CFH COOLING AGENT ALTERNATIVES

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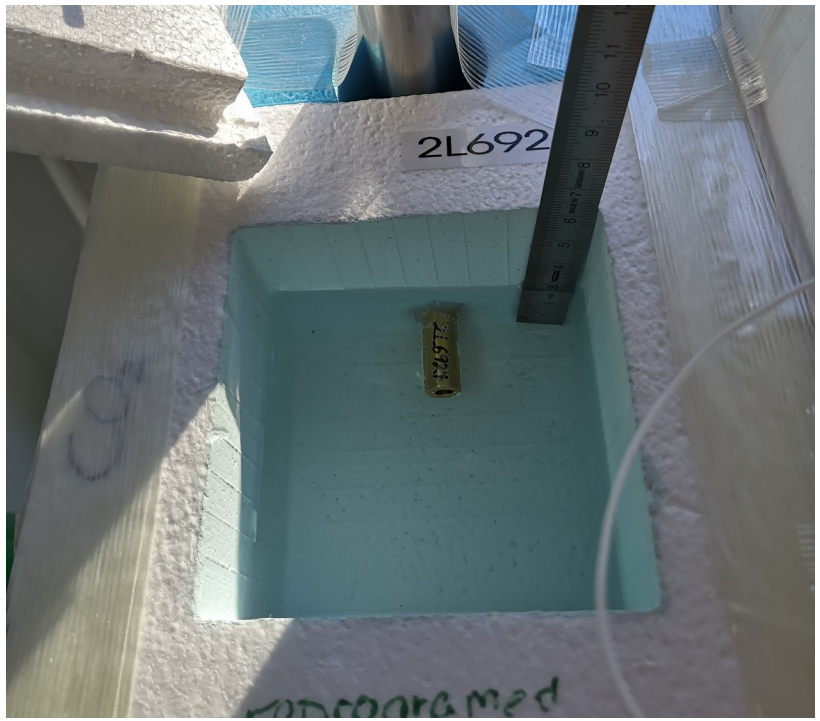
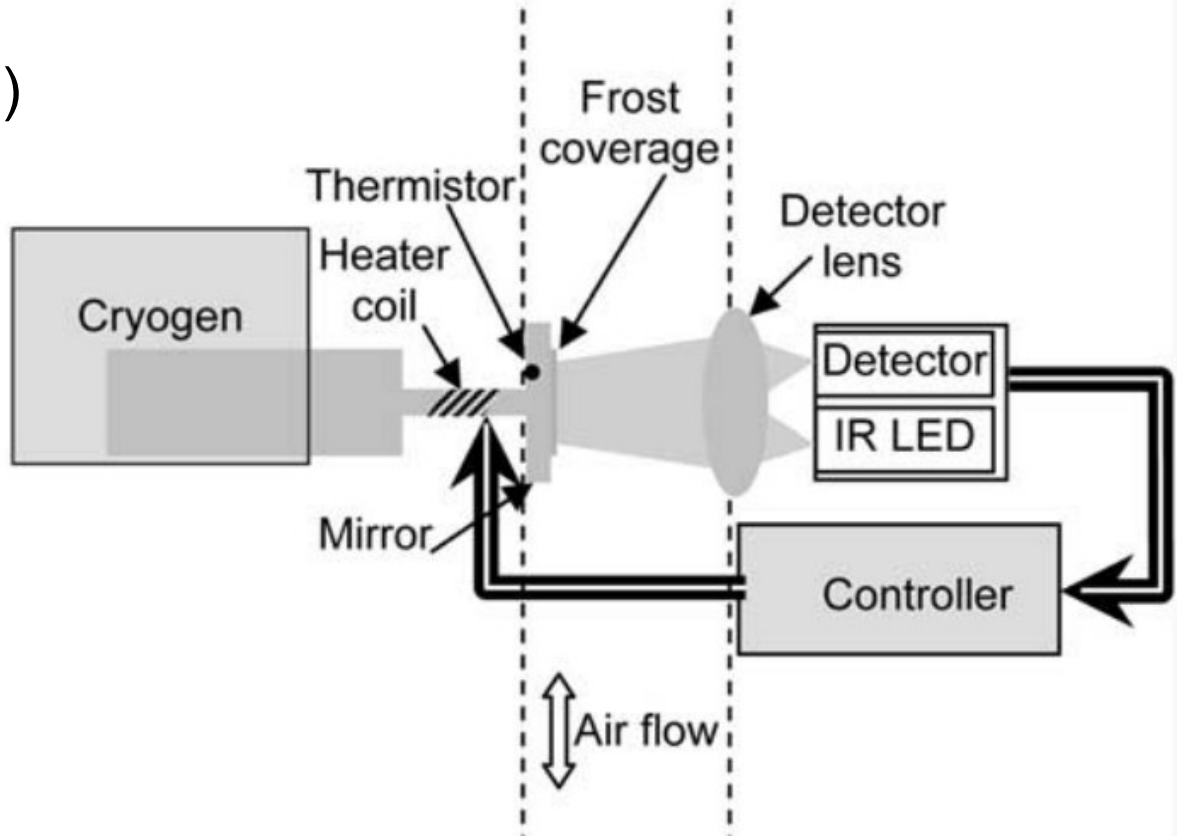
CRYOGENIC FROSTPOINT HYGROMETER (CFH)

- Mirror temperature is controlled by heating against a cold sink (fast response)
- Cold sink by cryogenic vessel with R23 (HFC-23)

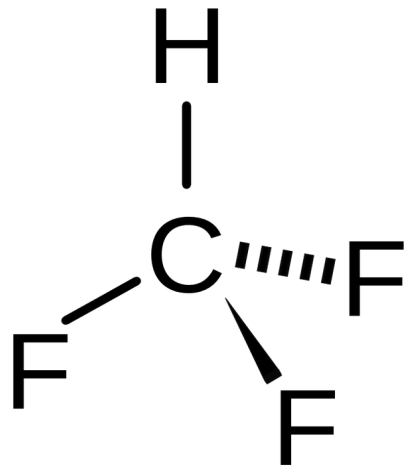




Vömel et al, JGR, 2007

R23 (HFC-23) REFRIGERANT

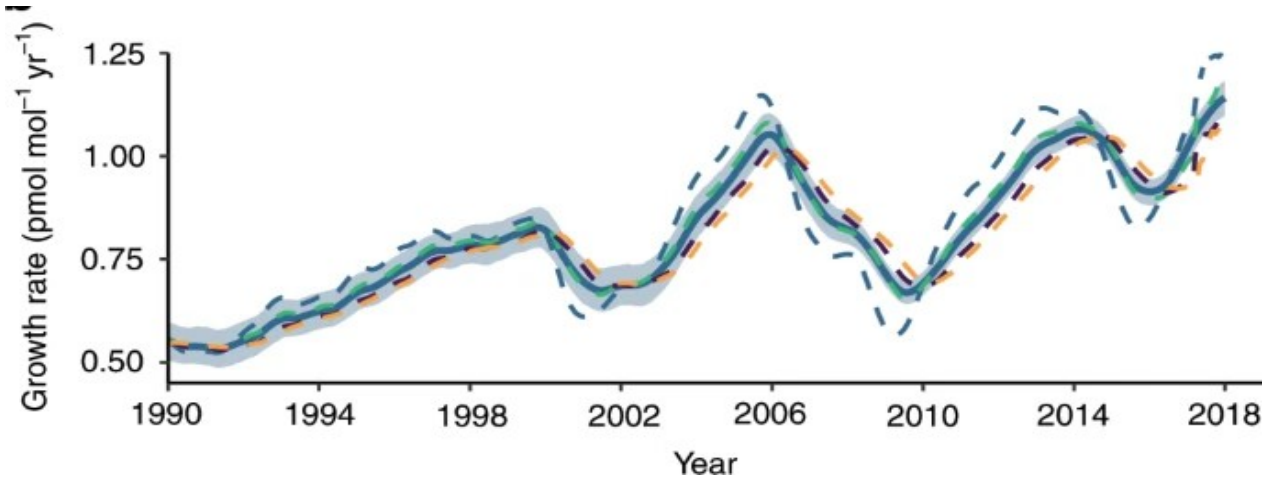
Trifluoromethane (CHF3)



- Global Warming Potential (100-year GWP): 12690
- Long atmospheric lifetime: ~228 years
- Regulated under the Kyoto Protocol
  of the United Nations Framework Convention on Climate Change (UNFCCC)
- European Commission: No 517/2014 on fluorinated greenhouse gases (16 April 2014)

  ➔ From 2020: F-gases with GWP of 2,500 are not possible to order (Fade out of R23 (HFC-23))

- Stanley et al., Nat. C., 2020
  still found a strong increase



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TESTED COOLING ALTERNATIVES

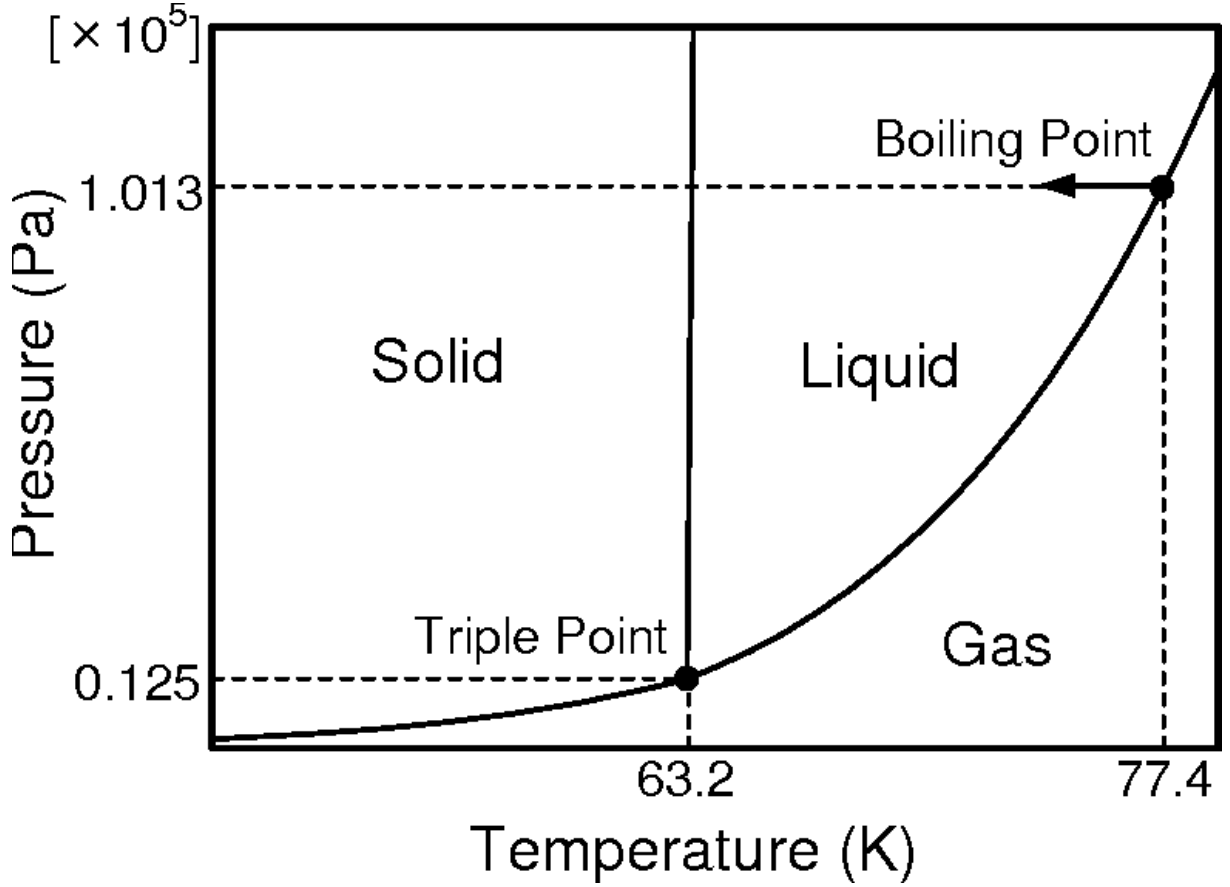
Criteria

- Environmental friendly, low cost, easy provision, harmless, and good heat conduction (liquid)

	R23	Liquid Nitrogen	CO2 (dry ice)
Boiling Temperature	-82,2 °C	-196 °C	-78,5 °C
ΔH_v enthalpy of evaporation	17,03 kJ/mol	5,59 kJ/mol	23,2 kJ/mol

LIQUID NITROGEN (LN2)

Subline



Takayoshi et al. Cryogenics, 2009

- Liquid nitrogen gets solid at pressures < 125hPa
- Not suitable for direct replacement of R23 for measurements on a balloon
- Small value of evaporation enthalpy
  - Amount of LN2 must be larger, thus more heavy payload

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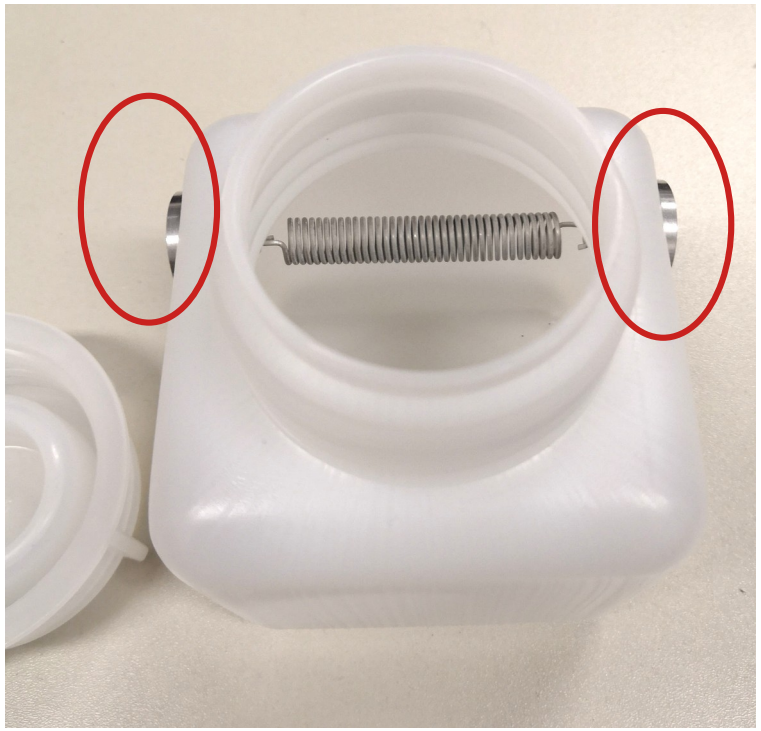
LIQUID NITROGEN (LN2)

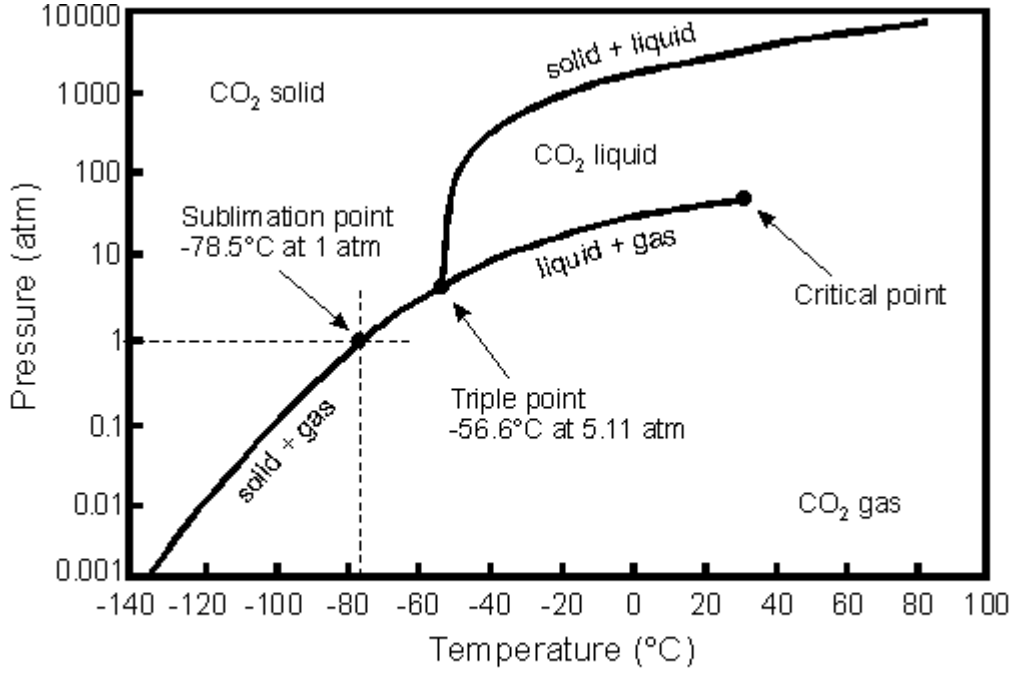
Pressure vessel



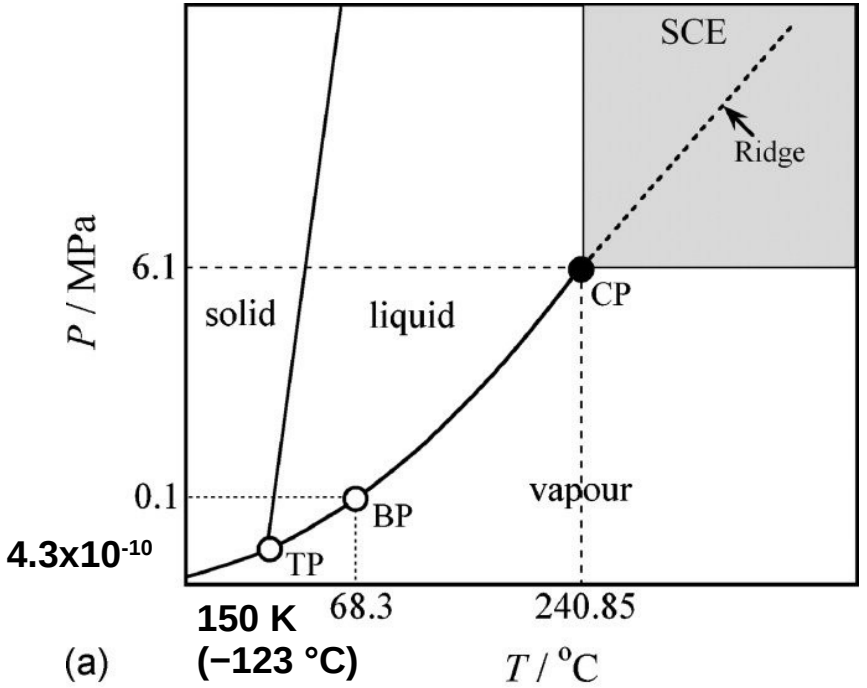
- Two valves with rubber ring and a spring connected to both lids
- Holds pressure to > 125 hPa tested in a climate chamber down to ambient pressures of 10 hPa
  → No freezing of LN2
- Open questions:
  - Connecting cold finger of CFH to LN2 (pressure-tight)
  - Danger of frozen valves ?

ETHANOL AND DRY ICE MIXTURE

Carbon Dioxide



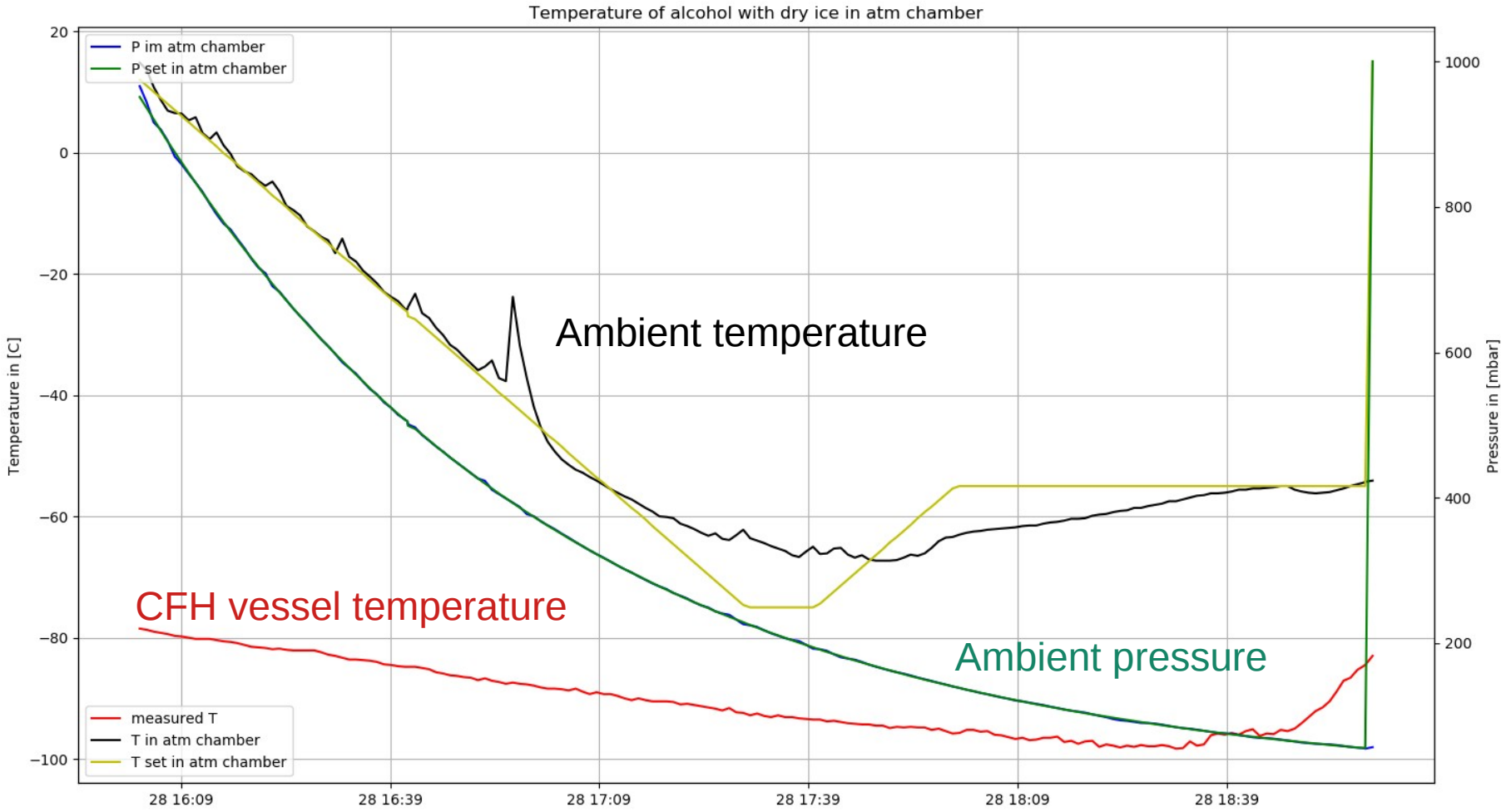
Ethanol



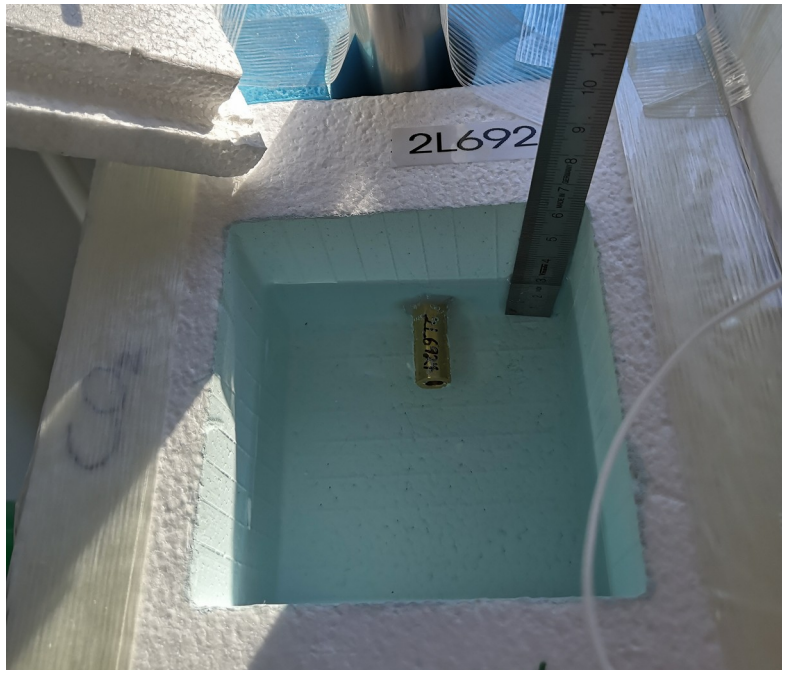
- Slush of Ethanol and CO_2
- Ethanol provide contact between CFH cold finger and CO_2

thermal conductivity:
0,198 W/m/K (@ -80°C)

CLIMATE CHAMBER TEST (ETHANOL, DRY ICE)



TEST FLIGHT WITH ETHANOL DRY ICE MIXTURE



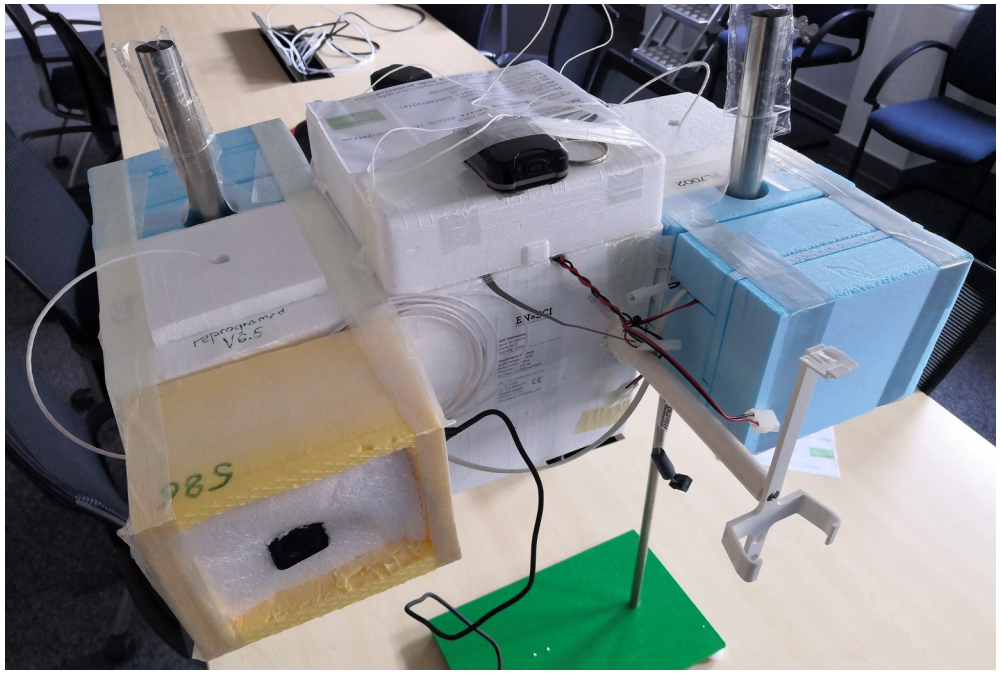
Filled with ~2.2 cm precooled Alcohol (spirit, 96.5%)

freezing temperature < -120°C

Cold finger was completely covered

Filled with ~ 250g dry ice pellets

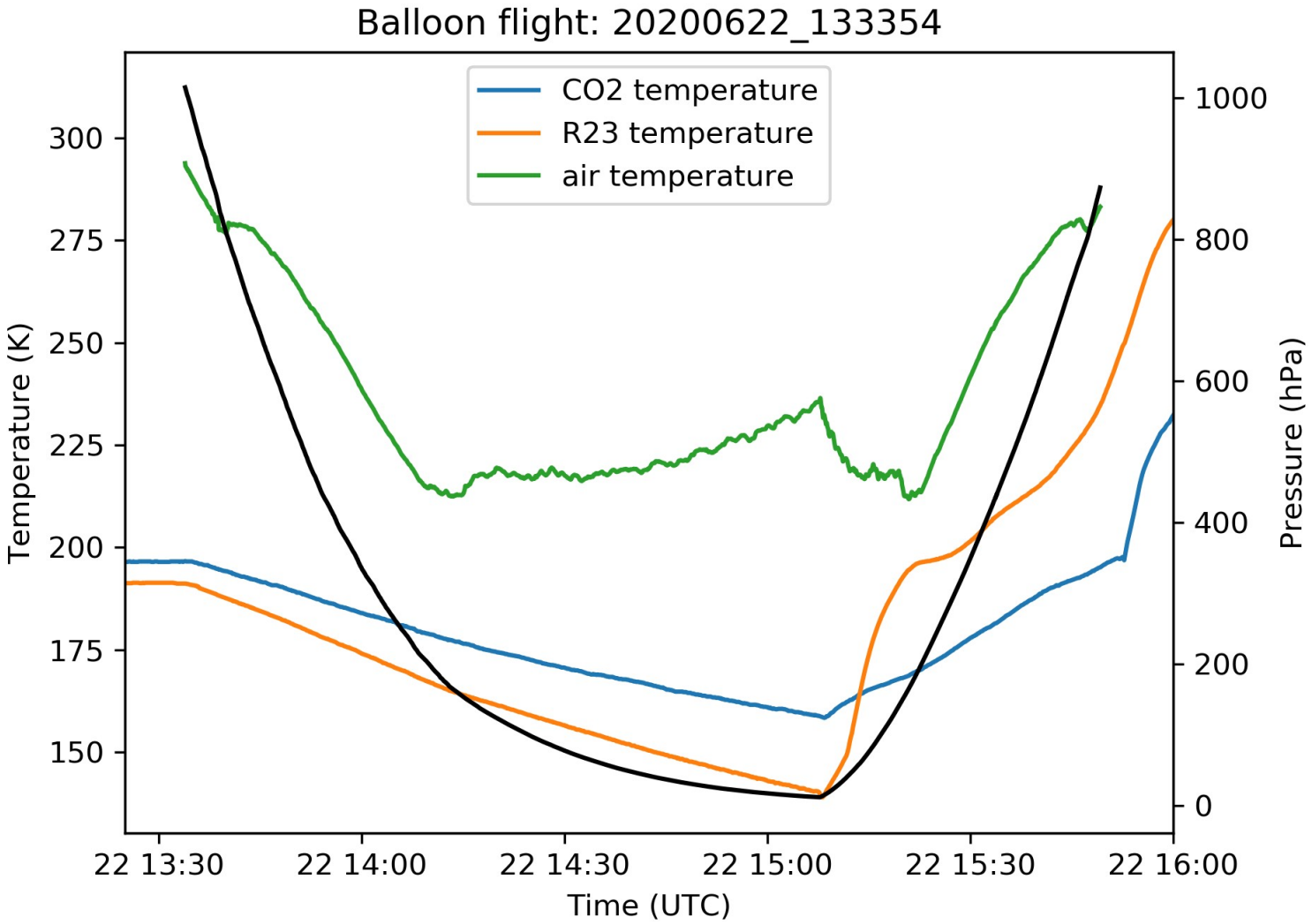
Dry ice should be compact and dense



Balloon flight with two CFHs

1x Ethanol/Dry ice
1x R23

TEST FLIGHT WITH ETHANOL DRY ICE MIXTURE



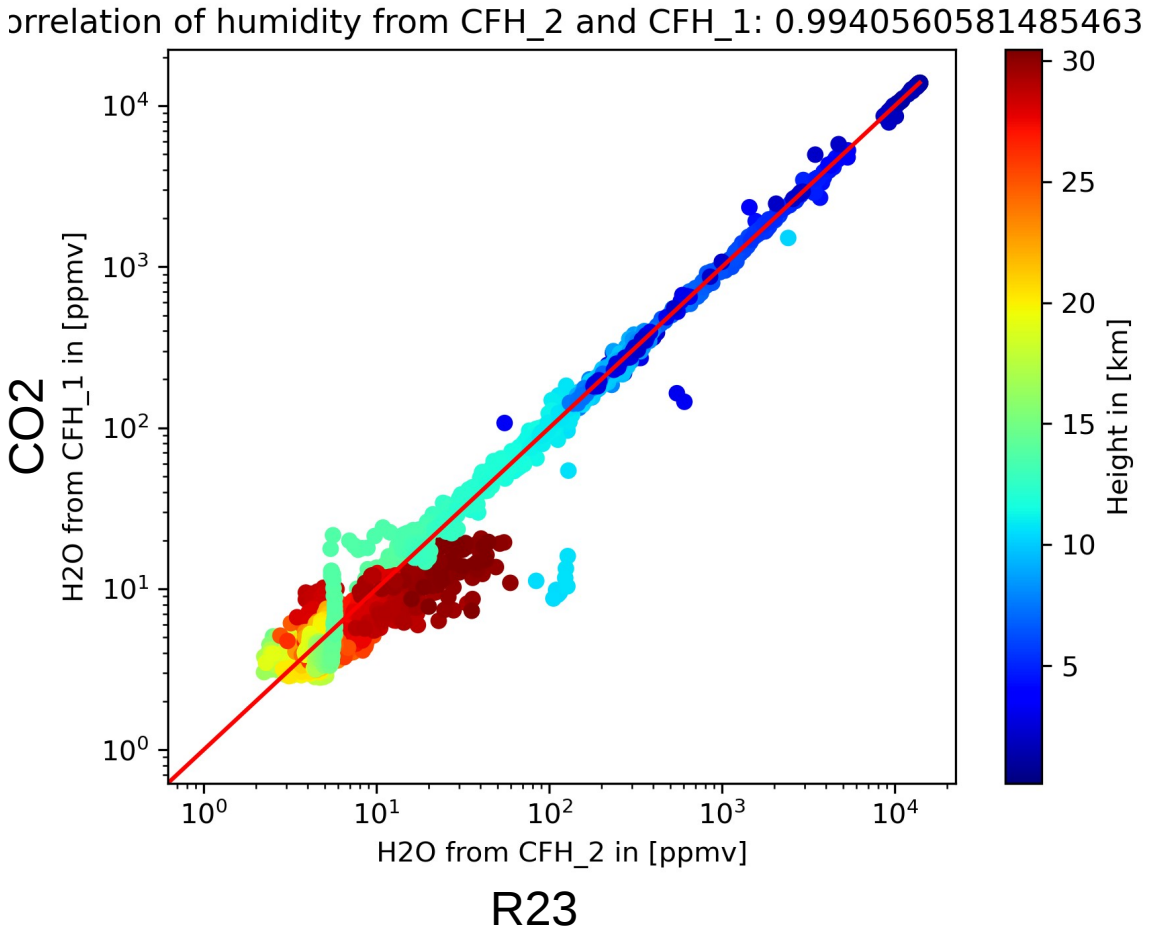
- Both vessels where equipped with a temperature logger
- Dry ice holds longer than R23

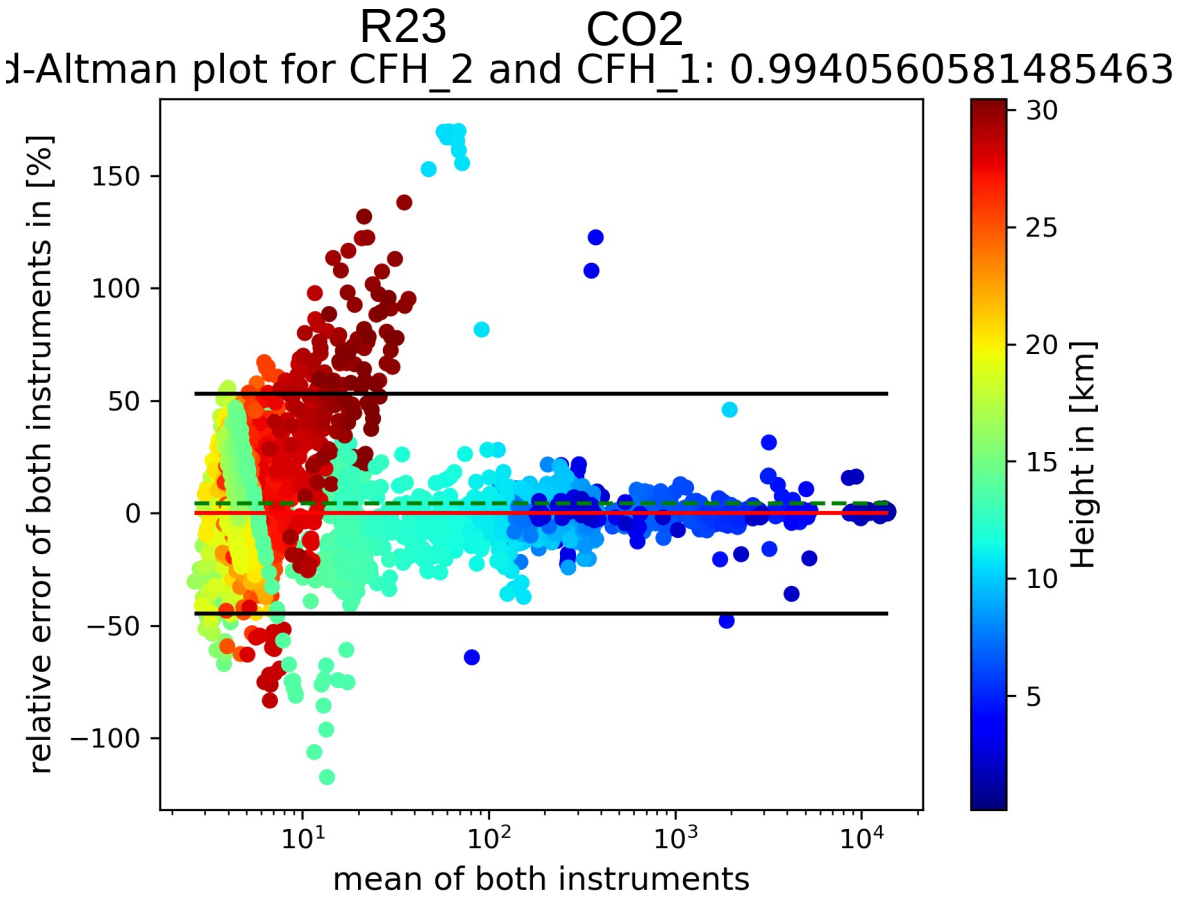
Temperatures:

- Dry ice min temp.:-115°C
- R23 min temp: -134°C
- Difference @ tropopause levels: ~10°C

➔ Could be causing problems at the cold tropical tropopause

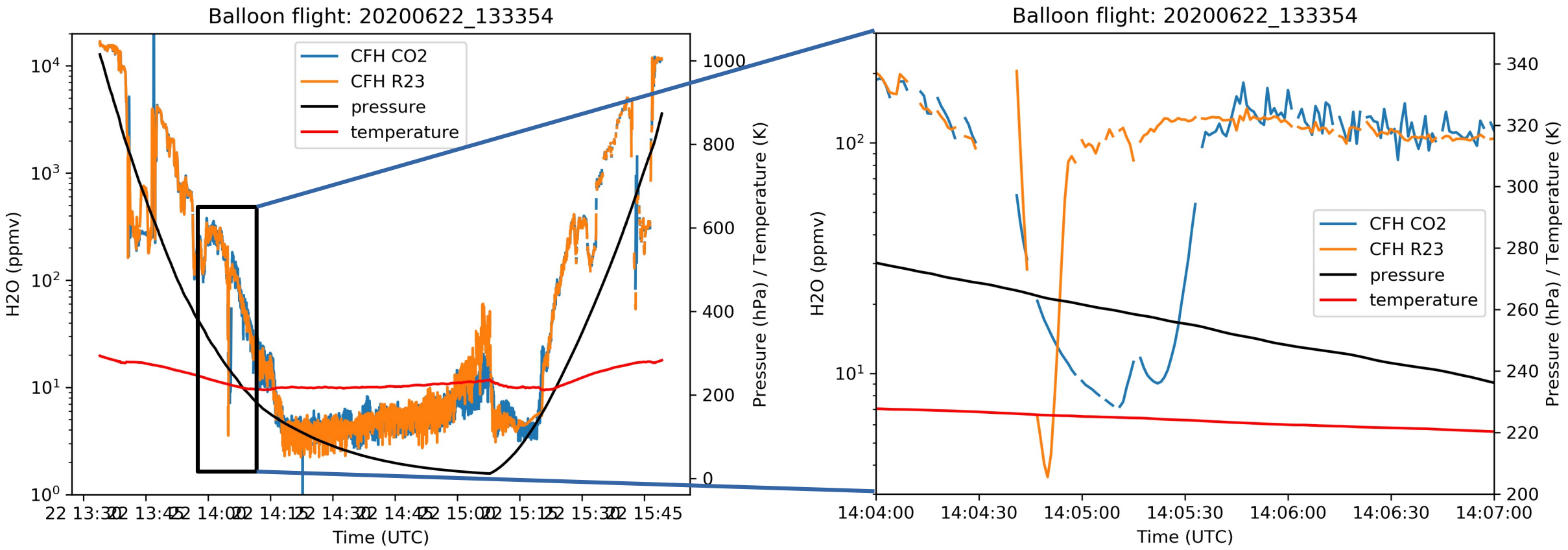
TEST FLIGHT WITH ETHANOL DRY ICE MIXTURE





CFH1 = CFH with CO2
CFH2 = CFH with R23

TEST FLIGHT WITH ETHANOL DRY ICE MIXTURE



ETHANOL DRY ICE MIXTURE

- Lower cooling efficiency with dry ice / ethanol mixture
- Improvement of mirror cooling with increased heat conduction (e.g. copper plate)

Duty cycle (% maximum heating power)

- CO2: 40% in the troposphere to
  2%-4% in the stratosphere
- R23: 20%-25% in the stratosphere

Test with copper plate

CONCLUSION + OUTLOOK

- **Urgent need for R23 replacement**
- **CO2 / Ethanol slush seems to be a good candidate**
- **Warmer compared to R23 (4-20°C) and less cooling efficiency**
- **Already good agreement between CFH (R23) and CFH (CO2) during test balloon launches**

Outlook

- Adjustment of CFH PID parameter to the slower cooling (Holger)
- Improvement of heat conduction/mirror cooling with a thicker bonding (EnSci)
- Improvement of connection between cold finger and alcohol bath (EnSci)