

Peltier Cooled Frost Point Hygrometer (PCFH)

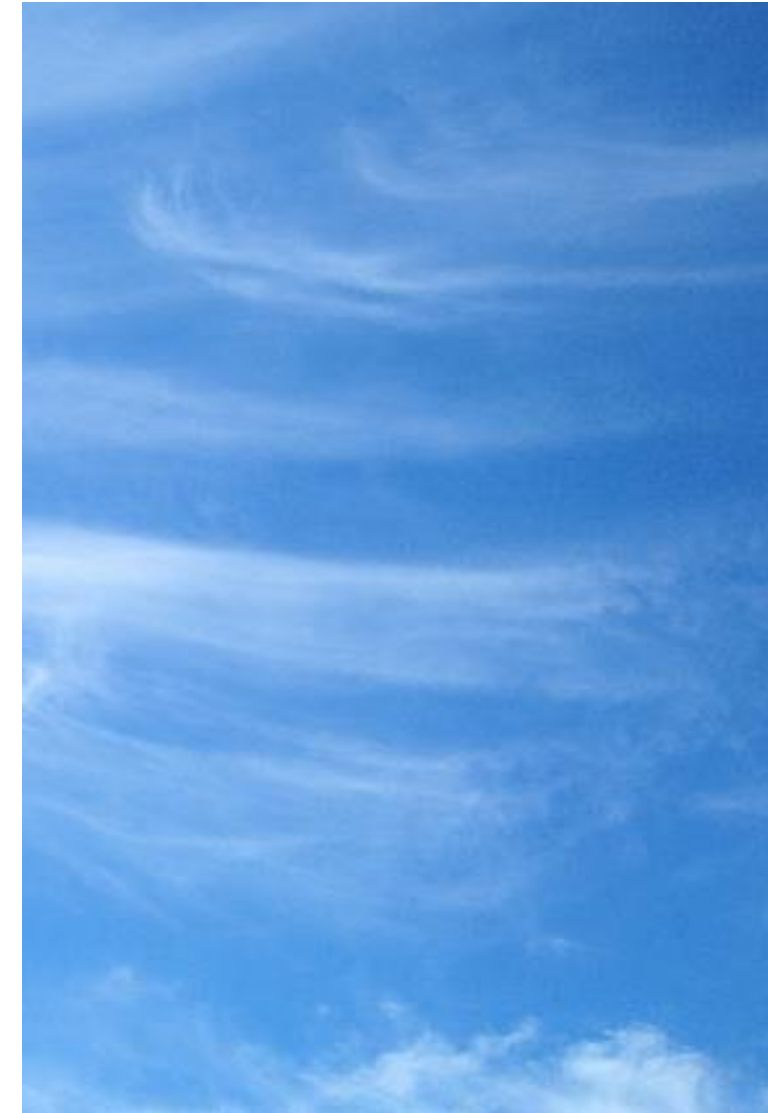
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GRUAN ICM-14, Reunion Island, 28 November 2022

Water Vapor in the Atmosphere

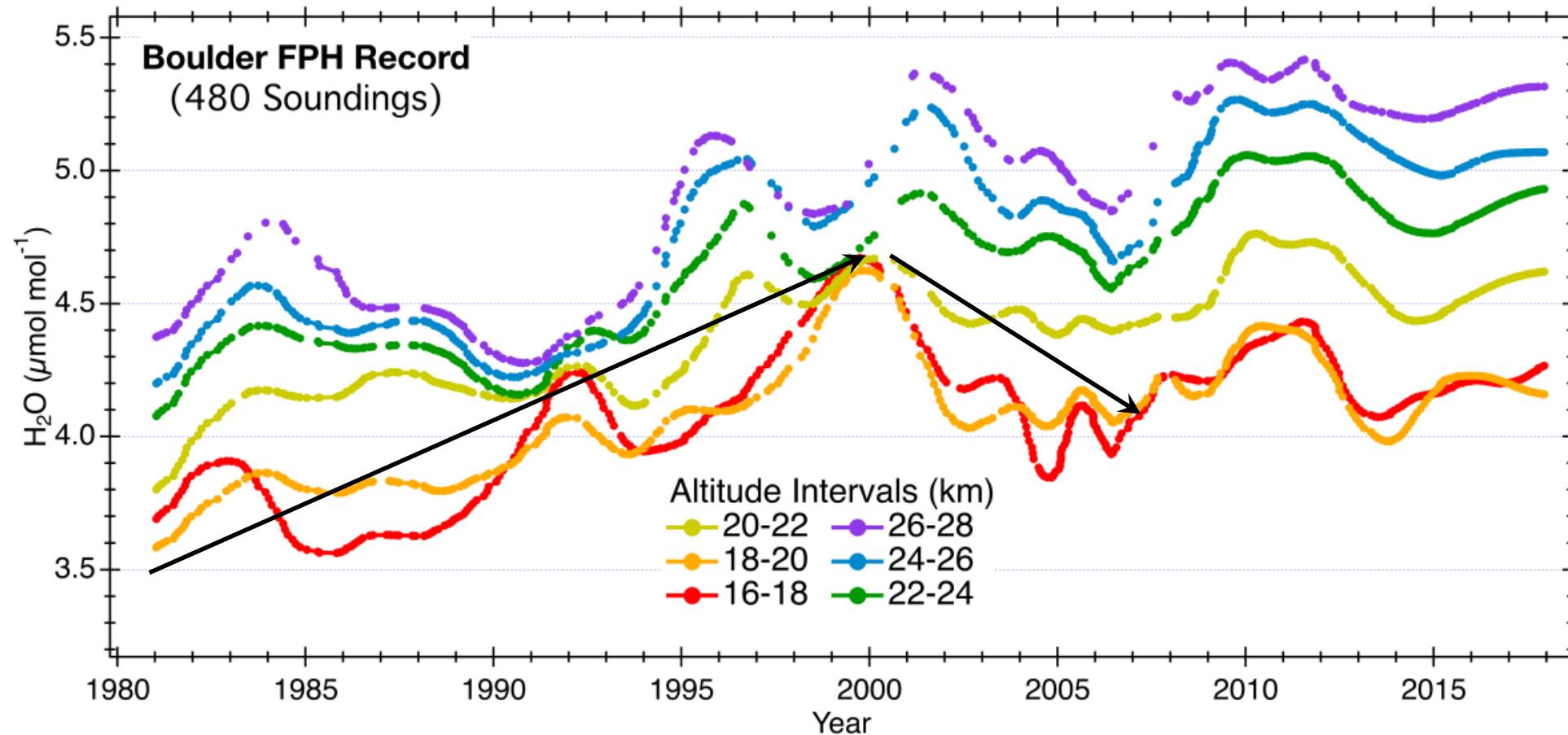
- Stratospheric water vapor is an important **driver of decadal global surface temperature** (Solomon et al., Science 2010)
- It **partly compensated warming** caused by the well mixed GHG increase **in 2001–2009 (by ~25%)** and **enhanced it in 1980–2000 (by ~30%)**
- In the upper troposphere, cirrus clouds
 - control stratospheric humidity
 - supply surface for heterogeneous chemistry affecting ozone
 - have a significant positive radiative climate forcing
- High-quality and long-term water vapor measurements are needed in upper troposphere/lower stratosphere (UT/LS) to
 - better understand visible/subvisible cirrus cloud formation
 - monitor water vapor changes



Cirrus photo: scool.larc.nasa.gov/

Water Vapor Trends

Stratospheric Water Vapor over Boulder, Colorado



Frost Point Hygrometer (FPH) data by Dale Hurst, <https://gml.noaa.gov/ozww/wvap>

PCFH Setup

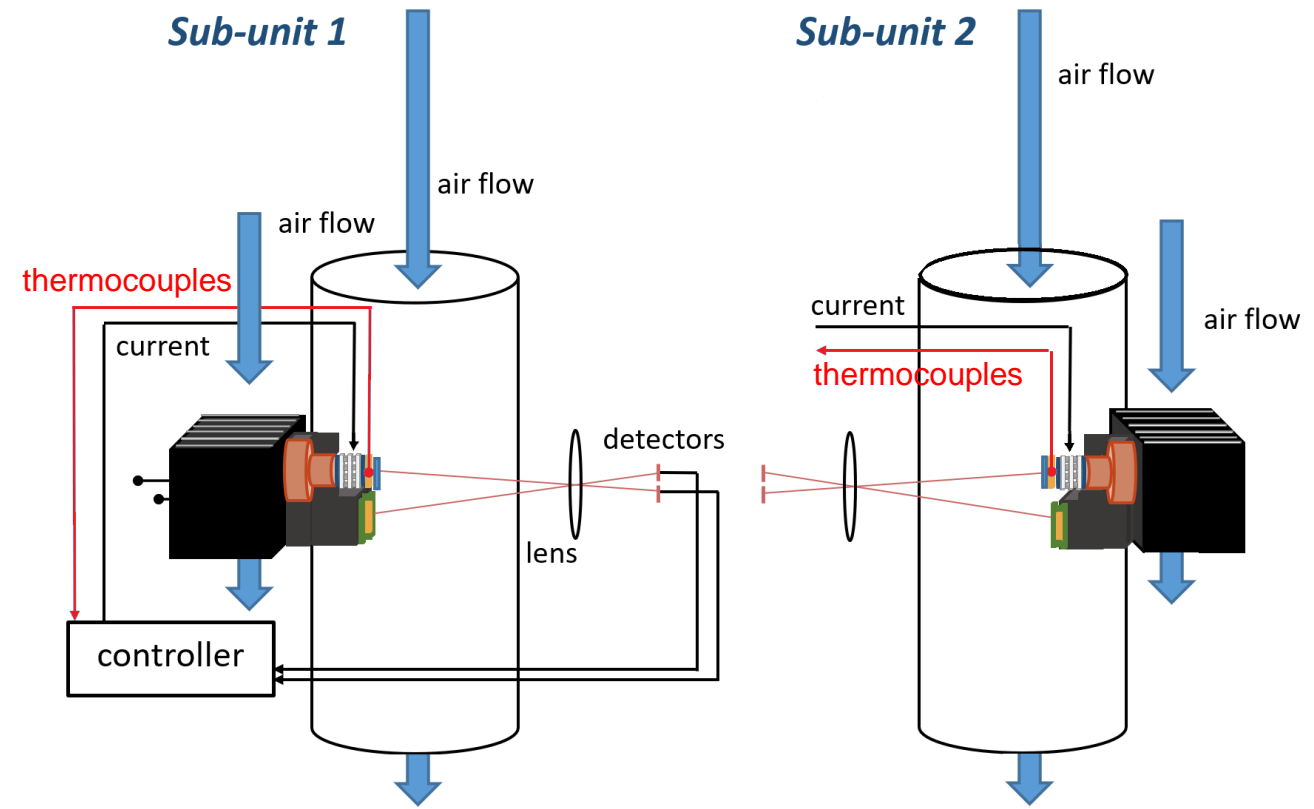
Goals

- Replace R23 by Peltier elements
- Reduce logistic and preparation efforts
- Identify artifacts and contamination

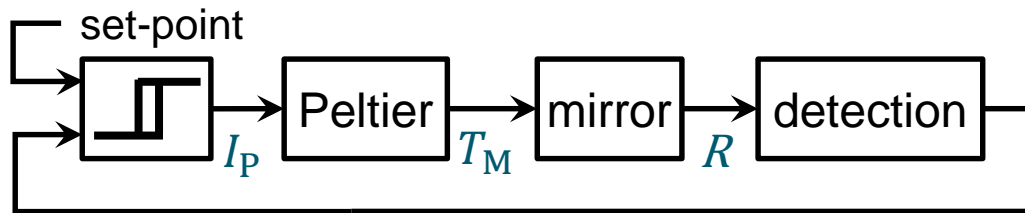
Realization

- Cooling by ambient air with solid state thermoelectric devices
- Two independent sub-units
- Simple application

Operation Principle



Relay Control



autonomous oscillation during flight

identify system by critical frequency and gain

mathematical model → **controller tuning**

assess system performance

side effect: **golden point generation**

frost point tracking remains troublesome

Golden Points

example:
in-flight **mirror signal**
between 9 and 10 km

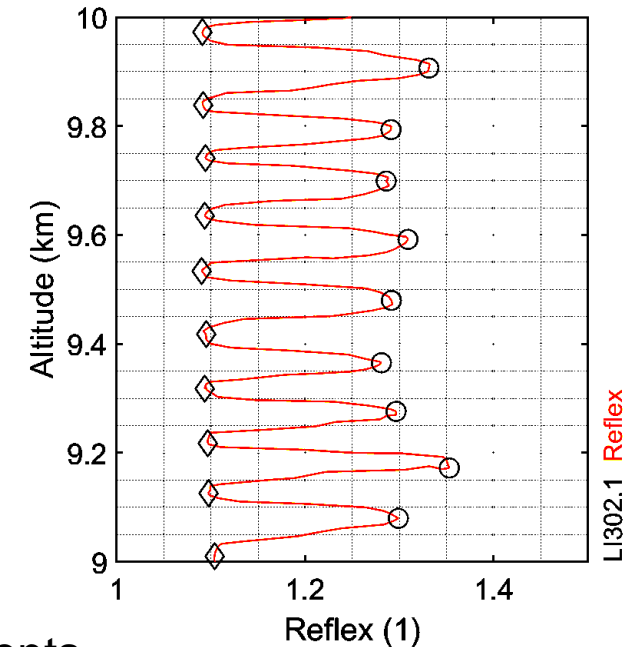
signal extrema:
transient equilibrium

$$T_{\text{mirror}} = T_{\text{fropoint}}$$

challenges:

- internal time shifts
- fast temperature transients

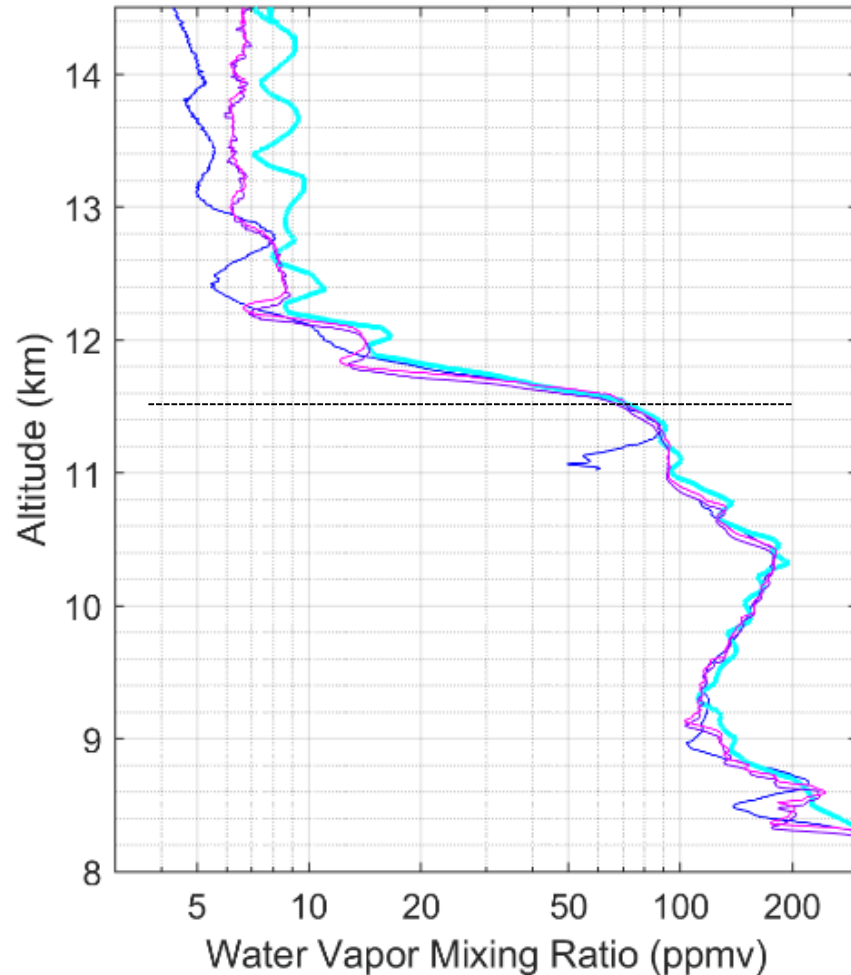
sampling time = time between golden points



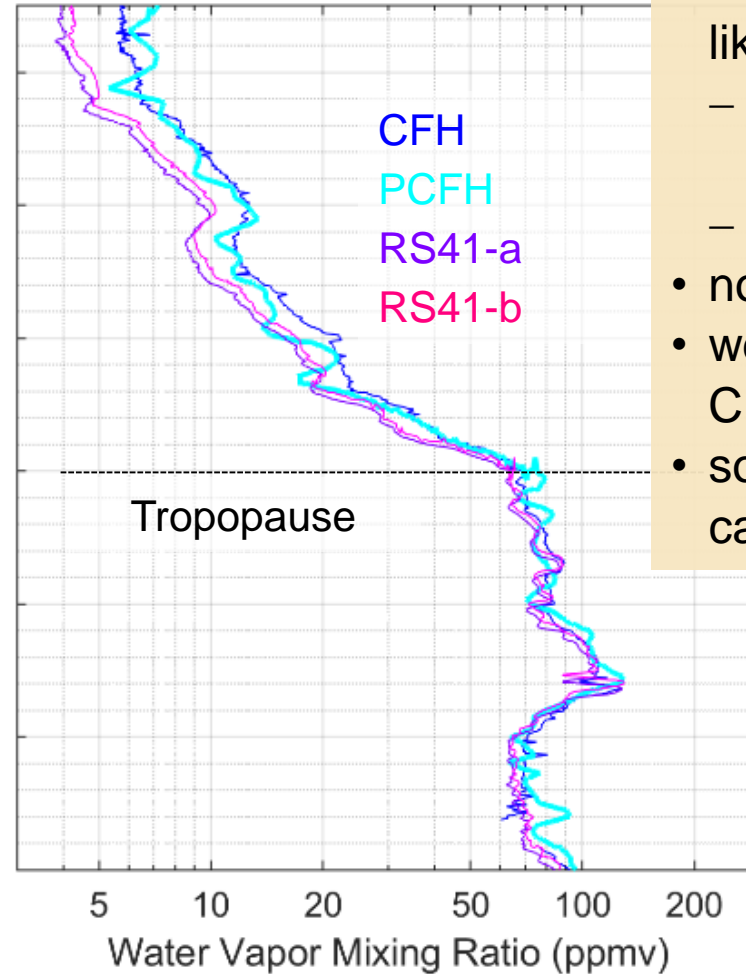
region	time	vertical resolution
troposphere	10 s	50 m
lowermost stratosphere	up to 60 s	300 m

Validation with CFH and Comparison to RS41

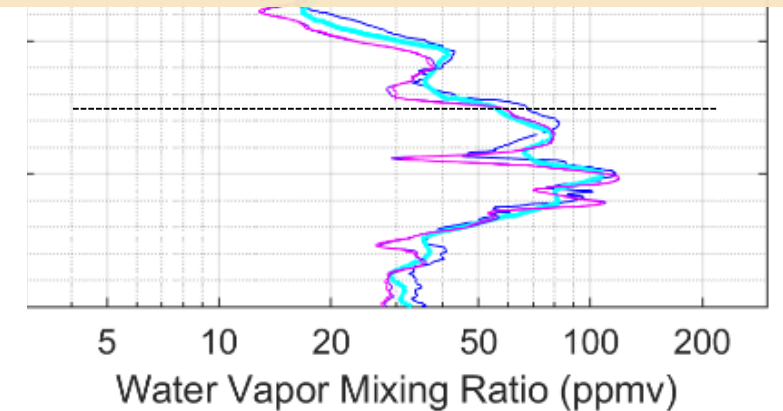
2021-0824 (LI-302)



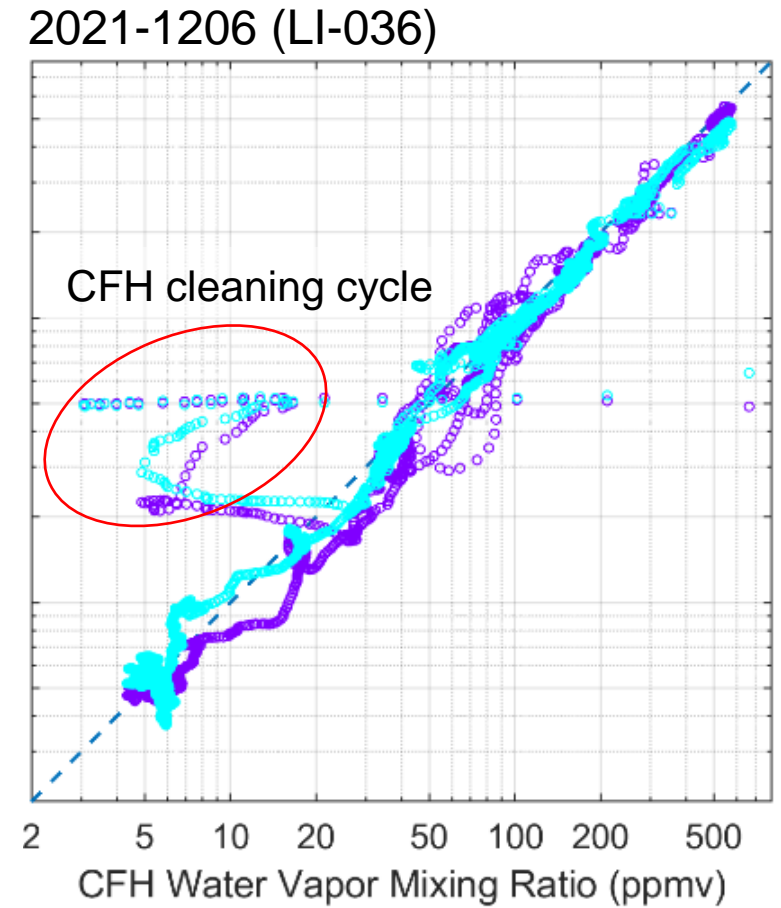
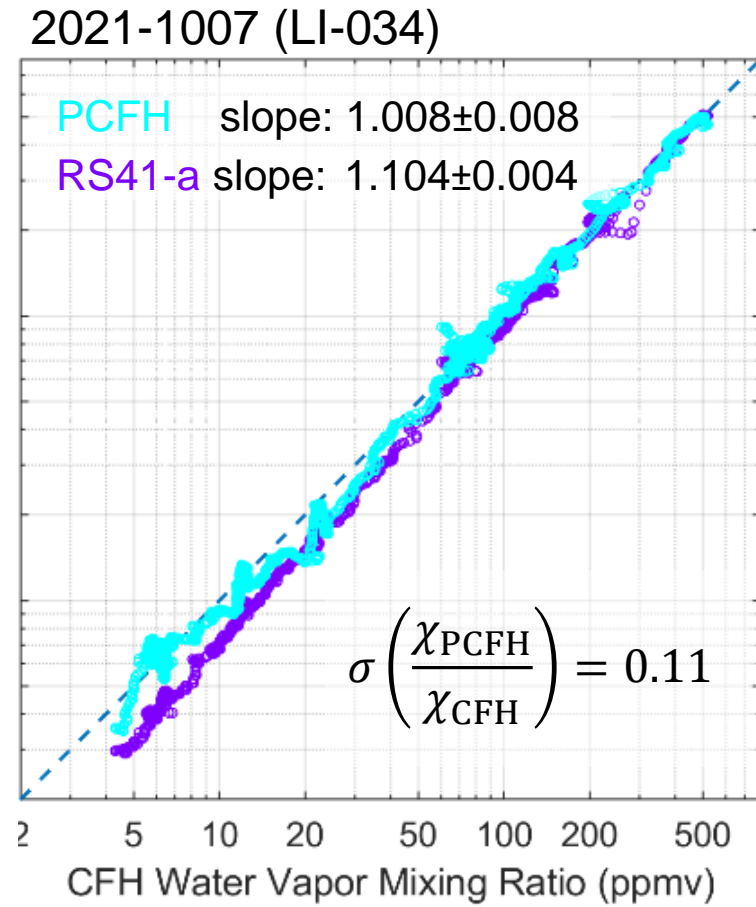
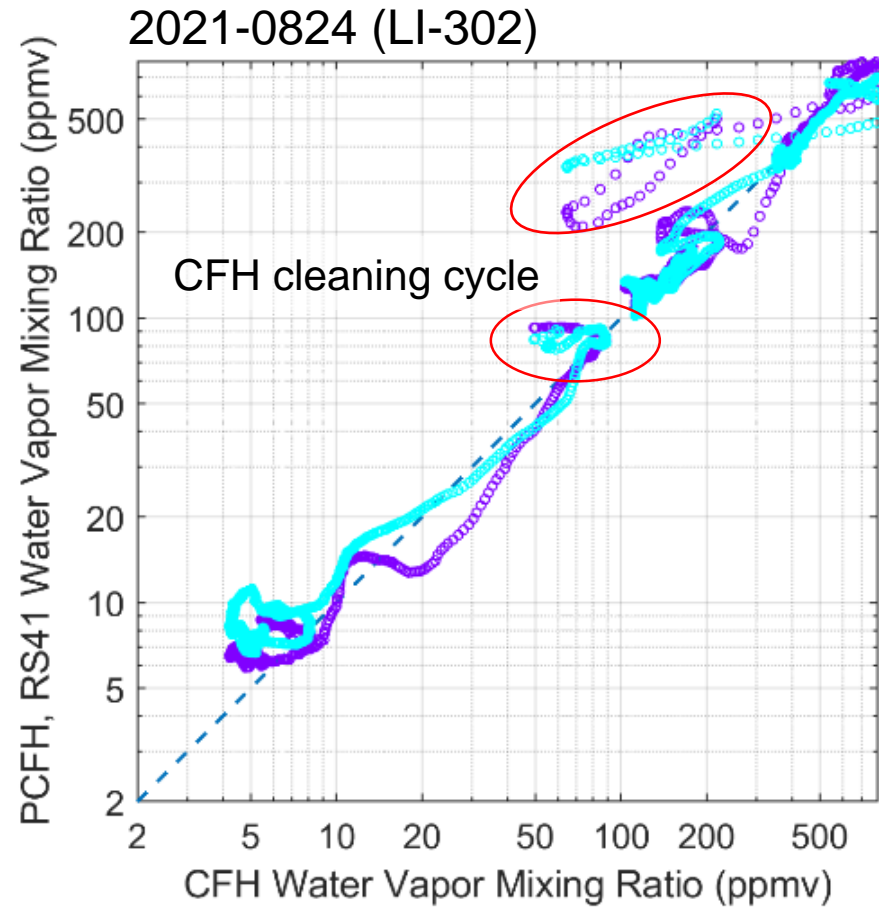
2021-1007 (LI-034)



- Flights operated by DWD Lindenberg
- good agreement with CFH and RS41
 - wet bias above 11.8 km on 24 August, likely caused by
 - pocket (dead volume) influence on rearward tilted mirror part
 - insufficient multiblock leak tightness
 - no wet bias in the other flights
 - wet / dry bias not consistent between CFH and RS41
 - some RS41 features in the profile captured by PCFH, but not CFH



Uncertainty Characterization



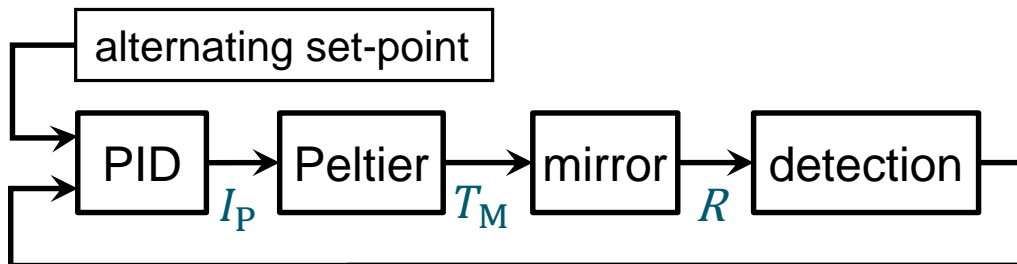
Swiss Federal Office for the Environment (FOEN) Environmental Technology Promotion

know-how transfer to mylab elektronik (Swiss SME)

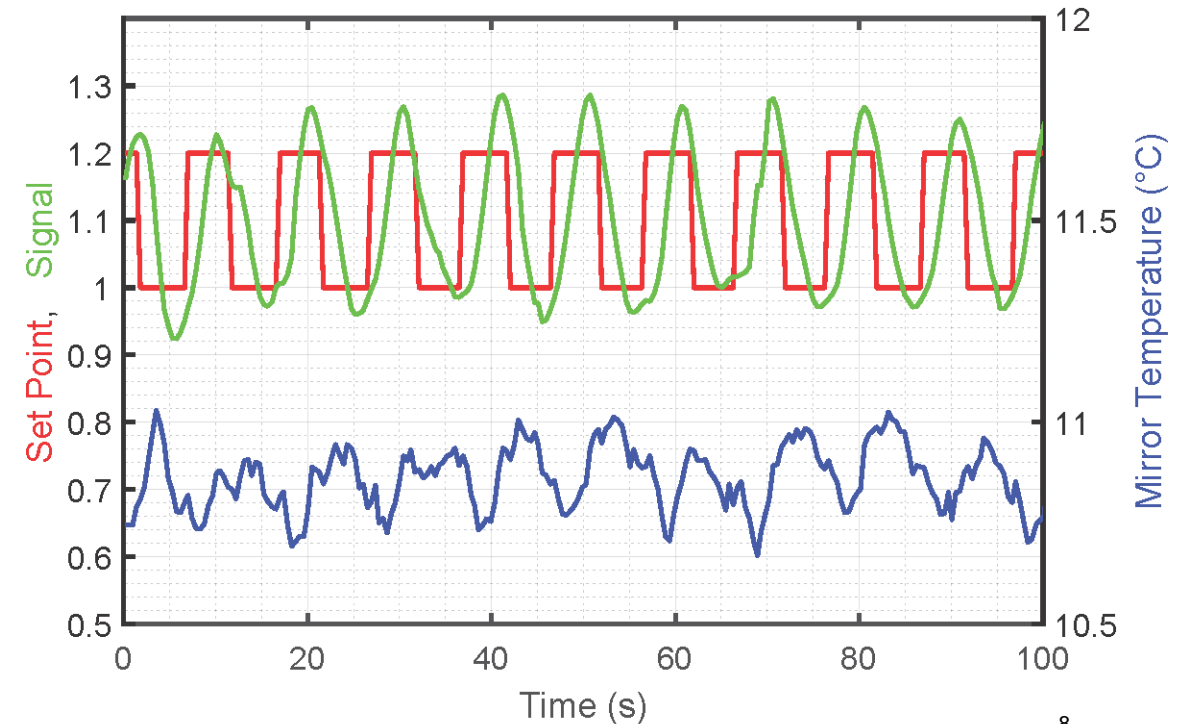
adapt engineering → **reliable production**

resolve known issues

golden point generation with frost point tracking



preliminary lab results



Joint GAW / GCOS Switzerland Call for Proposals

The Swiss H₂O Hub – high quality water measurements from ground to space

- close critical observational gaps in the water cycle by combining in-situ and remote sensing observations in a development and testing phase and a monitoring phase.
- continuously re-visiting calibration, traceability, and homogeneity of this Essential Climate Variable (ECV) in order to guarantee their usability for climate monitoring and climate change detection.
- IAP University of Bern: MIAVARA microwave radiometer
- MeteoSwiss Payerne:
RALMO lidar, Balloon sounding facility
- Empa Dübendorf:
ALBATROSS H₂O tunable QC diode laser
- ETH Zurich: PCFH

