HVRRD Humidity Measurements

Holger Vömel
NCAR/Earth Observing Laboratory

Fine Scale Atmospheric Processes and Structures (FISAPS) Workshop
31 Aug 2023

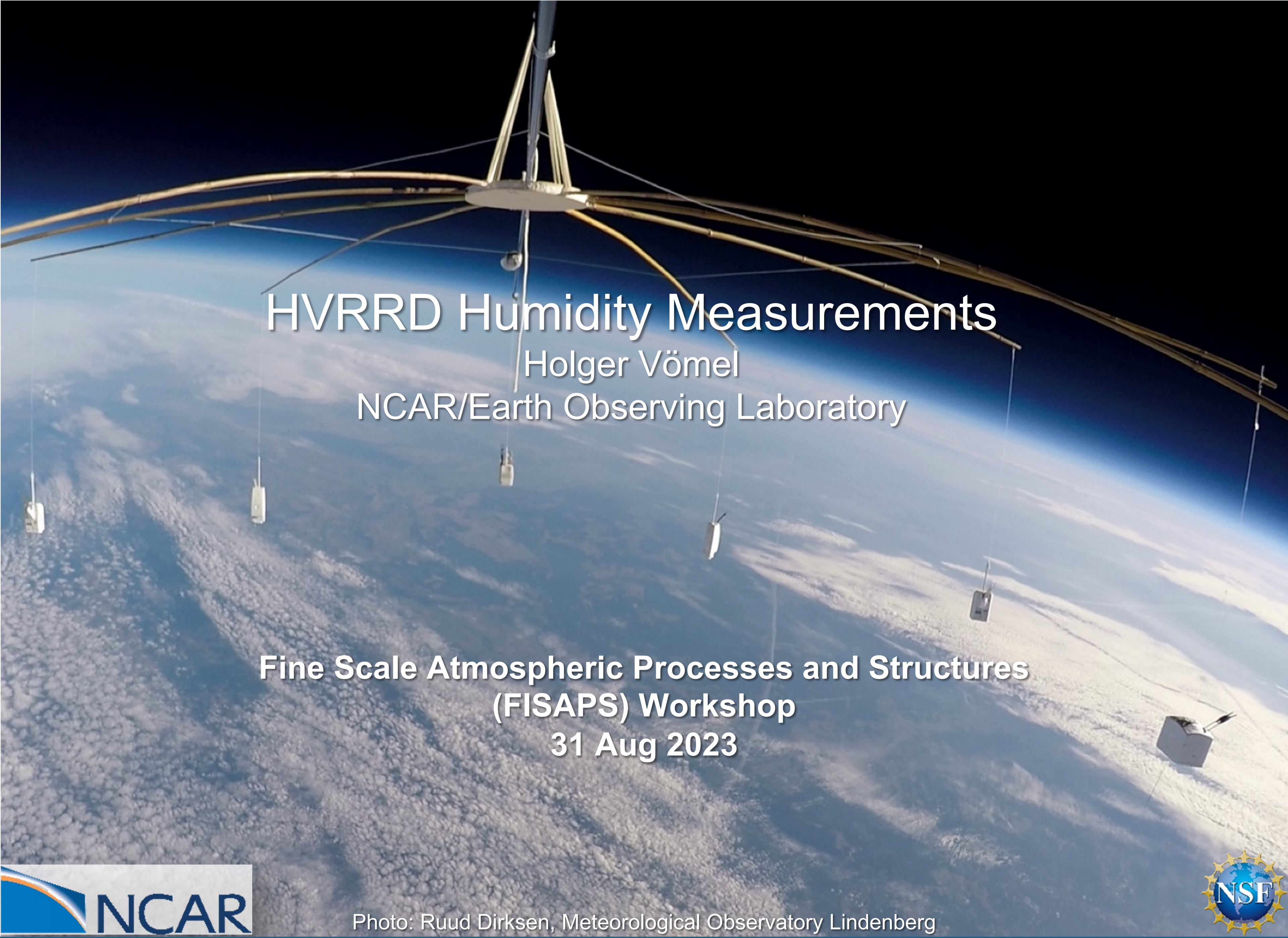

Photo: Ruud Dirksen, Meteorological Observatory Lindenberg

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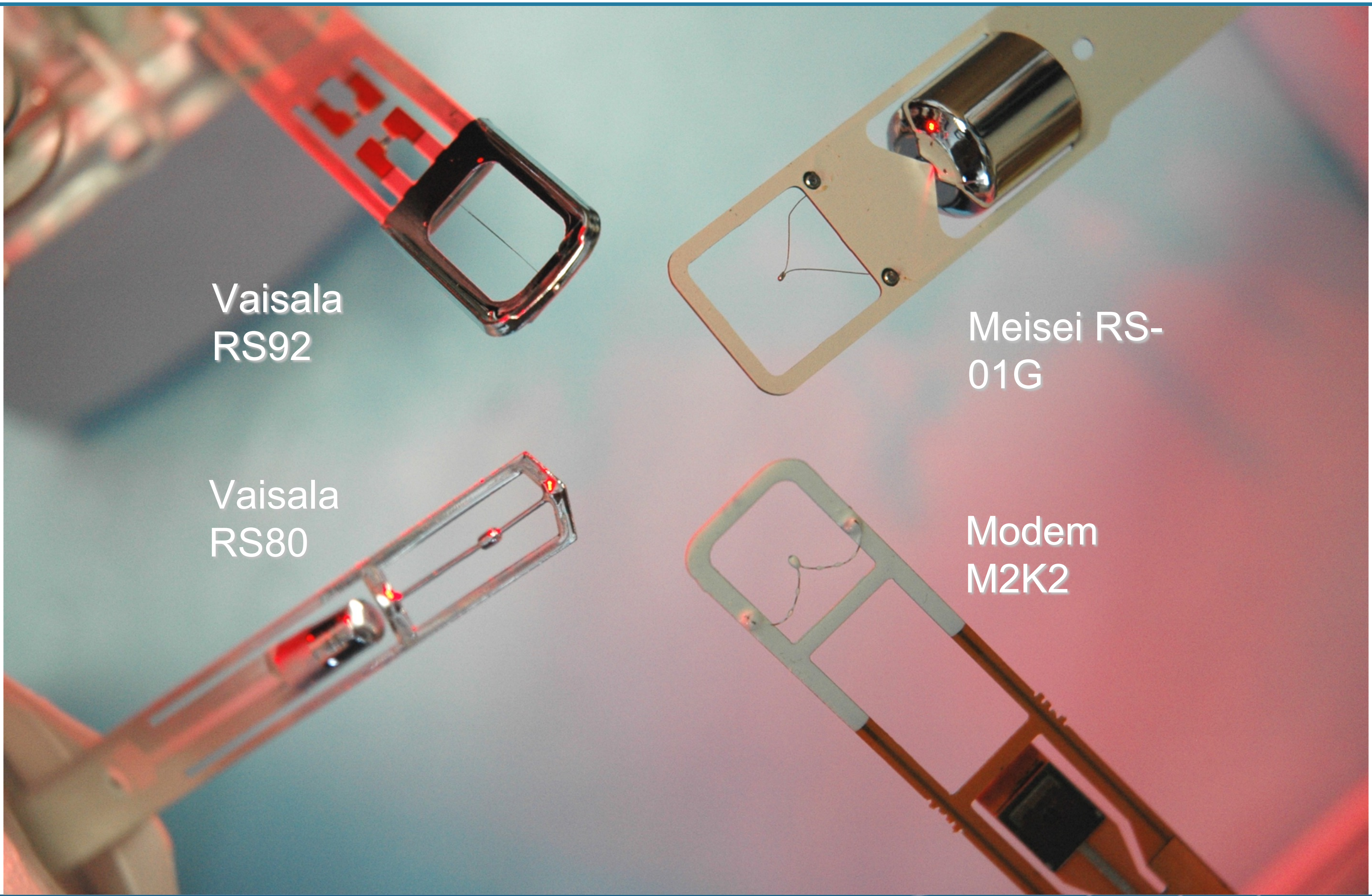
Overview

- Humidity sensors
- Sensor challenges
- Reports and data archives

Radiosonde sensors



How is humidity measured?

Most current radiosonde humidity sensors use thin-film polymer technology:

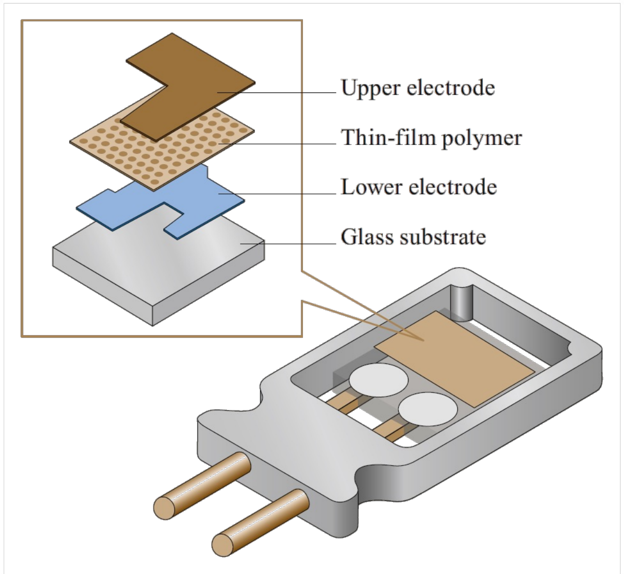
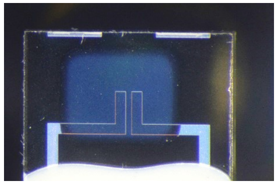
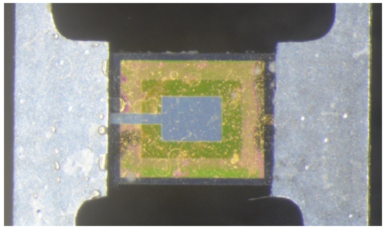


Image: Vaisala Oyj, Finland

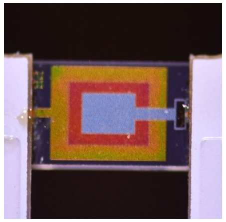
Real world sensors



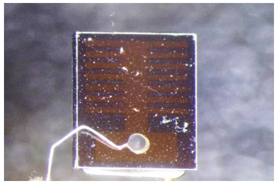
Vaisala RS80



Graw DFM-06

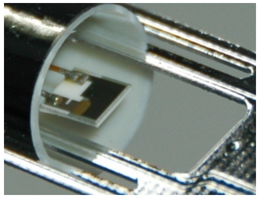


Intermet Imet-1

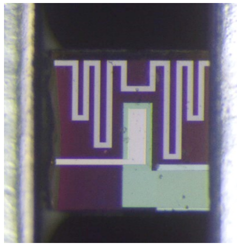


Meisei RS-01G

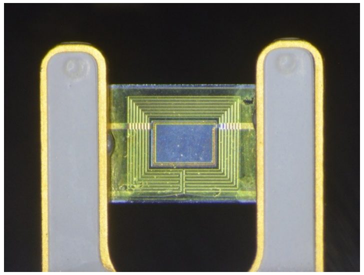
Intermet Imet-4



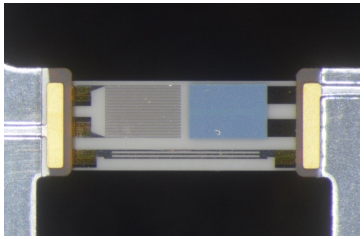
Changfeng CF-06



Vaisala RS92

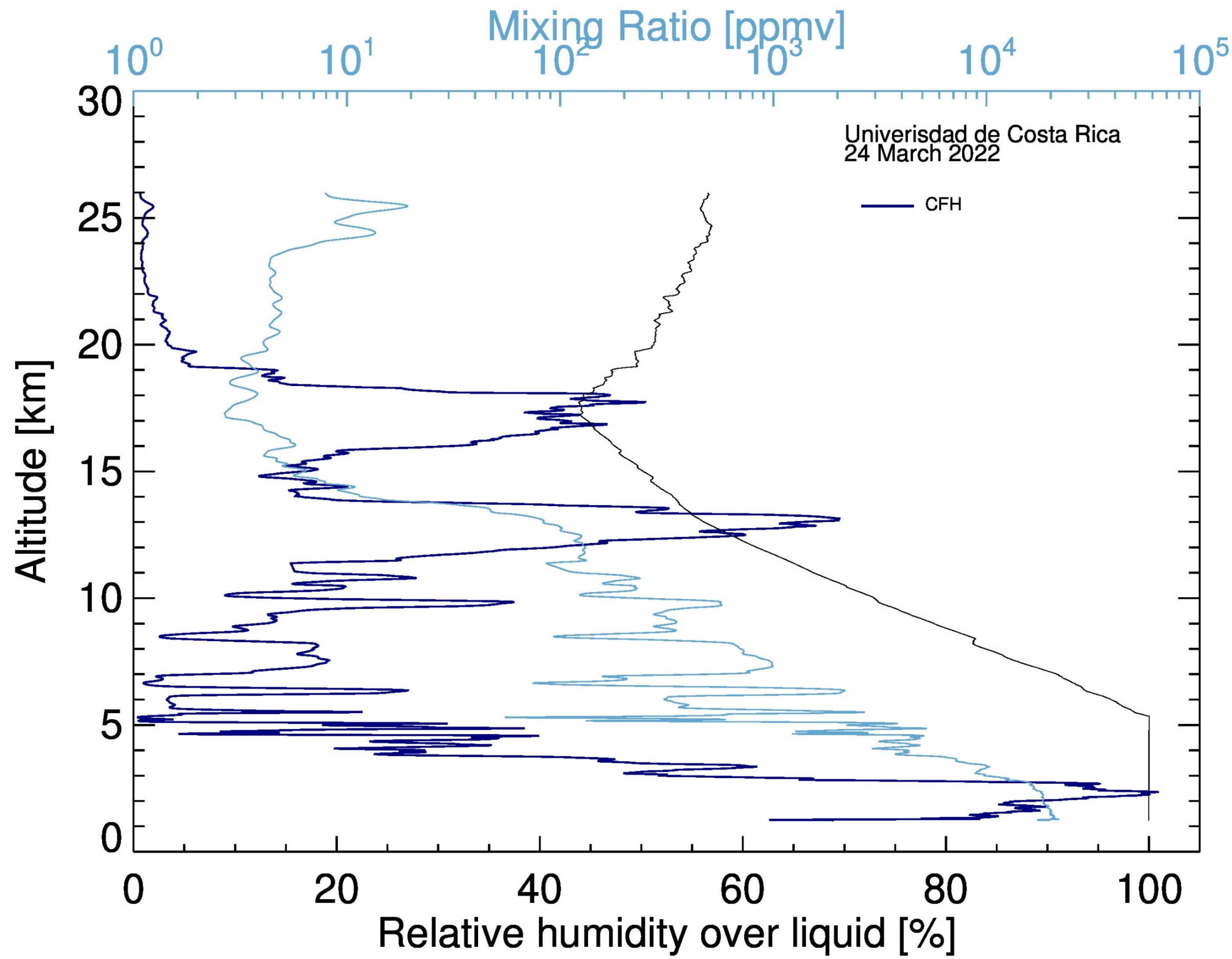


Intermet Imet-54

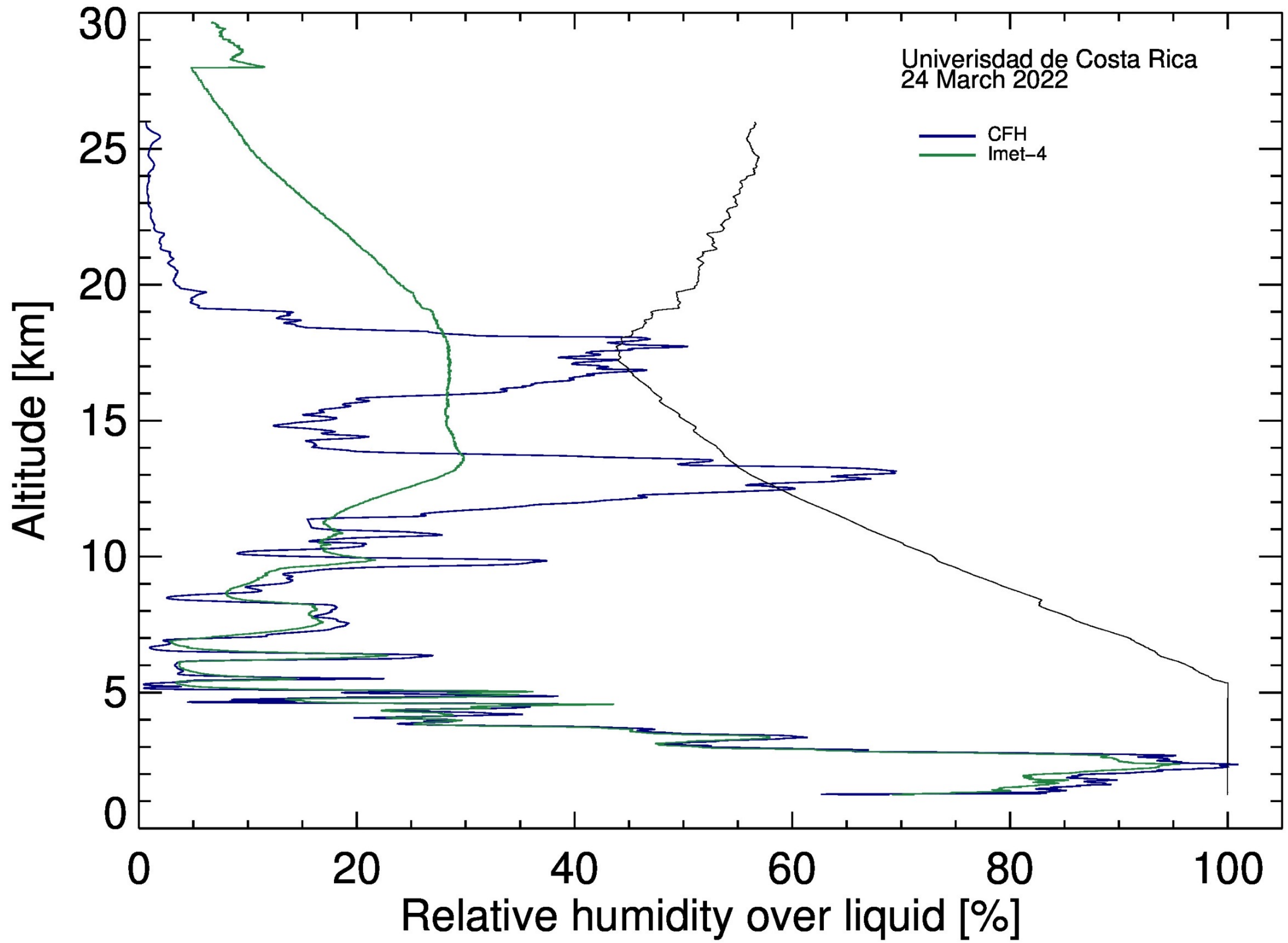


Vaisala RS41

RH profiles (frostpoint hygrometer)



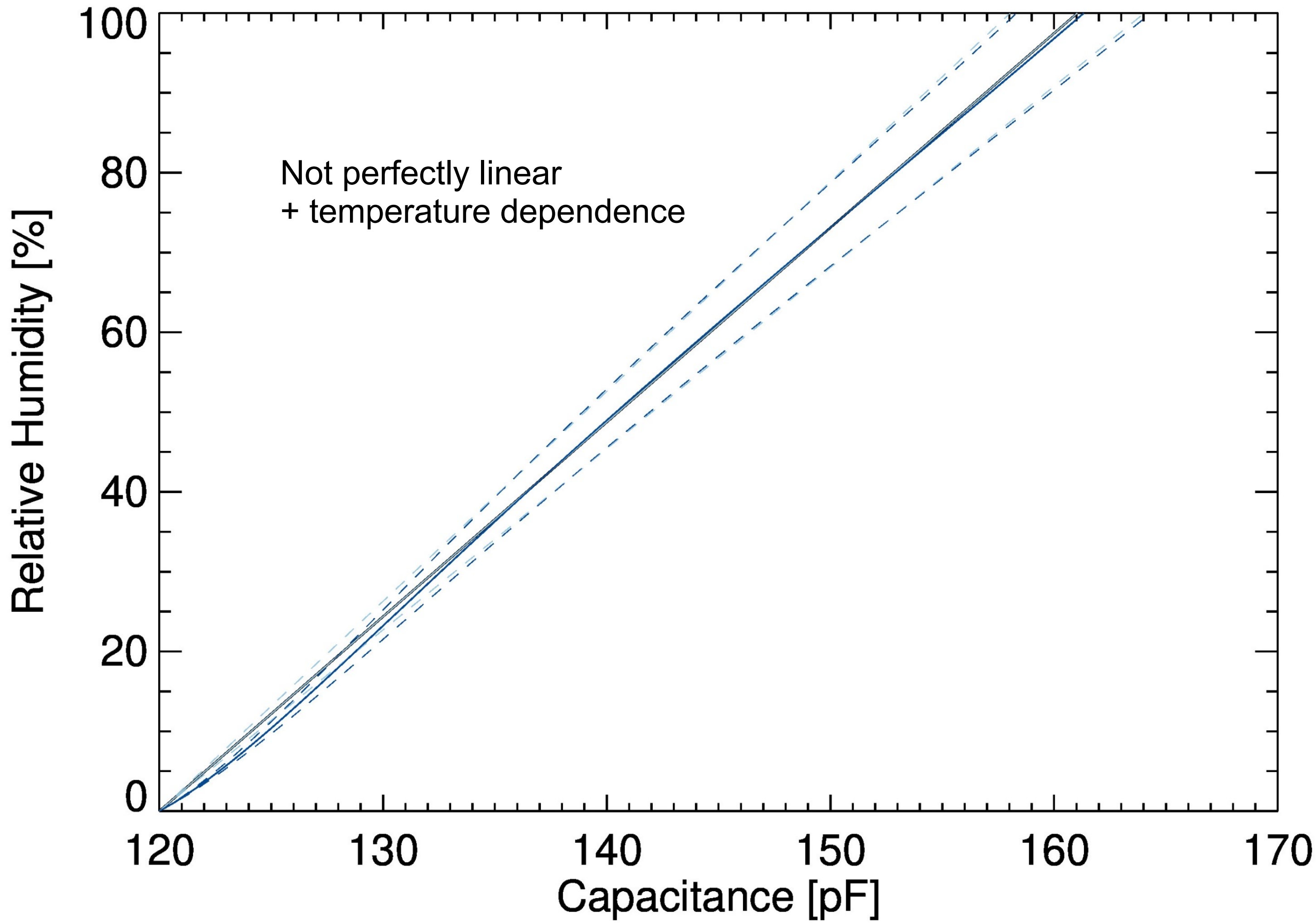
RH profiles



Universidad de Costa Rica
24 March 2022
CFH
Imet-4
Altitude [km]
Relative humidity over liquid [%]
0
5
10
15
20
25
30
0
20
40
60
80
100

Calibration

Sensor calibration



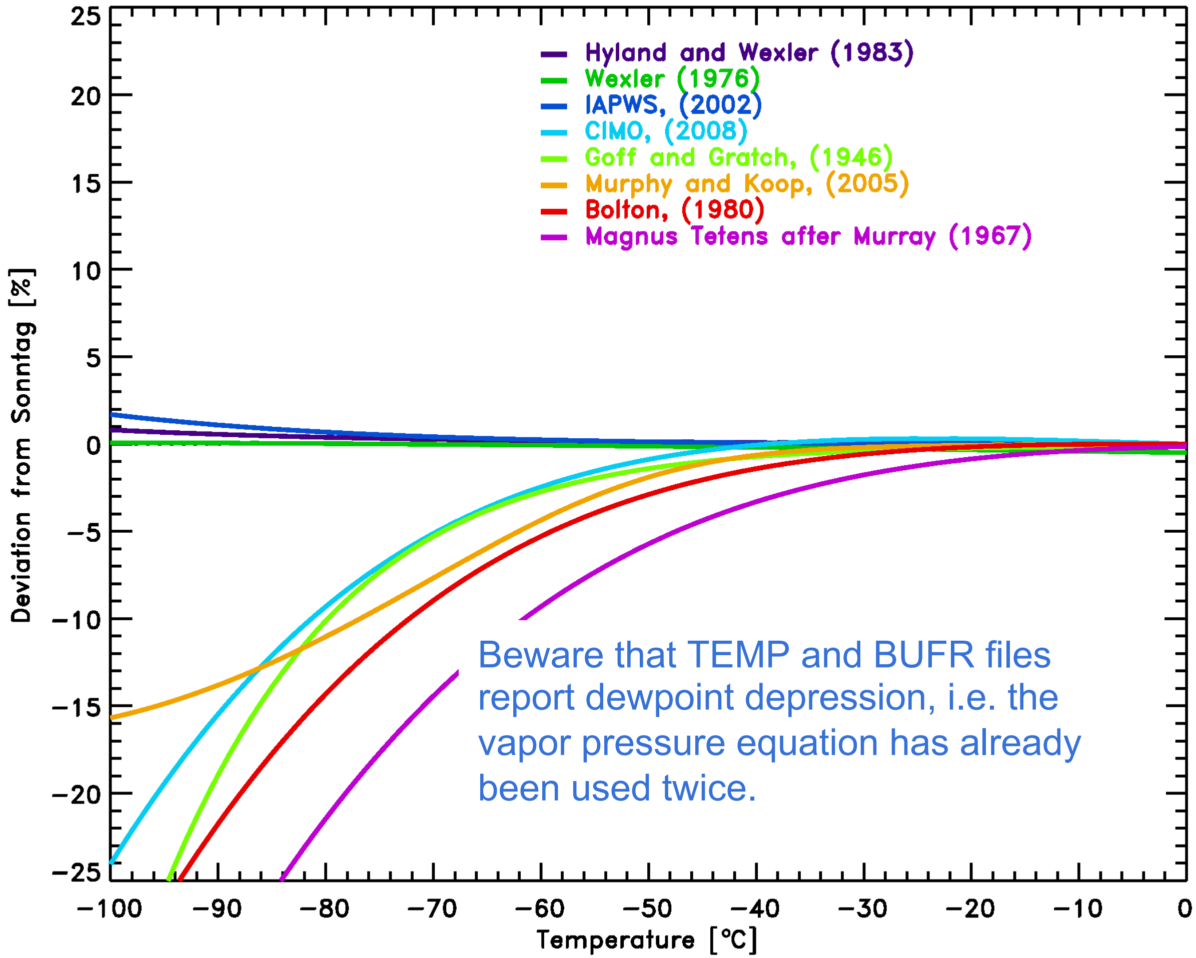
Imet54 sensor (E+E model HMC03M)

Calibration ranges

Manufacturer	Model	RH formula	Lowest Temperature RH Calibration [°C]	Lowest Temperature Temp Calibration [°C]
Vaisala	RS92-SGP	Wexler	-90	-90
Graw	DFM-09	Hyland Wexler	-80	-85
Modem	M2K2DC	Goff Gratch	-60	-90
Sippican	LMS 6	Wexler	-55	-70
Meisei	RD-06G	Buck (1981)	Room temp	-85
InterMet	InterMet 2-AA	Bolton (Goff Gratch)	Room temp	-70
Jinyang	RSG-20A	Goff Gratch	Room temp	-80
Nanjing	Da Qiao GTS 1-2	Goff (1957)	-40	-90
Huayun	GTS(U)1-1	Goff Gratch	-30	-90
Changfeng	CF-06-A	Goff Gratch	-60	-90

From: Nash, J., Oakley T., Vömel H. and Li W., 2011, WMO Intercomparison of High Quality Radiosonde Systems, Yangjiang, China, Instruments and Observing Methods Report No. 107, WMO.

Vapor pressure equation



Beware that TEMP and BUFR files report dewpoint depression, i.e. the vapor pressure equation has already been used twice.

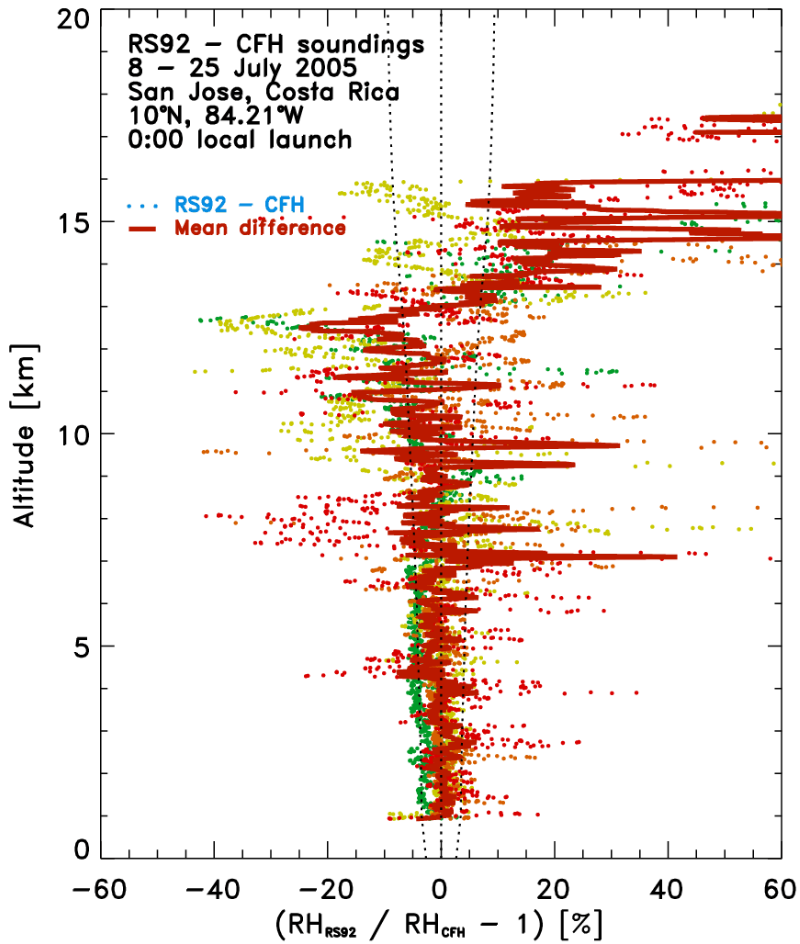
https://sciencepolicy.colorado.edu/~voemel/vp.html

Best equation is the one used by the manufacturer!

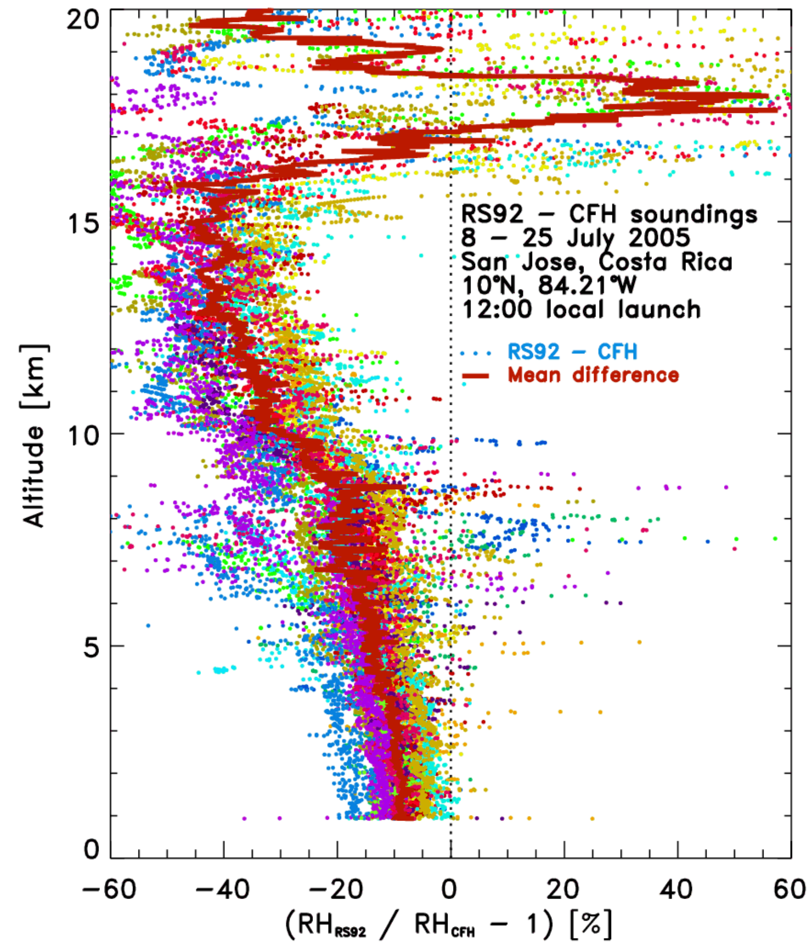
Daytime dry bias

Daytime dry bias

Comparison RS92 versus CFH



Nighttime



Daytime

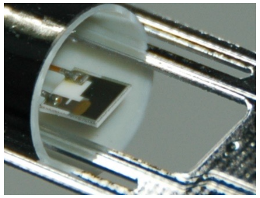
From: Vömel et al. (2007)

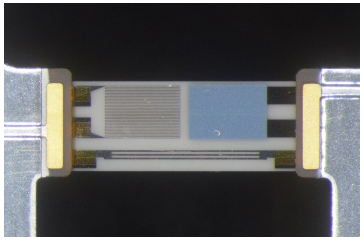
Daytime dry bias

Cause: RH sensor temperature ≠ Air temperature

Methods to counter daytime dry bias:

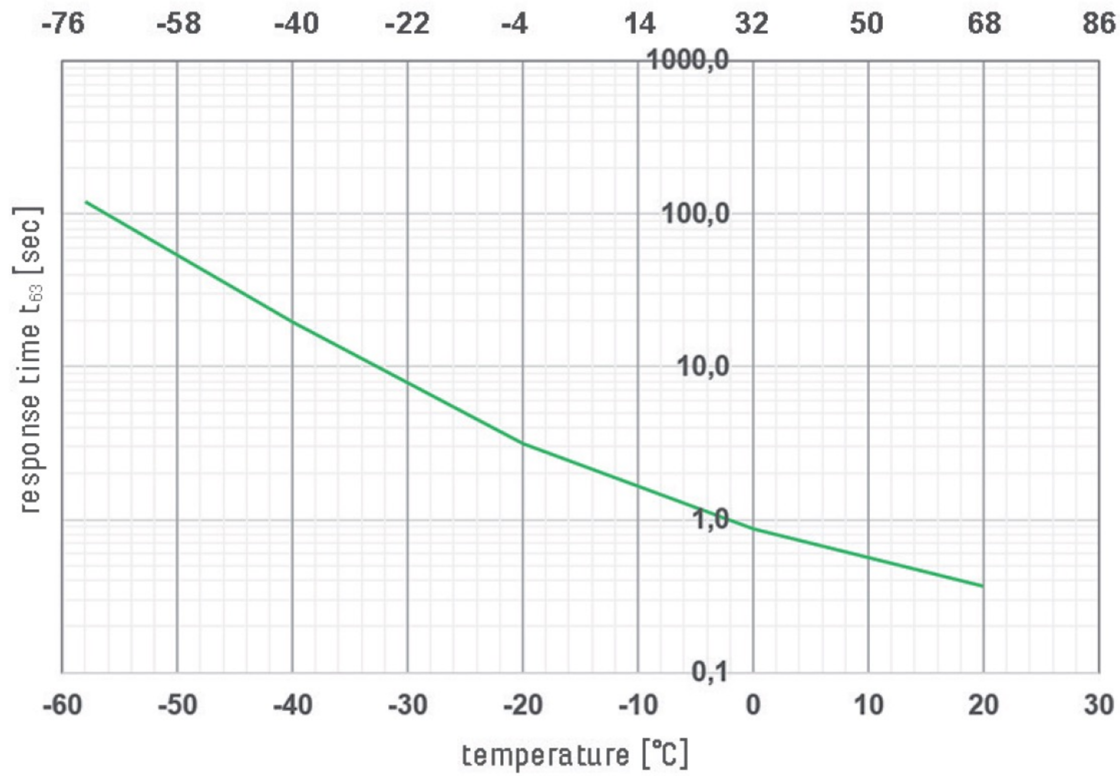
- Empirical corrections
  - Removes average bias
  - Cannot account for clouds and changes in albedo
  - Need metadata to track correction
- Use protective cap over sensor
  - Reduces air flow
  - Increases risk of icing
- Measurement of sensor temperature
  - Best solution
  - Technically more challenging





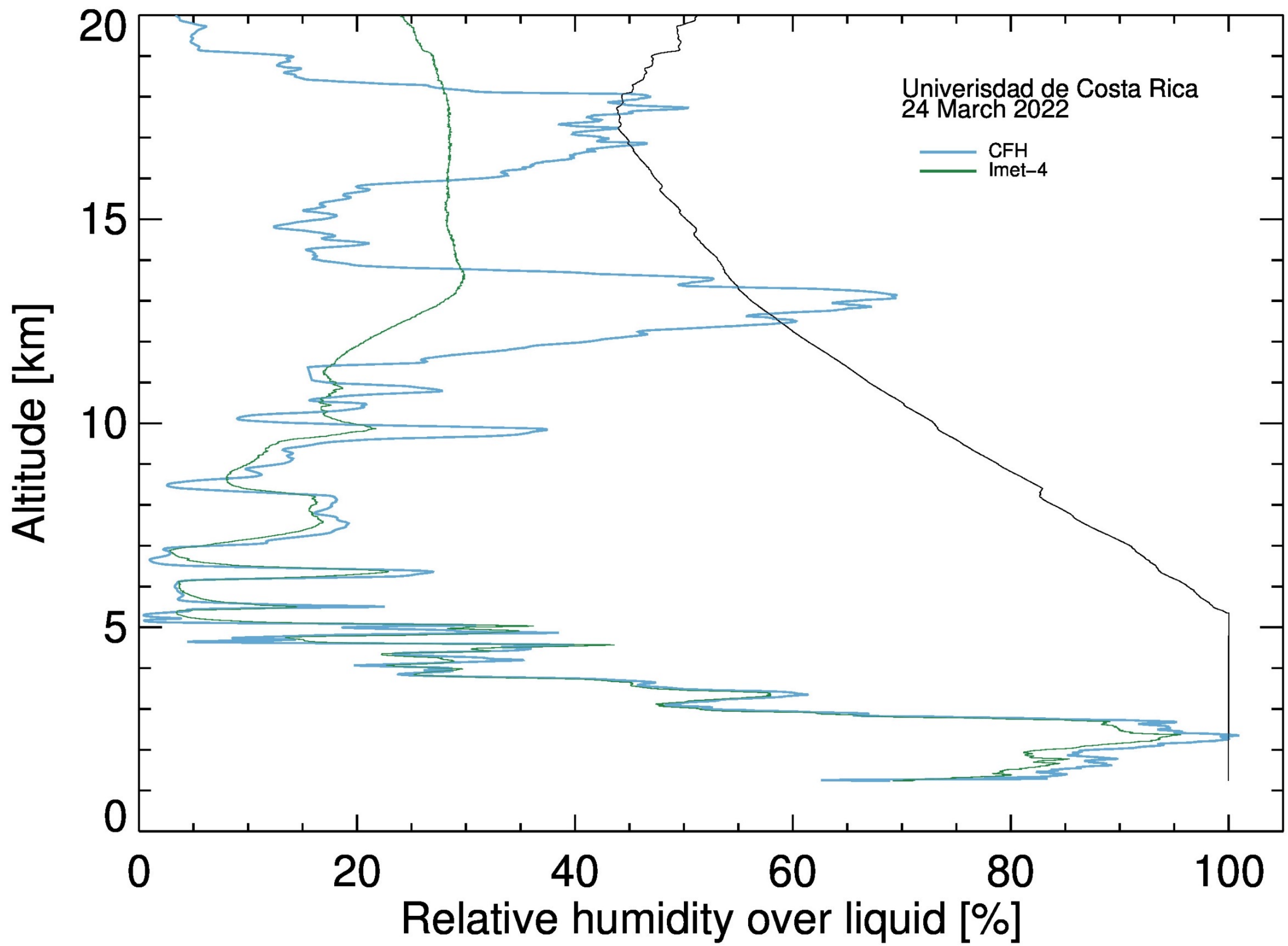
Response time

Response time

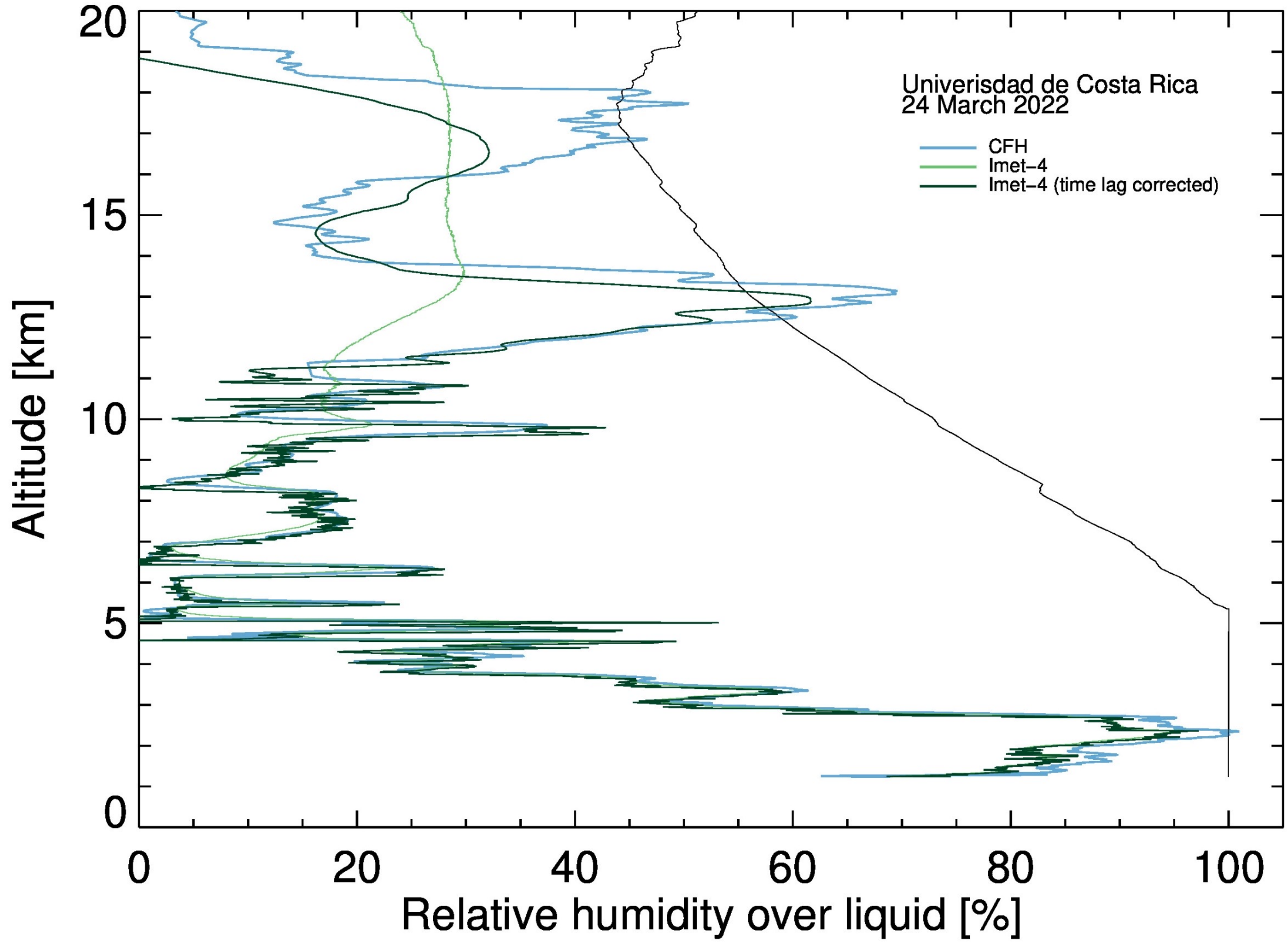


Imet54 sensor from E+E model HMC03M

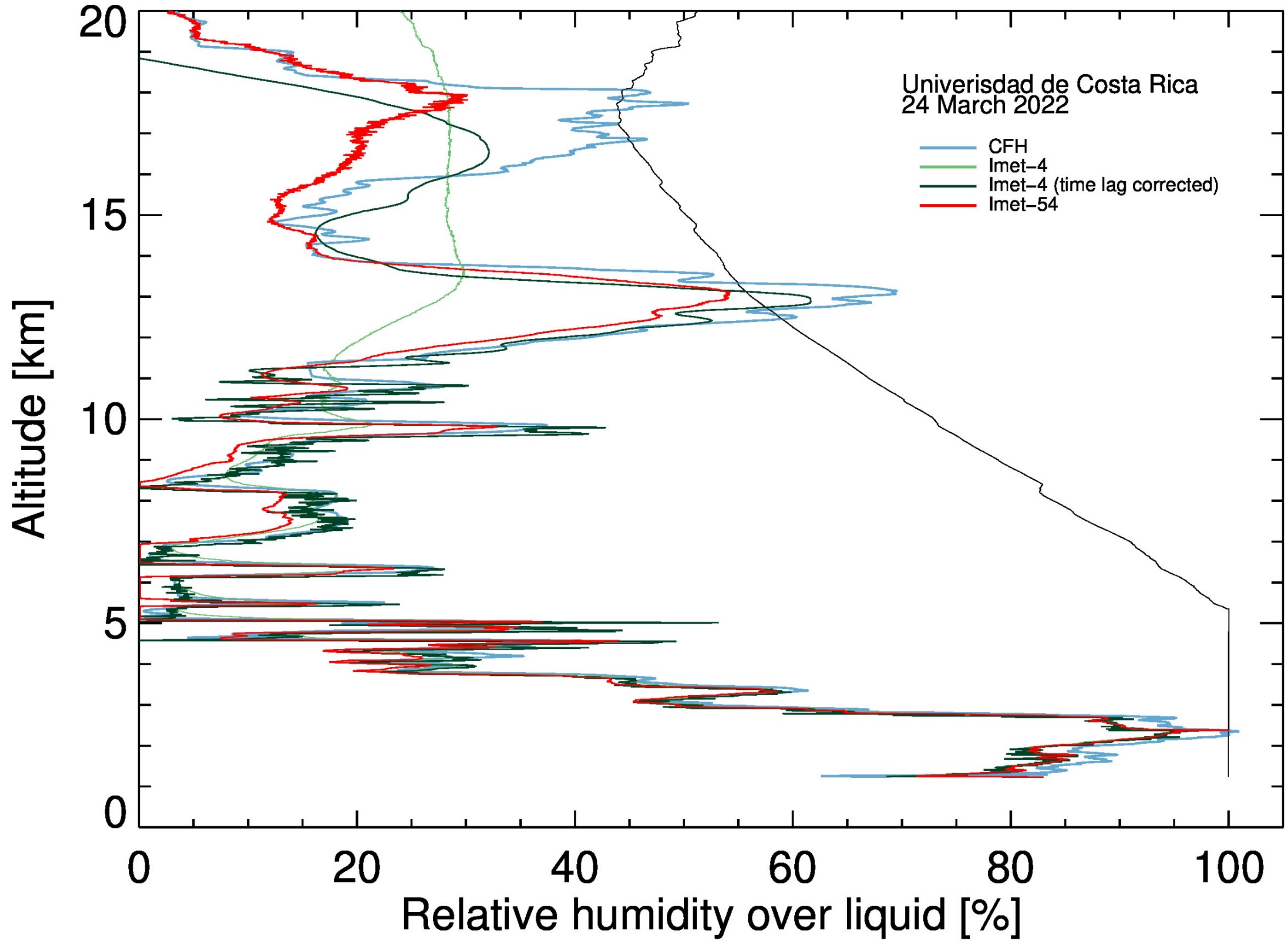
Response time



Response time



Response time



Response time

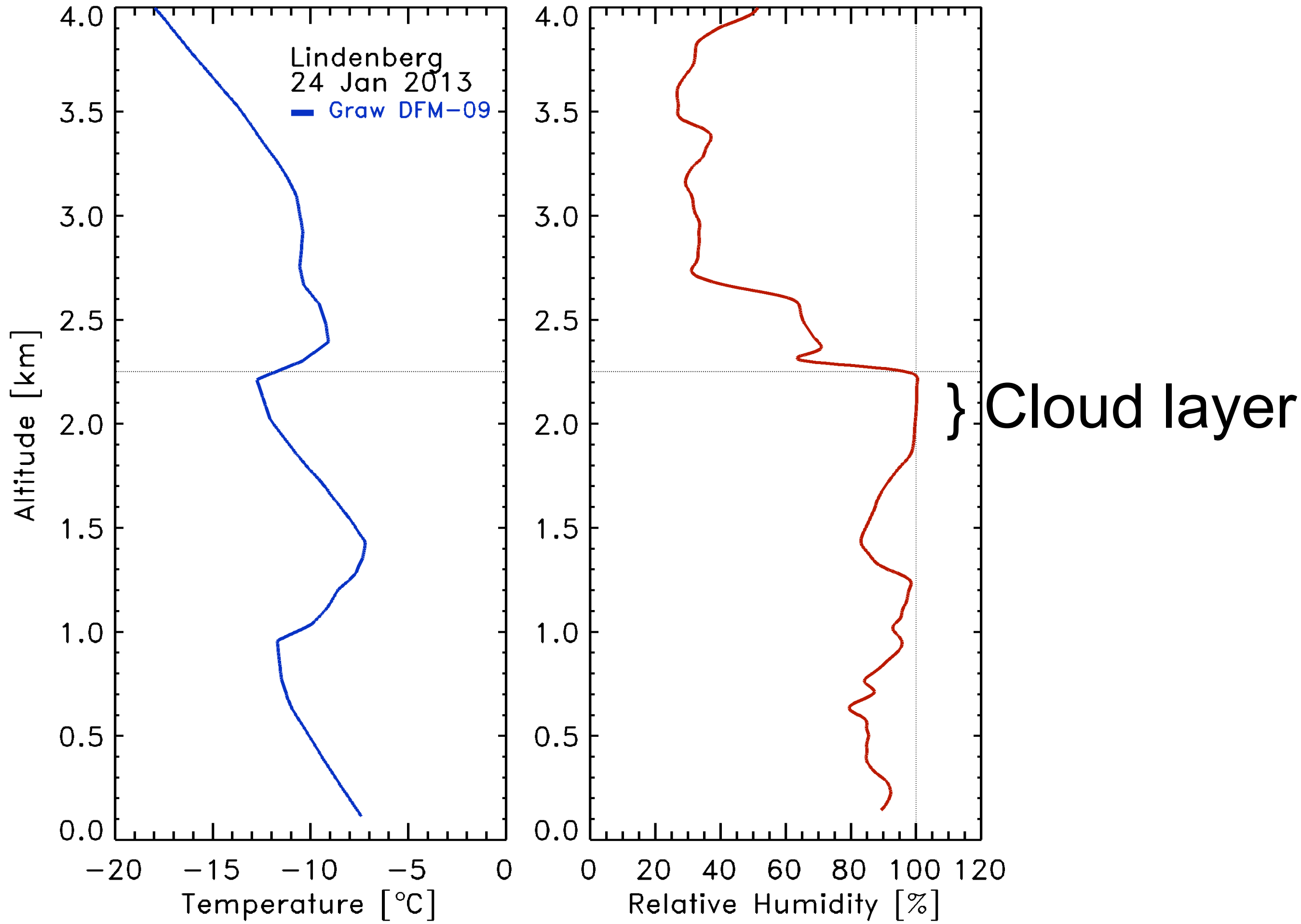
- Time response is highly temperature dependent
- Important in the middle to upper troposphere

- Time lag correction enhances noise -> Requires heavy smoothing at cold temperatures (exact algorithms are proprietary)

- Imet-54, Graw DFM-17, Vaisala RS41, and others use time lag correction
- Imet-4 (e.g. SHADOZ) does not use time lag correction
- Metadata about time lag correction is limited

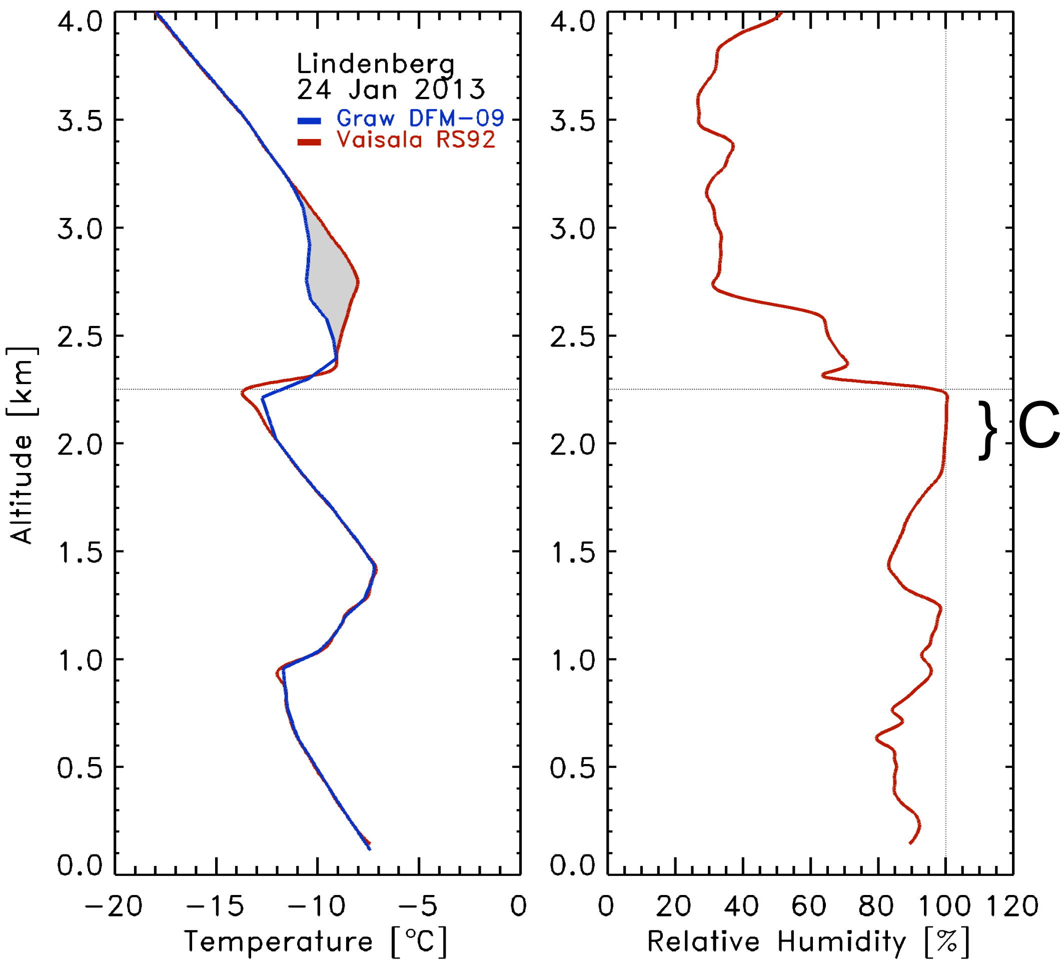
Sensor icing

Sensor icing



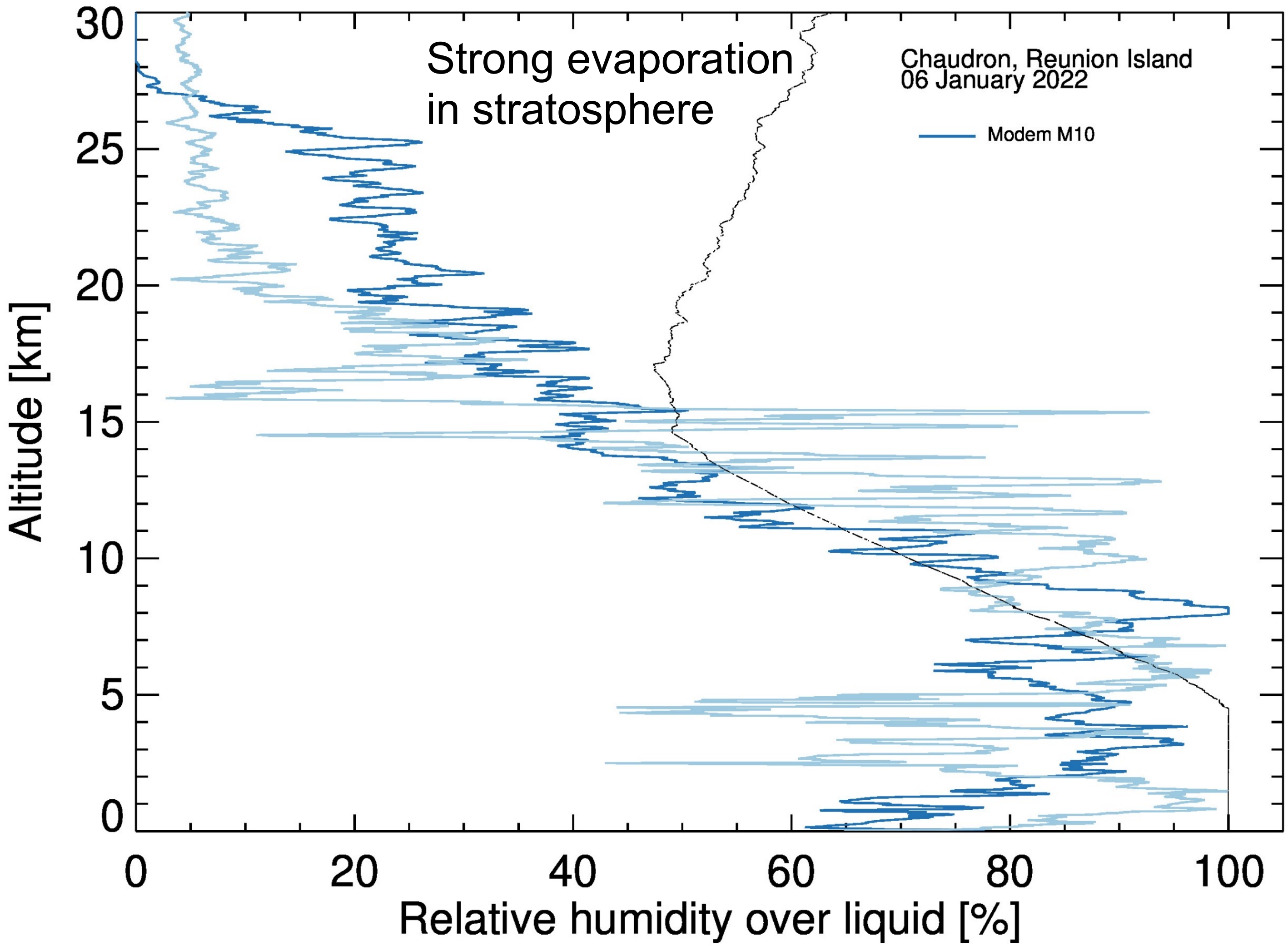
Sensor icing

2.5 K cold bias over ~500 m



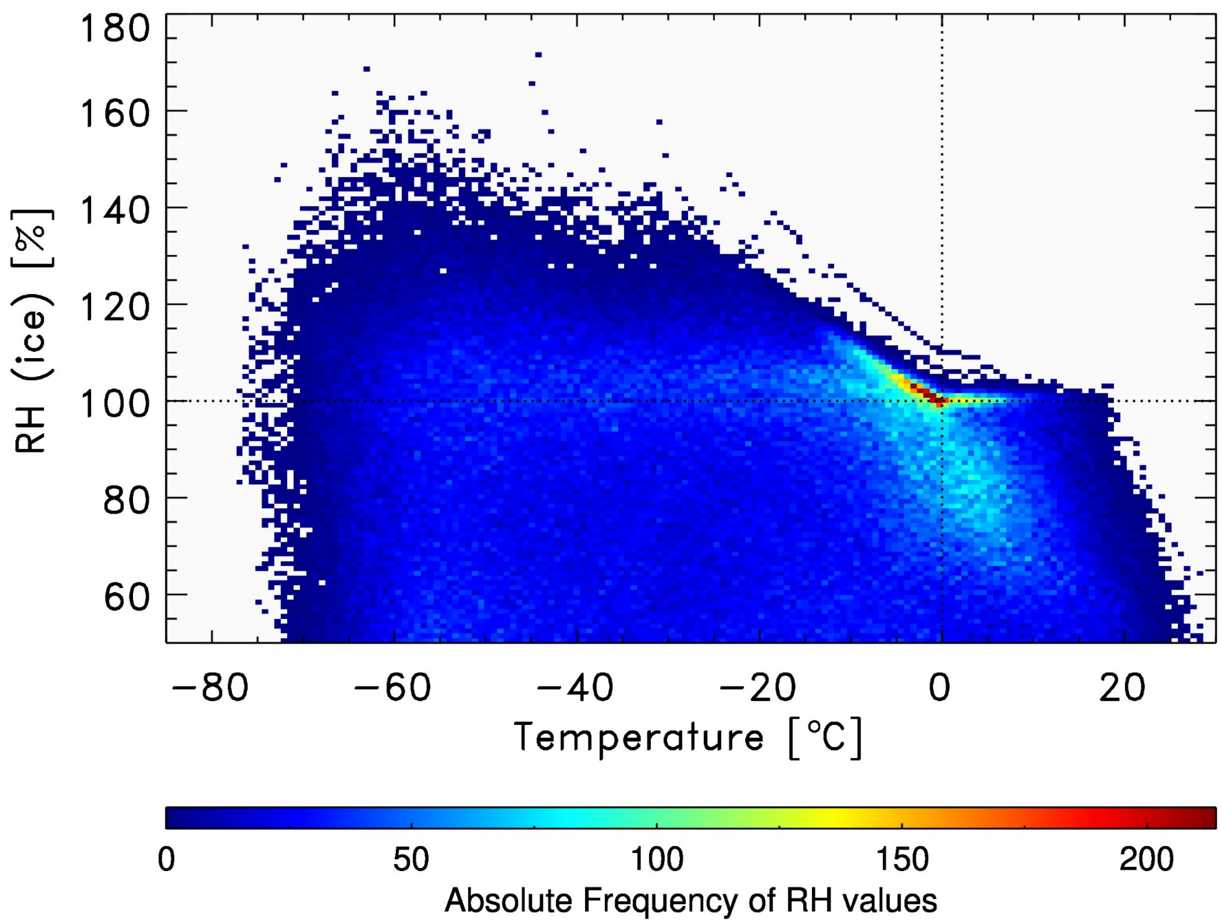
} Cloud layer

Sensor icing



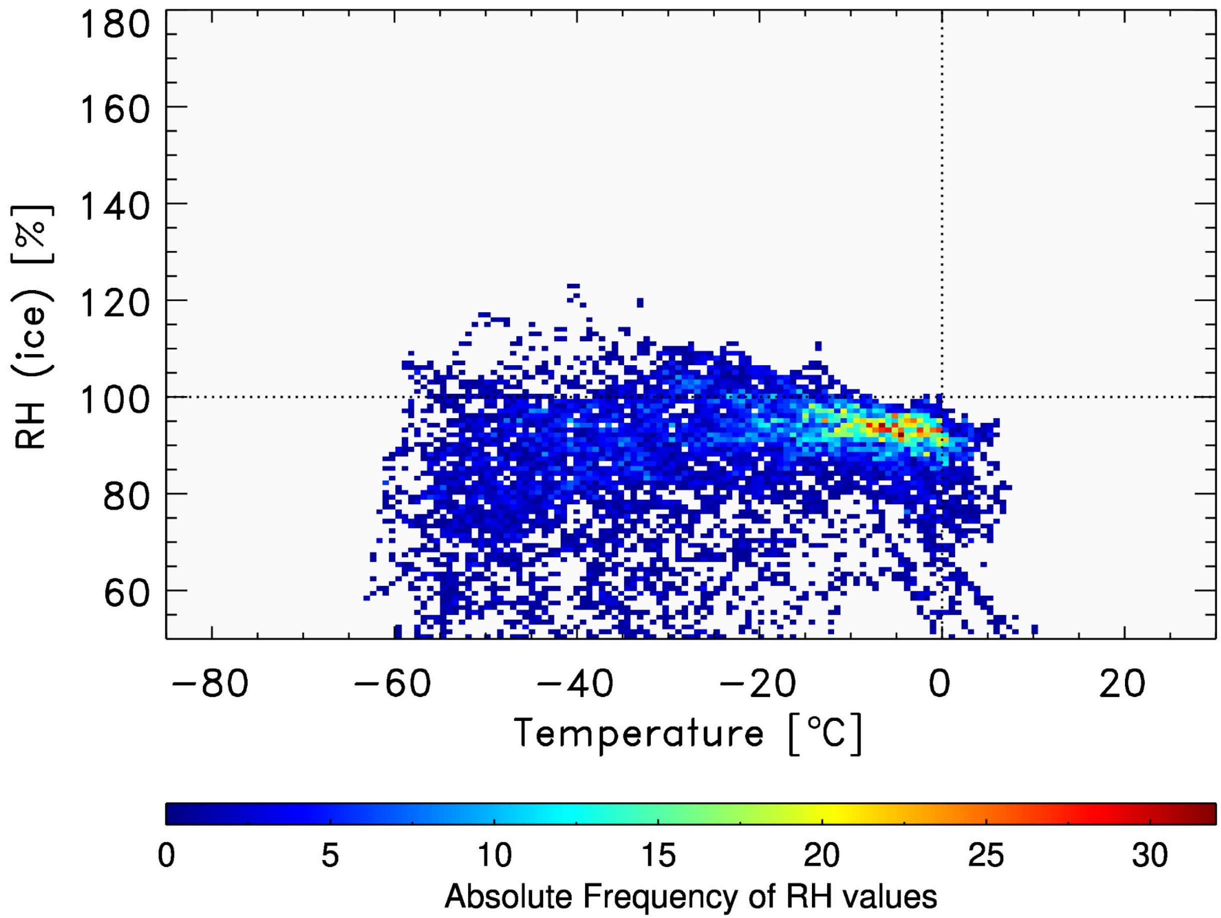
Sensor bias

Sensor bias



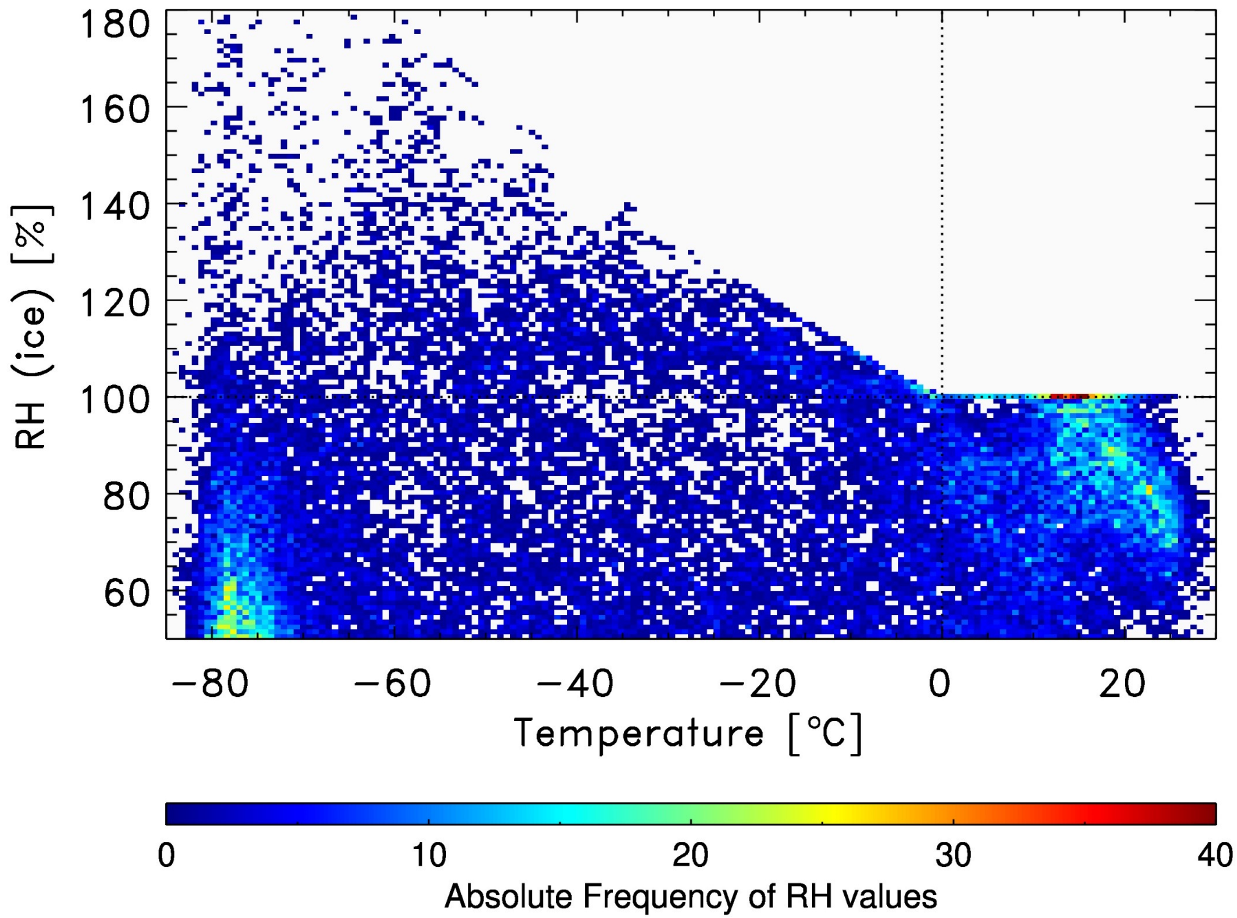
Vaisala RS92, 2006-2013, GRUAN processing

Sensor bias



Lockheed Martin Sippican LMS6, SNOWIE winter campaign

Sensor bias



Modem M10, Subtropical summer

Reports and data

Radiosonde evaluations

- 2010 WMO radiosonde intercomparison:
  Nash, J., Oakley T., Vömel H. and Li W., 2011, WMO Intercomparison of High Quality Radiosonde Systems, Yangjiang, China, Instruments and Observing Methods Report No. 107, WMO.

- 2022 WMO radiosonde intercomparison:
  Dirksen et al. (2023): in preparation
  (Lots of information, to be released this year)

- Numerous individual radiosonde comparisons

Data archives

University of Wyoming

- a) TEMP messages (Low resolution): http://weather.uwyo.edu/upperair/sounding.html
- b) BUFR messages (may be high resolution), some metadata, no radiosonde model: http://weather.uwyo.edu/upperair/bufrraob.shtml

NOAA

- IGRA https://www.ncei.noaa.gov/products/weather-balloon/integrated-global-radiosonde-archive (Limited metadata, no radiosonde model)
- RUC https://ruc.noaa.gov/raobs/ (Global man/sig archive back to the 1950s. Limited metadata, no radiosonde model)

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  (Global man/sig archive back to the 1950s. Limited metadata, no radiosonde model)
- NCDC rss data archive: ftp://ftp.ncdc.noaa.gov/pub/data/ua/rrs-data/
  (Older archive of bufr files, not GTS bufr)
- BUFR: https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ncdc:C01500

NCAR EOL (GTS feed): https://data.eol.ucar.edu/dataset/100.030

Data archives

Iowa State University:

https://mtarchive.geol.iastate.edu/2023/02/09/

University of Oklahoma:

http://www.mesonet.org/data/public/noaa/text/archive/2023/02/06/

British Atmospheric Data Centre (BADC)

- Falklands, St. Helena, Gibraltar: http://catalogue.ceda.ac.uk/uuid/c1e2240c353f8edeb98087e90e6d832e
- Antarctic stations Halley and Rothera: http://catalogue.ceda.ac.uk/uuid/37f2bef57e28bcd780a5cbfe077f4bf8

Norway: https://thredds.met.no

GRUAN: https://www.gruan.org/data/

SHADOZ (ozone sondes): https://tropo.gsfc.nasa.gov/shadoz/

WOUDC (ozone sondes): woudc.org/data/

NDACC (water vapor and ozone sondes):
https://www-air.larc.nasa.gov/missions/ndacc/

Questions?