Status of the Peltier Cooled Frost Point Hygrometer (PCFH) and First Comparison with CFH

ICM-13 Virtual Meeting – R23 Replacements

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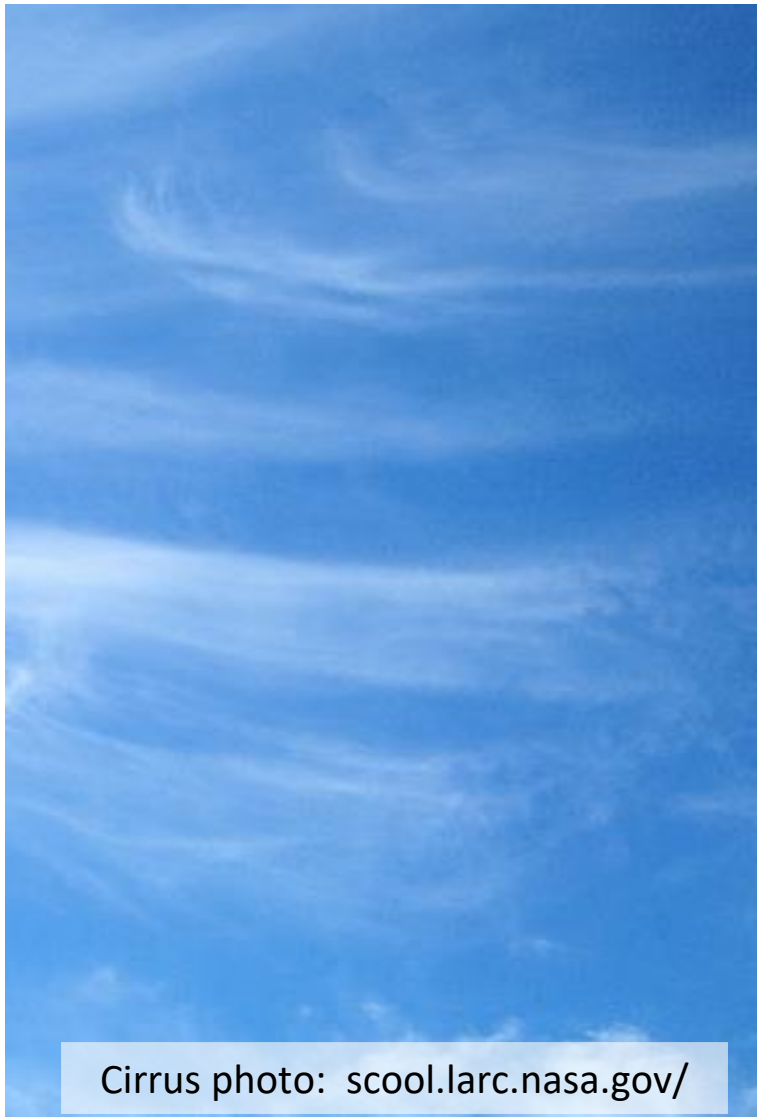
Outline

- water vapor and balloon borne frost point hygrometers
- previous instrument status, design modification
- Relays Control scheme – flight results
- frost point identification (‘Golden Points’)
- CFH / PCFH / RS41 intercomparison in Lindenberg
- further steps

Water Vapor in the Atmosphere

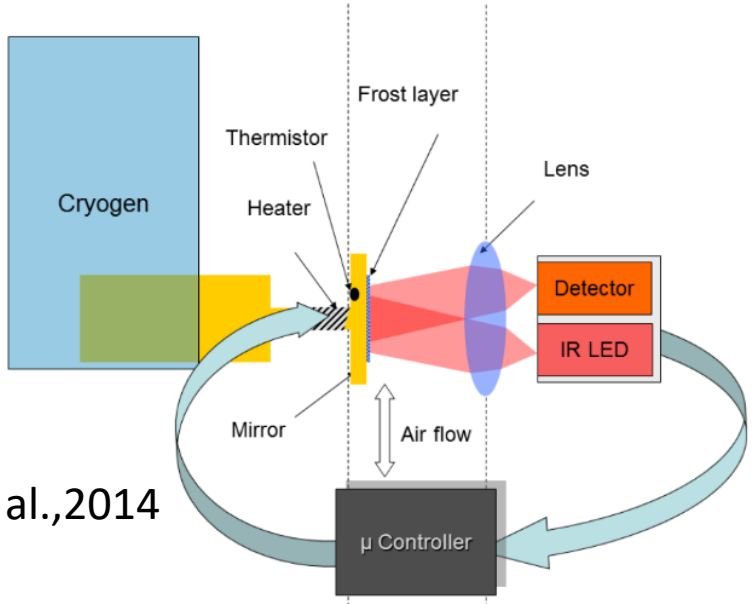
- strongest natural greenhouse gas
- small changes in stratospheric abundance
  $\rightarrow$ significant impact on radiative forcing:
  0.6 Wm^{-2} @ 2 K global surface temperature change (Dessler, 2013)
- atmospheric footprint with high dynamic range (10^5)
  and vertical resolution (50 m)
- cloud radiation interaction not sufficiently understood
  (depends on p_{H2O}, T, and cloud microphysics)
- required: long-term high-quality measurements in upper troposphere and lower stratosphere (UTLS)
  $\rightarrow$ monitor water vapor changes
  $\rightarrow$ improve understanding of cloud formation



Cirrus photo: scool.larc.nasa.gov/

Balloon-borne Frost Point Hygrometers

1. CFH

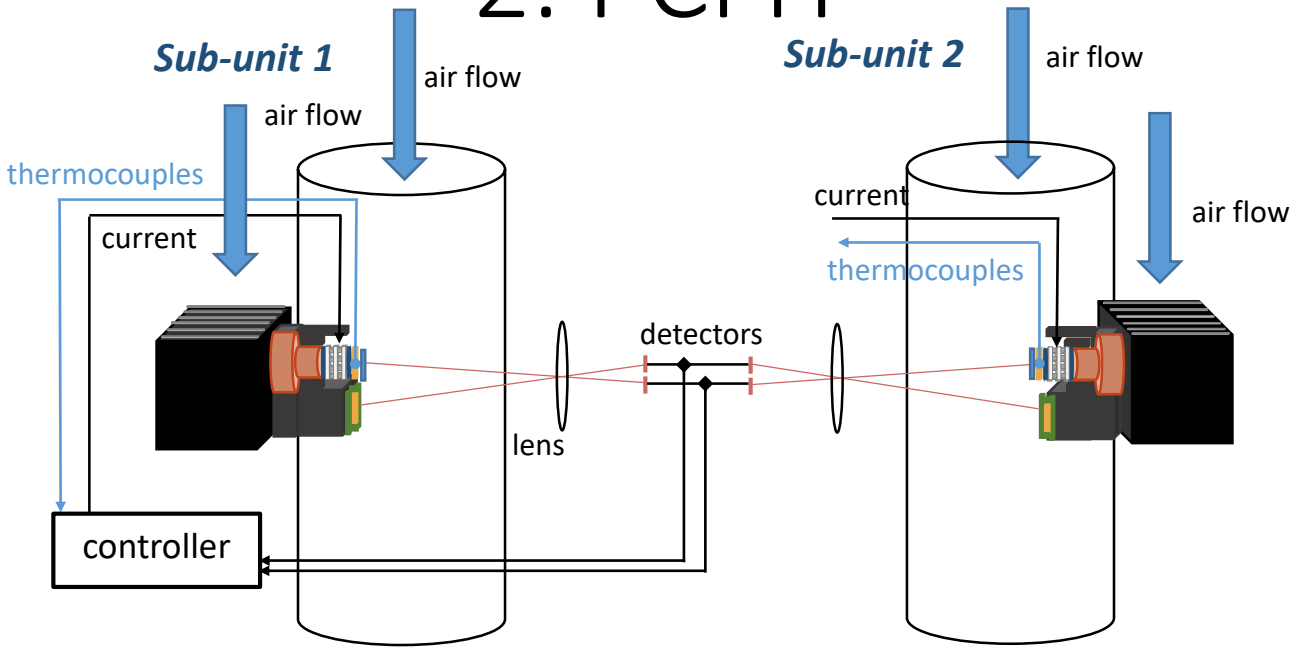


Fahey et al.,2014

Cryogenic Frost point Hygrometer (CFH)

- chilled mirror principle
- reference instrument
- cooling with R23 cryogenic liquid:
  high logistic demands & expert operation

2. PCFH



Peltier-cooled Frost point Hygrometer (PCFH)

- easy to use double instrument
- shared controller, electronics and housing
- cooling with Peltier elements by ambient air
- potential CFH replacement after the R23 phase-out under the Kigali Amendment to the Montreal Protocol

Status End of 2020 and Activities since then

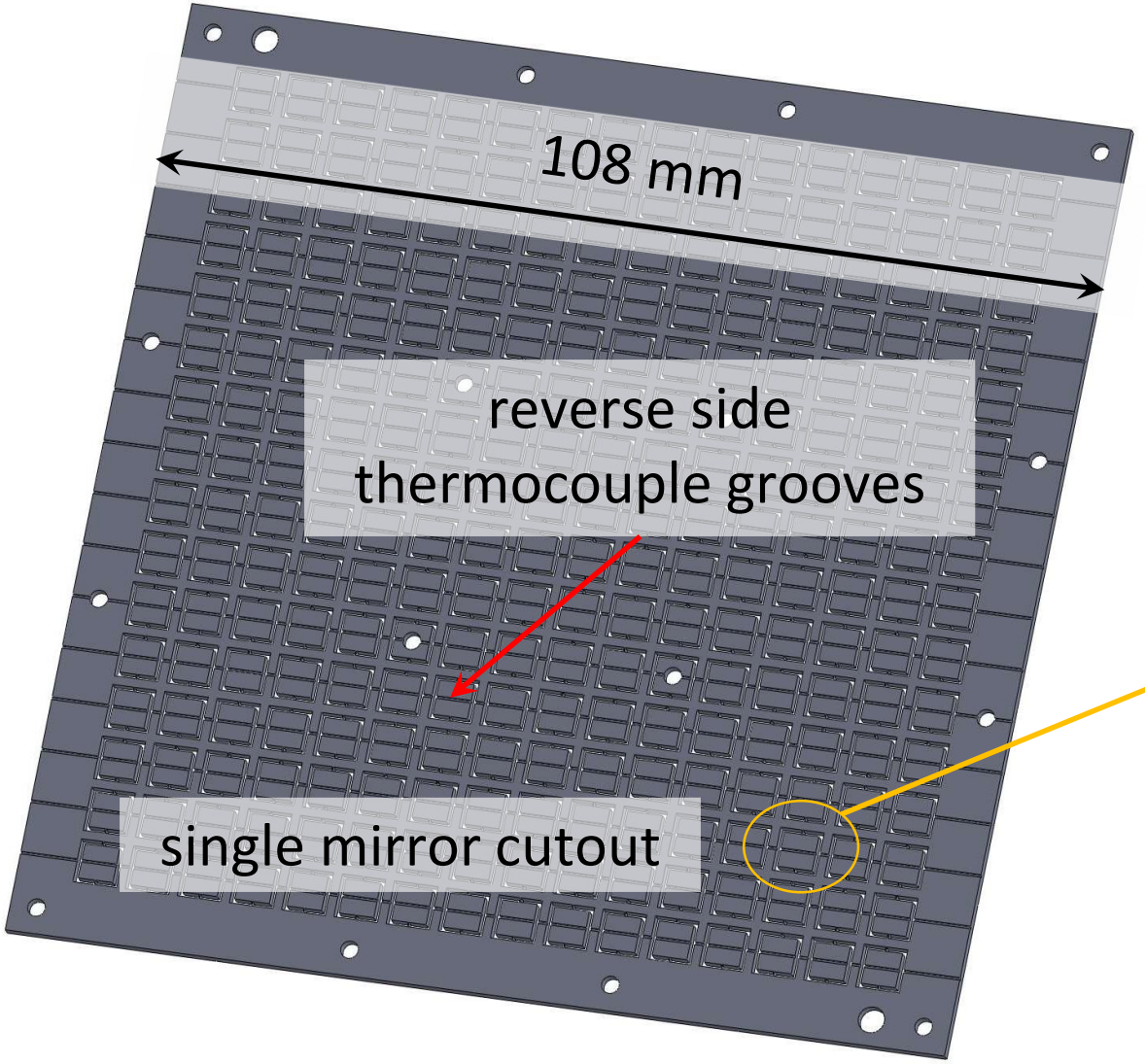
Instrumental

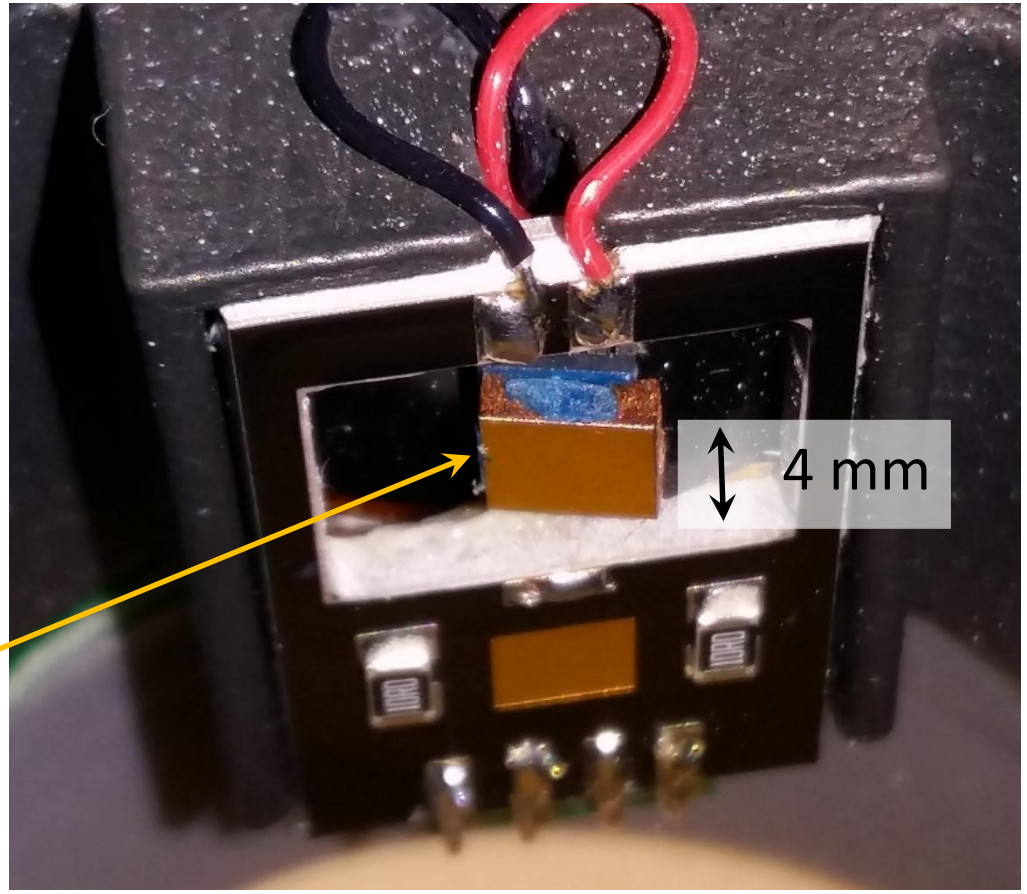
- adequate cooling up to the lowermost stratosphere
- good tracking of the CFH reference up to 300 hPa
- no response of the reflectance signal beyond 300 hPa

Activities

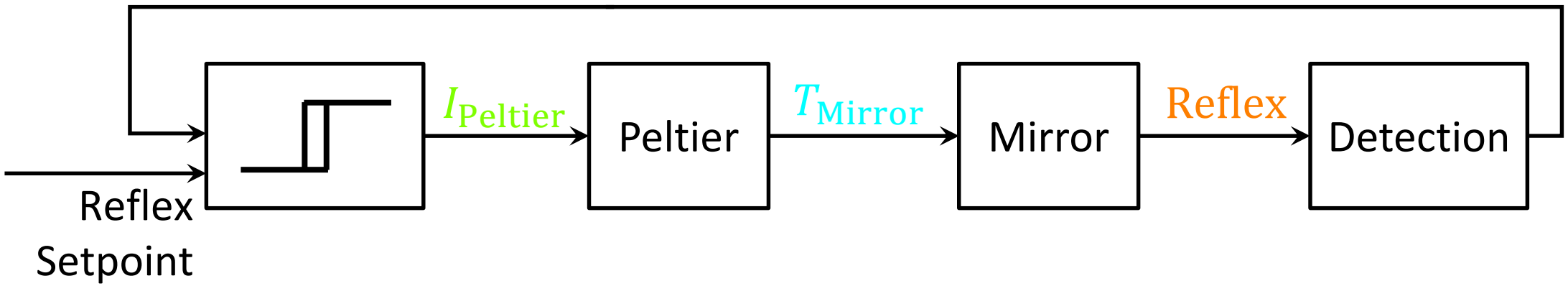
- design revision
- more than 12 flights from Zurich with 100% recovery
- knowledge transfer to DWD Lindenberg:
  flight preparation and refurbishment
- CFH intercomparison flights from Lindenberg

Instrument Modifications





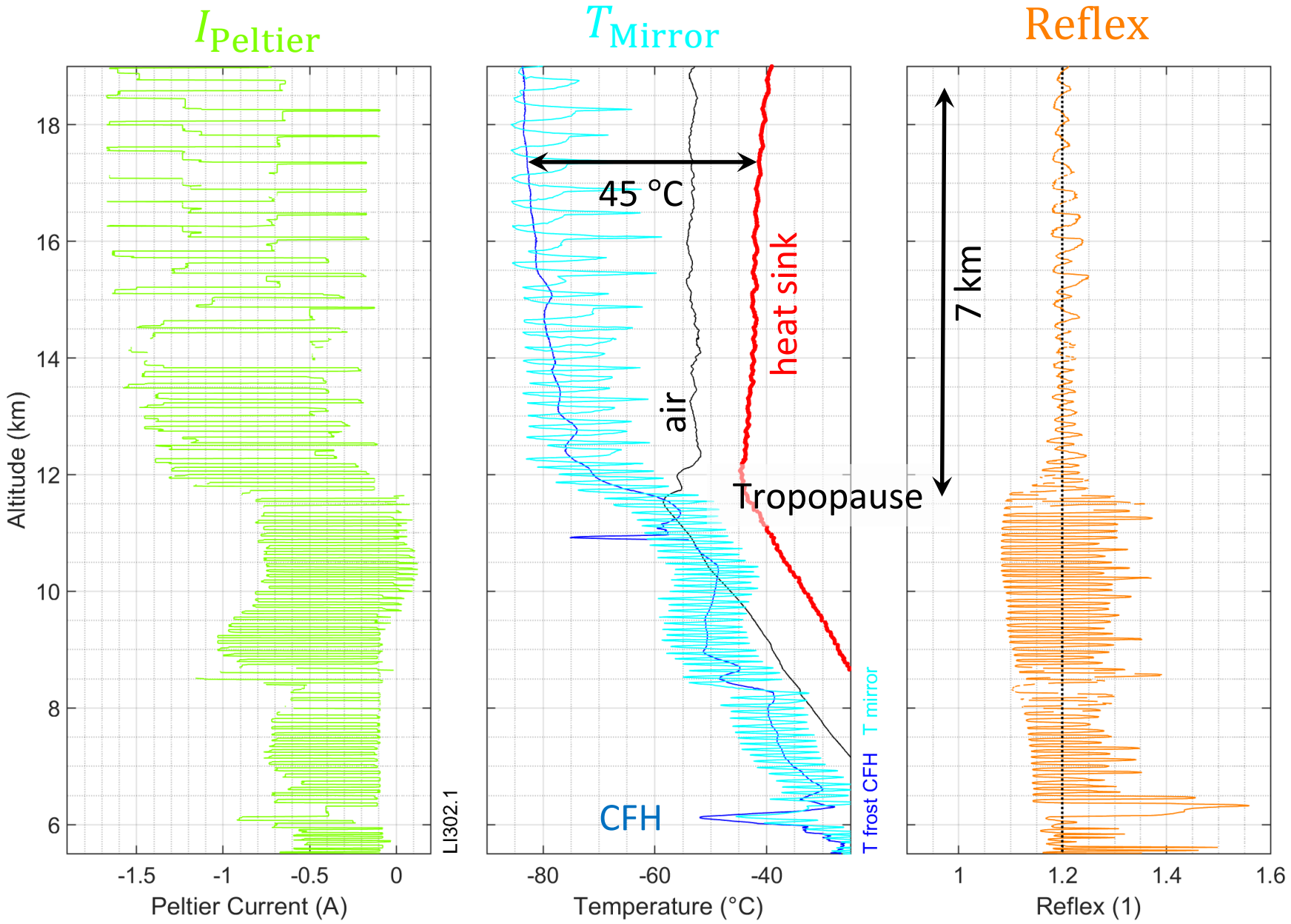
Relays Control



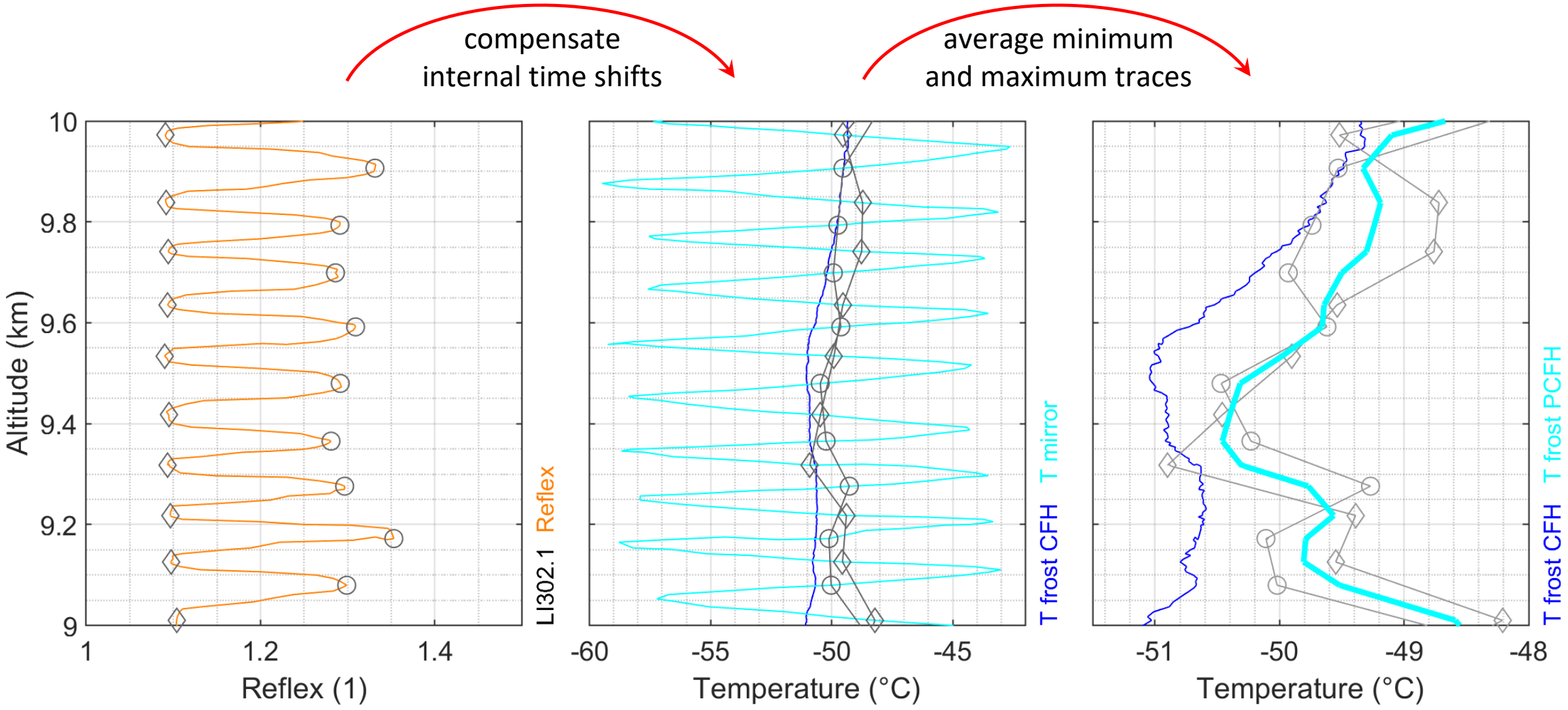
Purpose:

- autonomous oscillation during flight at critical frequency
- system identification by critical gain and critical frequency
- develop mathematical model of the system $\rightarrow$ controller tuning

Flight from Lindenberg, 24 August 2021

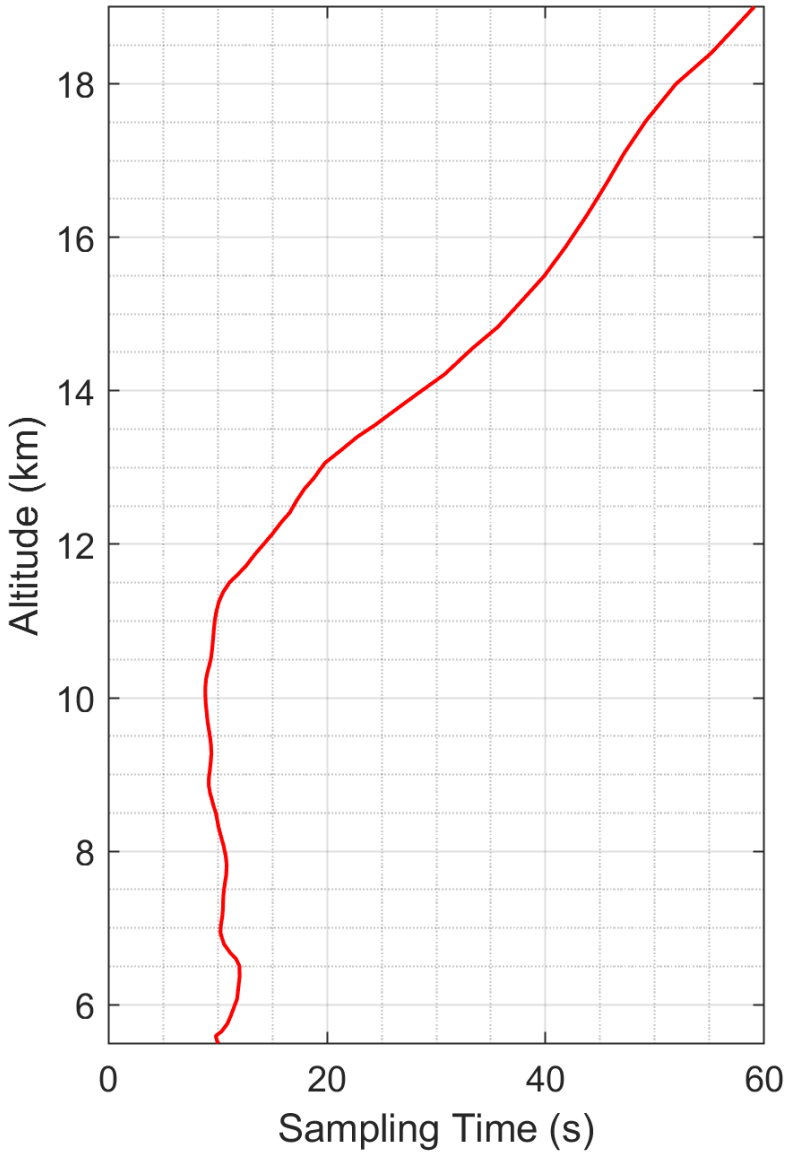


Frost Point Identification: “Golden Points”



◇ reflectance minima ○ reflectance maxima

Frost Point Identification Time Resolution



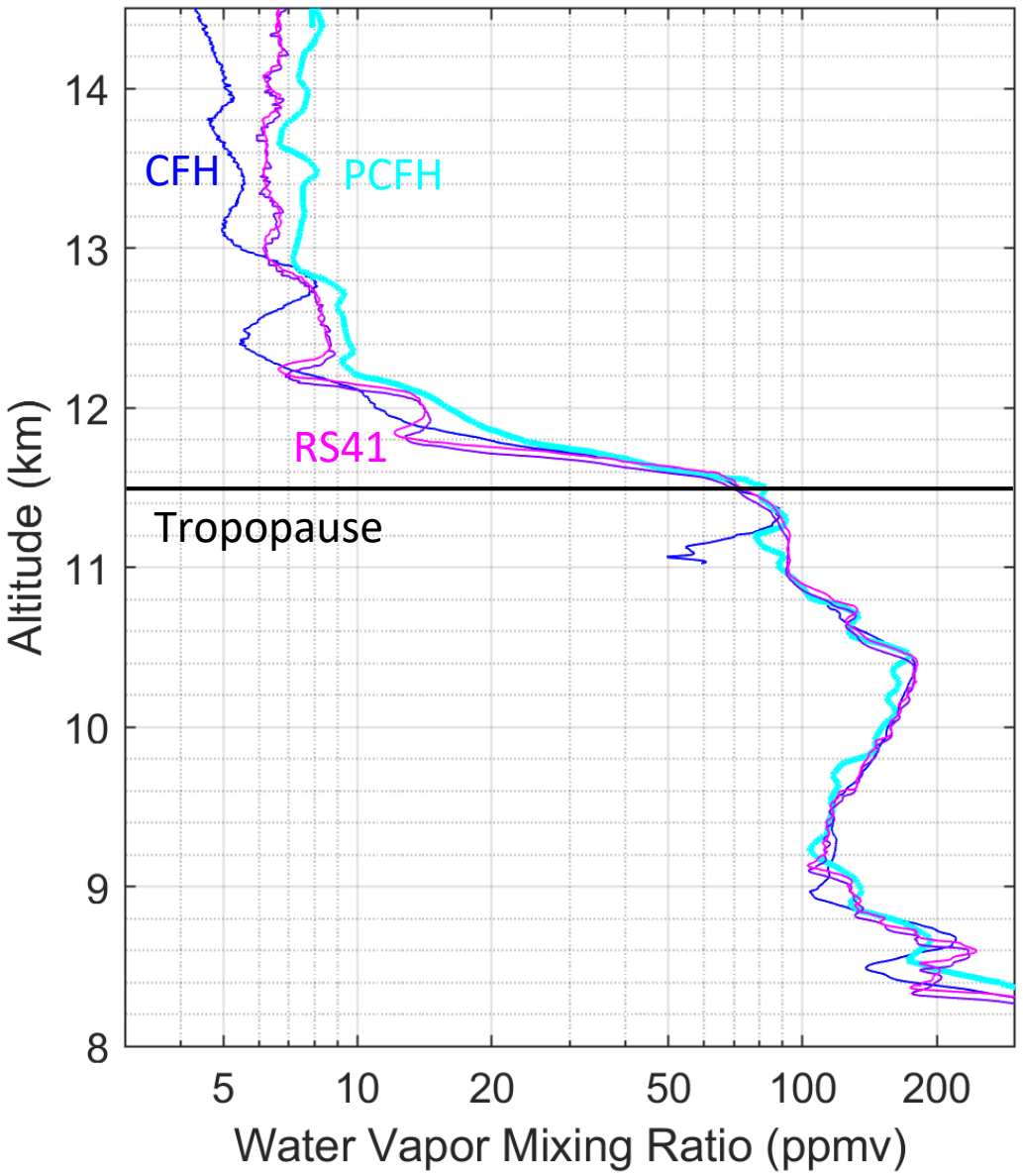
sampling time = time between golden points

- 10 s up to the tropopause
  $\rightarrow$ 50 m vertical resolution
- < 60 s in the lowermost stratosphere
  $\rightarrow$ 300 m vertical resolution

Comparison with CFH and RS41

Flight operated by DWD Lindenberg
on 24 August 2021

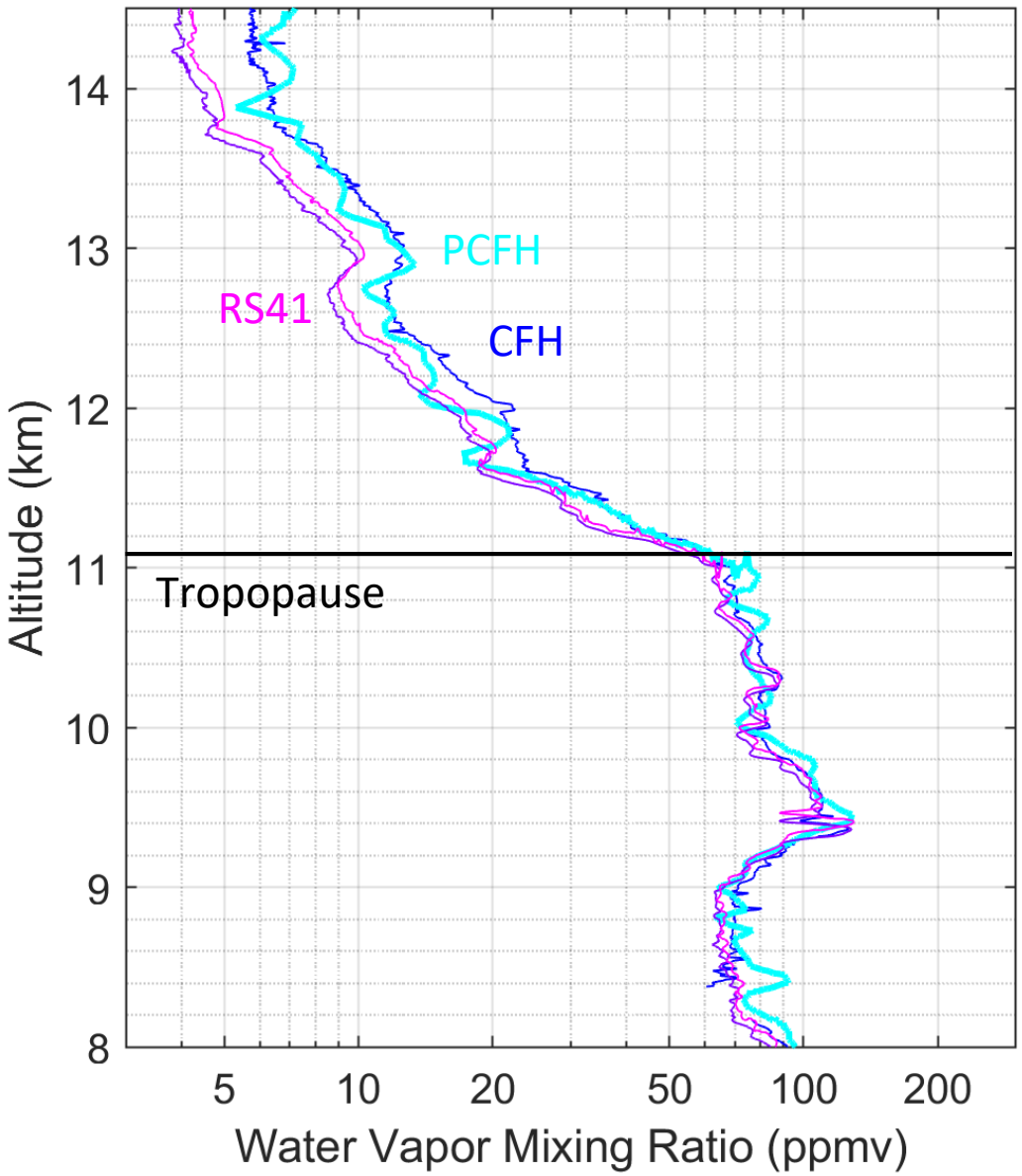
- good agreement with CFH and RS 41 below 11.8 km
- wet bias above 11.8 km, likely caused by
  - pocket (dead volume) influence on rearward tilted mirror part
  - insufficient multiblock leak tightness
- some features in the profile agree between RS41 and PCFH, but not CFH



Comparison with CFH and RS41

Flight operated by DWD Lindenberg
on 7 October 2021

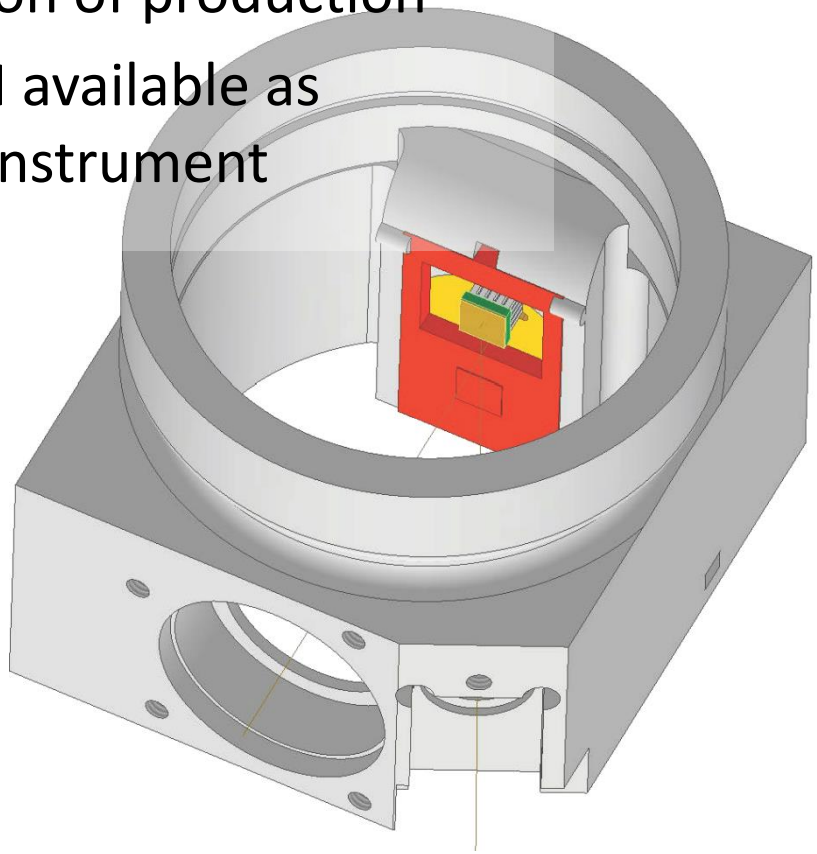
- all instruments agree below the tropopause
- wet or dry bias depends on the reference chosen
- some RS41 profile features captured again



Outlook: Further Steps

Short Term

- multiblock revision to resolve wet bias
- improve adaptive relays control
- system identification leading to PID control to ensure tracking
- superimposed temperature swing for optimized Golden Point generation

Long term

- more intercomparison flights
- regular soundings and campaigns
- professionalization of production
- from 2024: PCFH available as GRUAN-worthy instrument