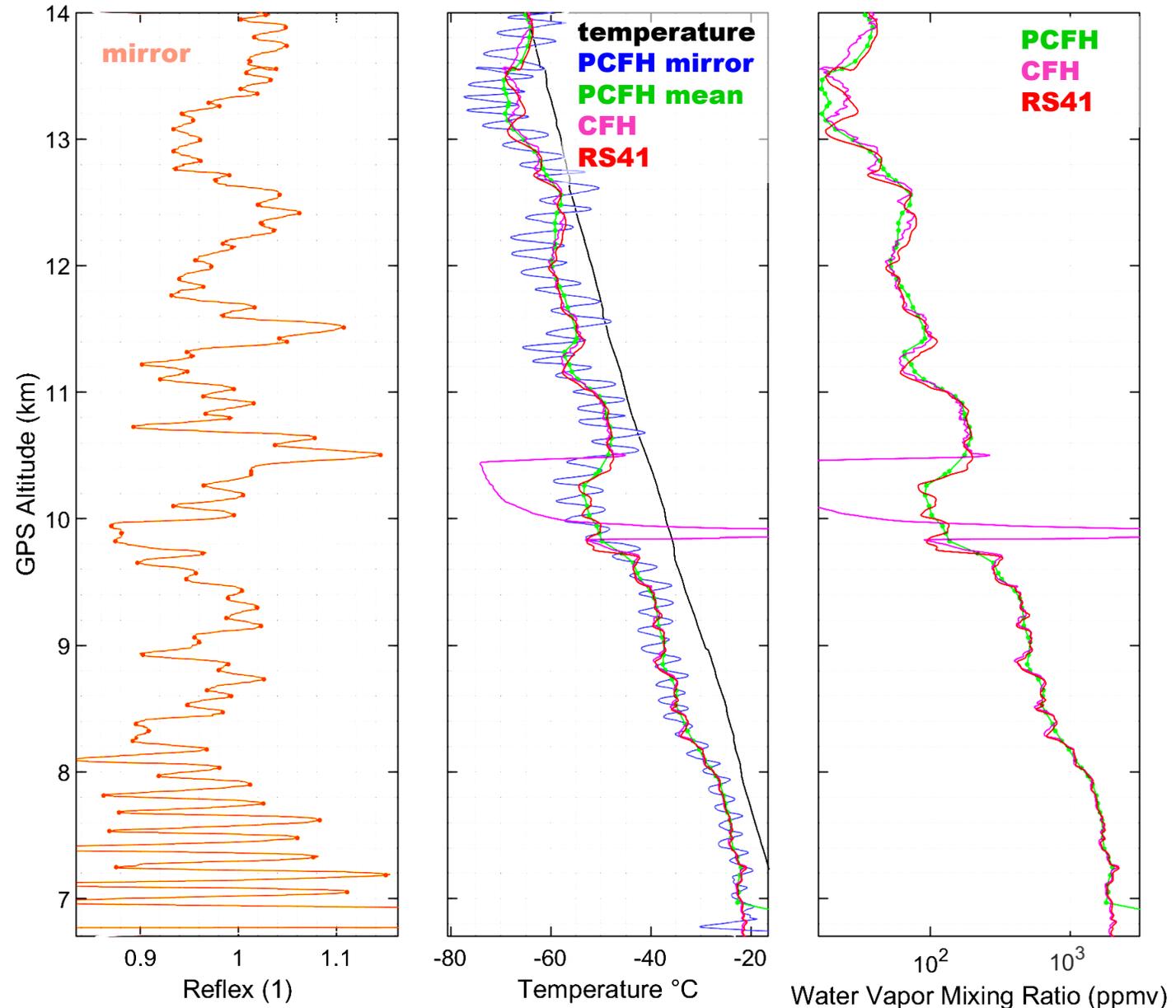
# Flight 2023-0829, H2O-Hub005, ascent

- Good instrument agreement with CFH and RS41 below the tropopause
- Stratosphere: contamination by low level cloud
  - PCFH less affected than CFH due to larger inlet tubes (Jorge et al., 2021)
  - RS41 not affected (heated sensor)
- In future
  - heated PCFH inlet tube(s)
  - covering inlet tube of one sub-unit up to tropopause



# Flight 2023-0906, H2O-Hub007

- Good agreement below 14 km of RS41, CFH, and PCFH
- Successfully generated Golden Points  $\approx 50$  m interval
- Interferences have irritated the controller above 14 km (resolved in the meantime)
- Heat sinks provide insufficient cooling above  $\sim 21$  km altitude (work in progress)



# Conclusions and Outlook

