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GRUAN Site Report for Boulder

(Submitted by Dale Hurst)

Summary and Purpose of this Document

Report from the GRUAN site Boulder for the period January to December 2021.

Overview

The Boulder GRUAN site, managed by NOAA's Global Monitoring Laboratory, continued to launch Vaisala RS41 radiosondes on the same balloons as our weekly ozone soundings (EnSci ECC model 2Z ozonesonde and InterMet model iMet-1/iMet-4 or RS-54 radiosonde). Throughout 2021 the frequency of water vapor (NOAA FPH) and ozone soundings was twice monthly and the payload was enhanced with a Portable Optical Particle Spectrometer (POPS) that measures aerosol number concentration and size distribution. These changes were requested by NOAA's Earths Radiation Budget (ERB) program. Data from all these sondes (except the RS-54 and POPS) were submitted to GRUAN for processing, quality control and archival. The RS-54 soundings are still experimental, and the POPS sounding data is the property of NOAA's Chemical Sciences Laboratory.

The GFZ-Potsdam-owned GNSS receiving system (TMS3) located at the NOAA Table Mountain facility near Boulder continues to provide data to GRUAN. We now doubt approval will ever come from the manager of the Marshall Field Site (property of NCAR) to move TMS3 from Table Mountain to the balloon-launching site at Marshall, as they remain concerned about who will care for and maintain TMS3 because it belongs to GFZ-Potsdam.

Change and change management

There were no changes in operations during 2021 at the Boulder GRUAN site. We continue to use InterMet radiosondes in our balloon payloads, mostly the newer iMet-4 sonde, but also the older iMet-1 sonde when launching the FPH payload. Soundings using RS-54 radiosondes from InterMet South Africa are still considered experimental and not much progress was made to incorporate their data stream into the SkySonde software suite. Several flights of a novel dry ice and ethanol-cooled FPH were made during 2021 but the data are considered experimental. At the point in time that we feel the new FPH is ready to replace the old R23-cooled FPH the change will be carefully managed through dual flights in each season.

There are no changes required for the description of the Boulder site on the GRUAN web page.

Resourcing

The Boulder GRUAN site is now stably funded by NOAA's ERB program.

Operations

Unlike for our ozone soundings, where balloons are allowed to ascend until they burst, the flight train for our FPH soundings continues to include a valve inserted into the balloon neck that opens

to release helium from the balloon at about 16 hPa, preventing burst and allowing controlled descent of the balloon. This enables contamination-free stratospheric water vapor measurements by the FPH during controlled descent. Hence, by design, about 50% of our soundings will not quite reach 10 hPa.

Covid-19

We continued to rely on a safe collaborative procedure for building, testing and launching the FPH to carry out all balloon soundings.

Site assessment and certification

The Boulder GRUAN site has already been certified and recertified.

GRUAN-related research

I contribute to GRUAN by serving as a co-chair of the Task Team of Site Representatives, a member of the Working Group GRUAN, and the Boulder site representative.

The Boulder site continues to test the use of a dry ice + ethanol cold bath as the coolant for the NOAA Frost Point Hygrometer thanks to a CIRES innovative research grant awarded in late 2019. This research was mostly suspended in 2020 due to COVID-19 but was again pursued in 2021 when time allowed. We feel the current version of the new instrument is able to adequately measure vertical profiles of water vapor from the surface to ~28 km in the Northern middle latitudes, but testing at a tropical location still needs to be performed.

D. Hurst was a co-author on 5 peer-reviewed journal papers published in 2021 and early 2022 that have scientific connections to GRUAN:

- Read, W.J., G. Stiller, S. Lossow, M. Kiefer, F. Khosrawi, D. Hurst, H. Vömel, K. Rosenlof, B.M. Dinelli, P. Raspollini, G.E. Nedoluha, J.C. Gille, Y. Kasai, P. Eriksson, C.E. Sioris, K.A. Walker, K. Weigel, J.P. Burrows, and A. Rozanov, The SPARC Water Vapor Assessment II: assessment of satellite measurements of upper tropospheric humidity, *Atmos. Meas. Tech.*, 15, 3377-3400, doi:10.5194/amt-15-3377-2022, 2022.
- Konopka, P., M. Tao, F. Plöger, D.F. Hurst, M.L. Santee, J.S. Wright, and M. Riese, Stratospheric moistening after 2000, *Geophys. Res. Lett.*, 49, doi:10.1029/2021GL097609, 2022.
- Ma, D., J. Bian, D. Li, B. Zhixuan, Q. Li, J. Zhang, H. Wang, X. Zheng, D.F. Hurst, and H. Vömel, Mixing characteristics within the tropopause transition layer over the Asian summer monsoon region based on ozone and water vapor sounding data, *Atmos. Res.*, 271, 106093, doi:10.1016/j.atmosres.2022.106093, 2022.

- Livesey, N.J., W.G. Read, L. Froidevaux, A. Lambert, M.L. Santee, M.J. Schwartz, L.F. Millán, R.F. Jarnot, P.A. Wagner, D.F. Hurst, K.A. Walker, P.E. Sheese, and G.E. Nedoluha, Investigation and amelioration of long-term instrumental drifts in water vapor and nitrous oxide measurements from the Aura Microwave Limb Sounder (MLS) and their implications for studies of variability and trends, *Atmos. Chem. Phys.*, 21, 15409-15430, doi:10.5194/acp-21-15409-2021, 2021.
- Davis, S.M., K.H. Rosenlof, D.F. Hurst, and H. Voemel, Stratospheric Water Vapor [in “State of the Climate in 2020”], *Bull. Amer. Meteor. Soc.*, 102 (8), S95-S98, doi:10.1175/2021BAMSSStateoftheClimate.1, 2021.

WG-GRUAN interface

The Boulder GRUAN site requires no special assistance or support by the WG at this time.

Other archiving centers

Ozone and water vapor sounding data from Boulder are archived on the NOAA/GML anonymous FTP server (<ftp://aftp.cmdl.noaa.gov/data/ozwv/>), the NDACC public data ftp server (<ftp://ftp.cpc.ncep.noaa.gov/ndacc/station/boulder/ames/>) and at NOAAs National Centers for Environmental Information (NCEI) in Asheville, North Carolina.

Participation in campaigns

There were no campaigns conducted at the Boulder GRUAN site during 2021. We continued to perform ozone and water vapor soundings in coordination with overpasses of Boulder by the Stratospheric Aerosols and Gas Experiment III instrument aboard the International Space Station (SAGE III/ISS). The ECC and FPH (and now POPS) profiles are being used to validate the SAGE III/ISS measurements of ozone, water vapor and aerosol extinction. Data from these soundings have been submitted to GRUAN if a RS41 was included in the payload.

Future plans

Our plan for 2022 is to continue to development and testing of the novel dry ice + ethanol-cooled FPH, performing multiple dual soundings with the older R23-cooled instrument at Boulder and at a tropical site.



GRUAN Site Report for Boulder (BOU), 2021

Reported time range is Jan 2021 to Dec 2021

Created by the Lead Centre

Version from 2022-11-15

1 General GRUAN site information

Object	Value
Station name	Boulder
Unique GRUAN ID	BOU
Geographical position	39.9500 °N, -105.2000 °W, 1743.0 m
Operated by	GMD Global Monitoring Division, part of: ESRL Earth System Research Laboratory, part of: NOAA National Oceanic and Atmospheric Administration
Main contact	Hurst, Dale F.
WMO no./name	-
Operators	currently 5, changes +0 / -0
Sounding Site	1
GNSS	2

1.1 General information about GRUAN measurement systems

System	Name	Type	Setups	Measurements
BOU-GN-01	GNSS Site P041	GNSS	0	not operational
BOU-GN-02	GNSS site TMS3	GNSS	1	operational
BOU-RS-01	Radiosonde Launch Site (Marshall)	Sounding Site	4	47

1.2 General comments from Lead Centre

No comments from Lead Centre.

2 System: GNSS Site P041 (BOU-GN-01)

Object	Value
System name	GNSS Site P041
Unique GRUAN ID	BOU-GN-01
System type	GNSS (GN - GNSS)
Geographical position	39.5658 °N, -105.1139 °W, 1728.8 m
Operated by	GMD Global Monitoring Division, part of: ESRL Earth System Research Laboratory, part of: NOAA National Oceanic and Atmospheric Administration
Instrument contact	Hurst, Dale F.
Started at	2004-02-13
Defined setups	-
Possible streams	-

2.1 Lead Centre comments

No comments from Lead Centre.

3 System: GNSS site TMS3 (BOU-GN-02)

Object	Value
System name	GNSS site TMS3
Unique GRUAN ID	BOU-GN-02
System type	GNSS (GN - GNSS)
Geographical position	40.0748 °N, -105.1358 °W, 1668.7 m
Operated by	GFZ Deutsches GeoForschungsZentrum GFZ, part of: HELMHOLTZ Helmholtz-Gemeinschaft
Instrument contact	Bradke, Markus
Started at	2014-06-20
Defined setups	1 (HOURLY)
Possible streams	-

3.1 Lead Centre comments

No comments from Lead Centre.

4 System: Radiosonde Launch Site (Marshall) (BOU-RS-01)

Object	Value
System name	Radiosonde Launch Site (Marshall)
Unique GRUAN ID	BOU-RS-01
System type	Sounding Site (RS - Radiosonde)
Geographical position	39.9500 °N, -105.2000 °W, 1743.0 m
Operated by	GMD Global Monitoring Division, part of: ESRL Earth System Research Laboratory, part of: NOAA National Oceanic and Atmospheric Administration
Instrument contact	Hurst, Dale F.
Started at	-
Defined setups	4 (RESEARCH, OZONE, FPH-OZONE, FPH)
Possible streams	FPH, IMET-1, RS41, RS80, RS92

4.1 Lead Centre comments

4.1.1 Dataflow

Operational dataflow of radiosonde measurement data to the GRUAN LC since August 2014.

Currently, the dataflow includes radiosoundings with Vaisala RS41-SG, Intermet iMET-1, ECC Ozone and FPH. All data are transmitted using the RsLaunchClient within one month after the sounding.

A regular and intensive measurement program for the observation of stratospheric water vapor was performed using FPH.

4.2 GRUAN data products

Product	Version	Soundings received	Available at LC	Distributed by NCEI
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4.2.1 Stream: ECC

ECC		47	47	
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4.2.2 Stream: FPH

FPH		20	20	
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4.2.3 Stream: IMET-1

IMET-1		47	47	
IMET-1-RAW	001		46	

4.2.4 Stream: RS41

RS41		47	47	
RS41-RAW	001		47	
RS41-EDT	001		43	
RS41-GDP	001		42	
RS41-GDP-BETA	002		23	
RS41-GDP-BETA	003		33	

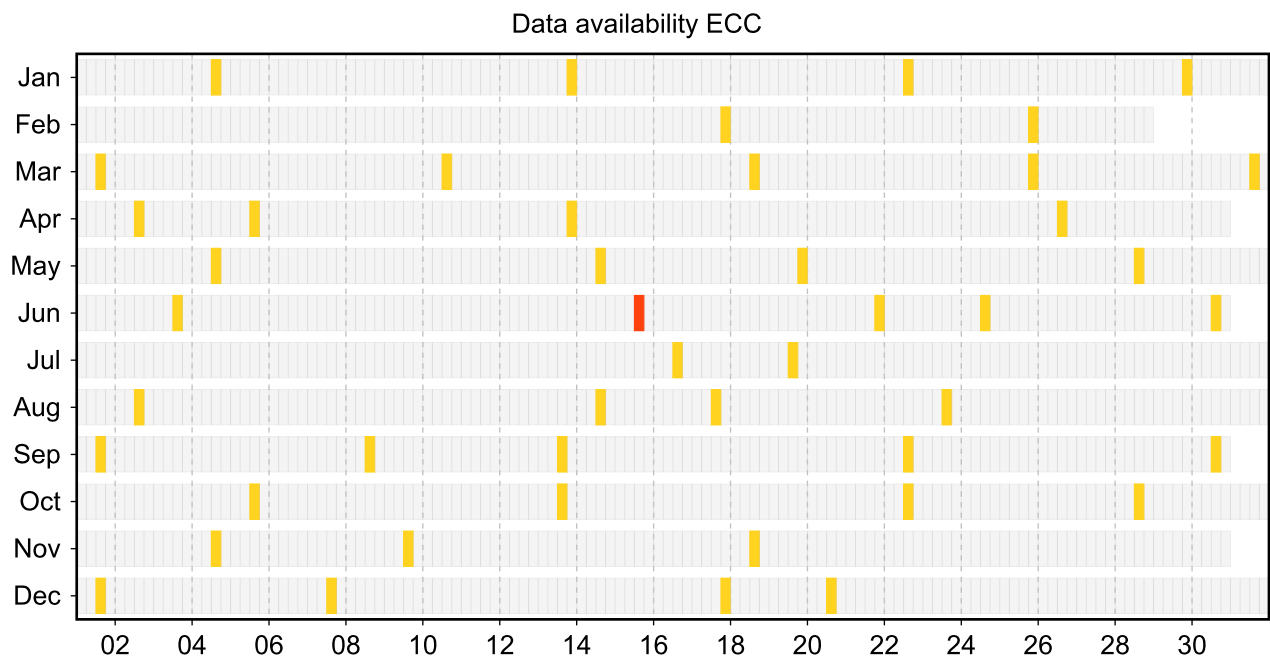
4.3 Availability of data products

Available (green): All steps of data processing have been successfully completed. The data product file is available at LC (e.g. files that didn't pass QA/QC or uncertified GRUAN data products) and/or at NCEI (a certified GRUAN data product file that did pass QA/QC).

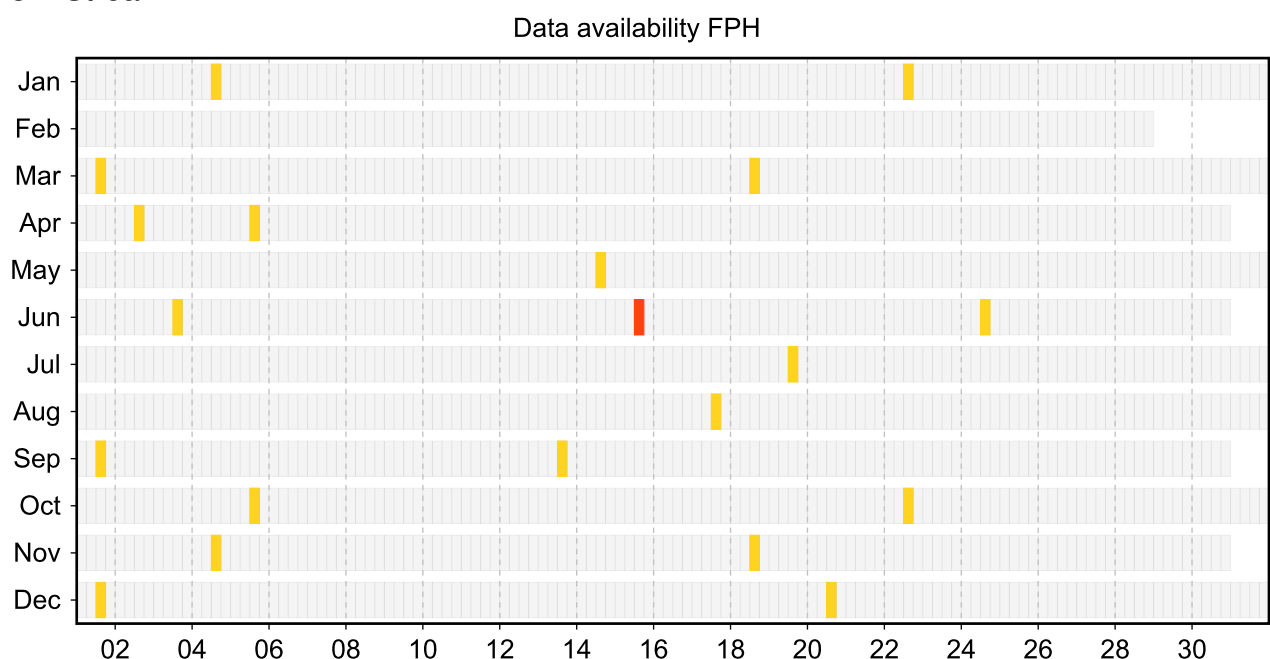
Unprocessed (yellow): The manufacturer-produced file with raw measurement data has been successfully converted into a GRUAN-standardized raw data format (NetCDF). The GRUAN data processing has not been performed or was aborted. Reasons for this may be a still missing GRUAN data processor or a processing-software error.

Original (red): The original, manufacturer-produced, raw data file is available (e.g. MWX data file) but was not converted into a GRUAN-standardized raw data format (NetCDF). Reasons for this may be missing data conversion software, a software error, or a corrupt data file.

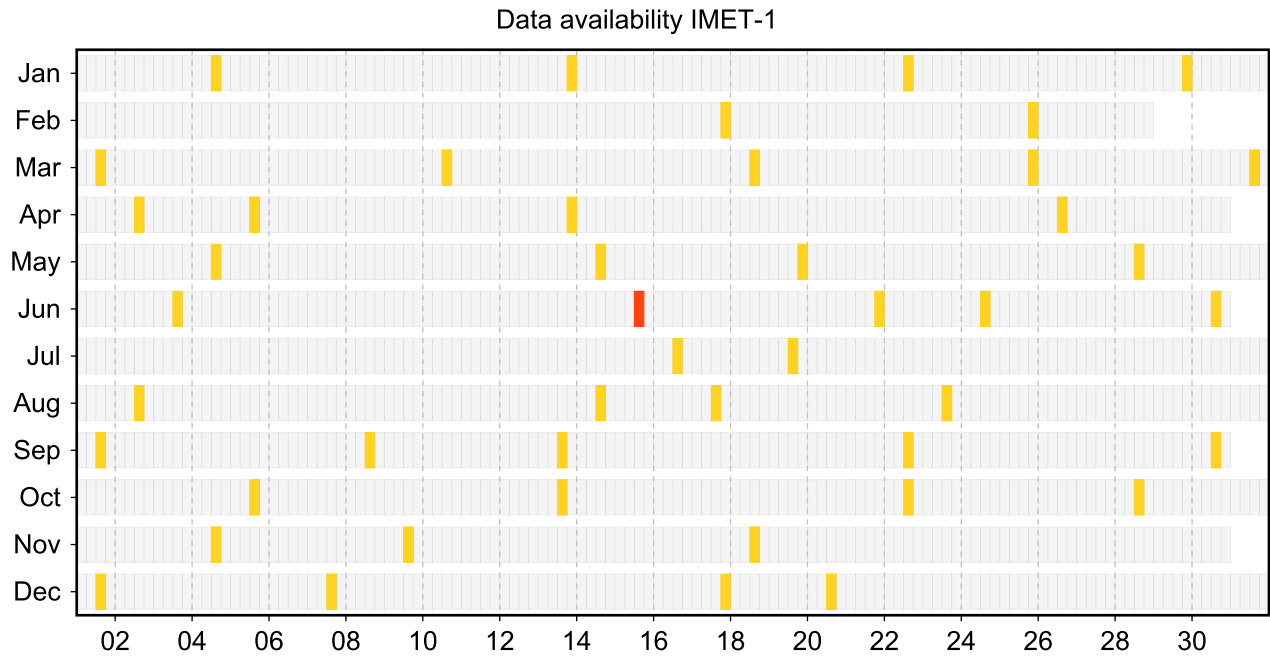
4.3.1 Stream: ECC



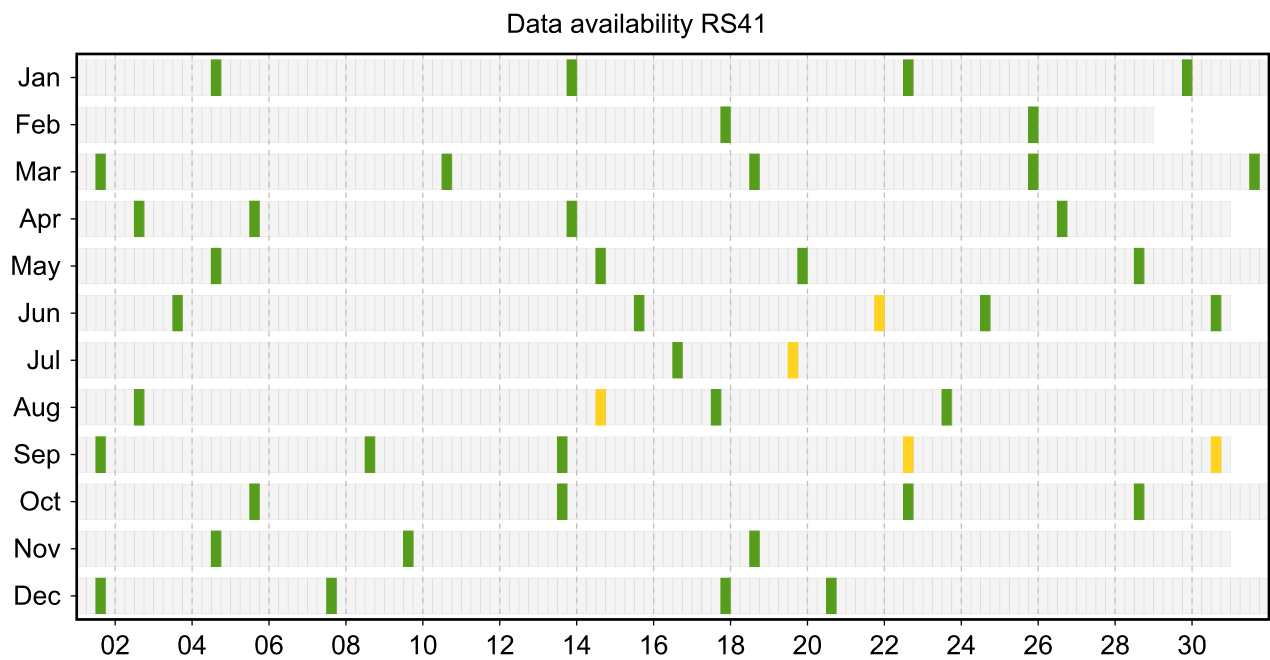
4.3.2 Stream: FPH



4.3.3 Stream: IMET-1



4.3.4 Stream: RS41



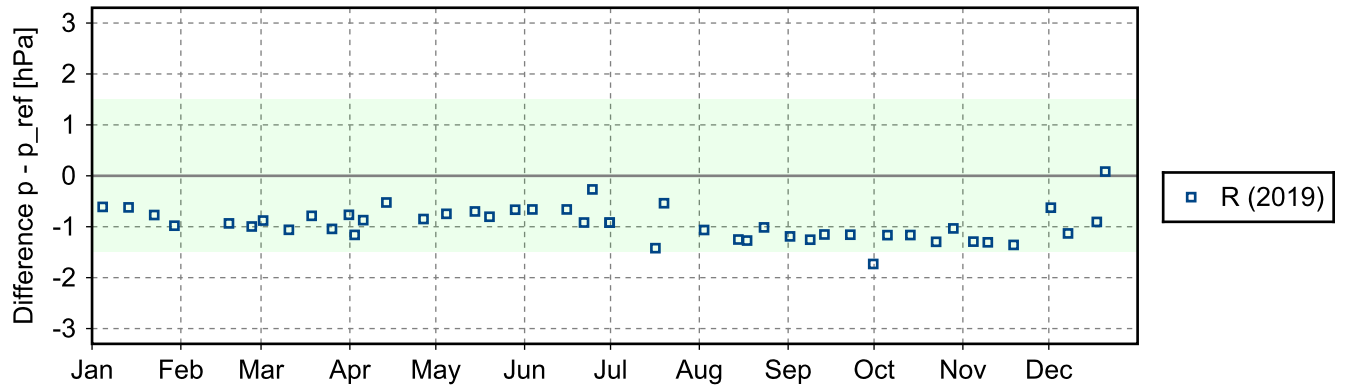
4.4 Instrument combinations of BOU-RS-01

Count	Instrument combination
20	ECC, FPH, IMET-1, RS41
27	ECC, IMET-1, RS41

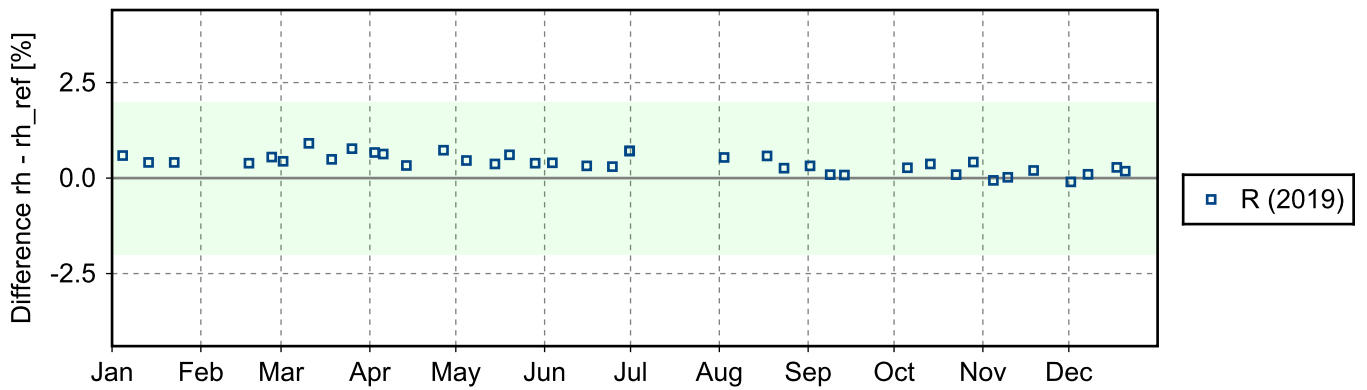
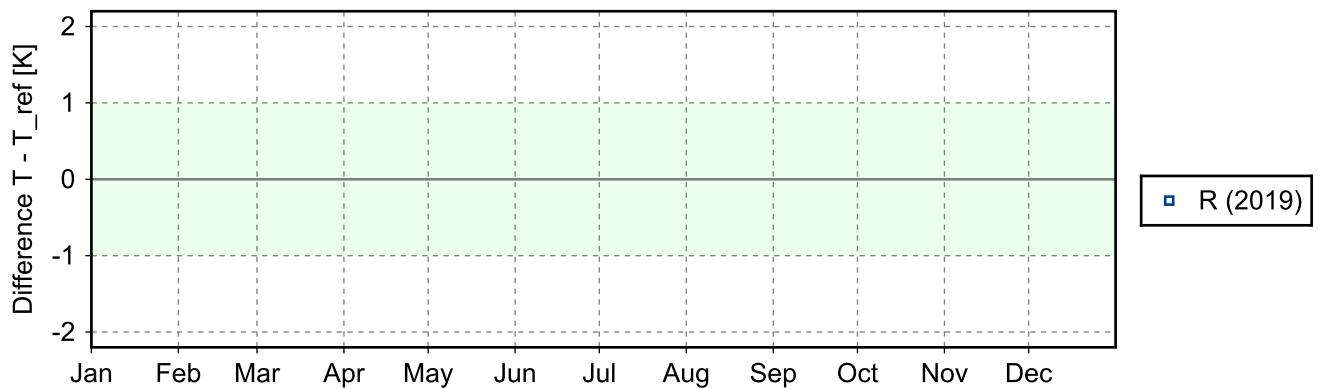
4.5 Instrument ground check

4.5.1 Stream: RS41

(1) GroundCheck: GC-RI41



(2) GroundCheck: GC-SHC



4.6 Measurement events

