GCOS Reference Upper-Air Network

The climate reference network

M10 GPD, overview of organization and progress, correction and uncertainty, strategy of validation and results

JC. Dupont (IPSL), D. Vignelles (MODEM), S. Evan (LaCy)

Outline

1. **Introduction** (JC. Dupont, IPSL)
2. **Correction and uncertainty strategy** (D. Vignelles, MODEM)
3. **Data flow** (JC. Dupont, IPSL)
4. **Validations of the results** (S. Evan, LaCy)

Organization

Who : which organization for the GRUAN GDP M10

1. **IPSL** (JC. Dupont, M. Haeffelin, MA. Drouin) : leader of the project, scientific relationship with GRUAN, algorithm development for M10 L1 and GDP + SIRTA site instruments
2. **Météo-France** (F. Marin, P. Jann) : Operationnal aspect for radiosondes at TRP and REU sites
3. **AERIS/ESPRI** (S. Cloché, C. Laplace) : data flow at AERIS Data Center
4. **MODEM** (D. Vignelles) : correction and uncertainty for M10 RS
5. **LACy** (S. Evan) : M10 GDP validation and Maïdo site instruments

Status of M10 GDP

GRUAN

Status of the GRUAN certification for M10 RS in TRP and REU site : a work in progress and almost finished

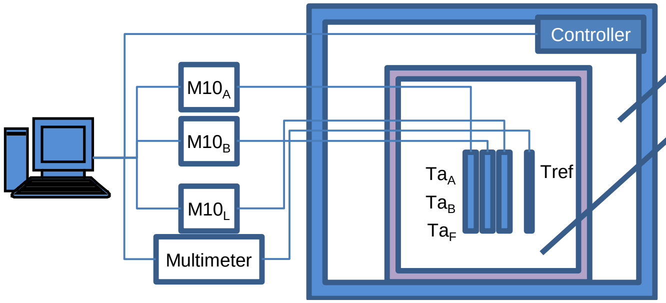
1. Technical Document (last TD-8), version 1 submitted on september 2020 (241 pages). **OK**
2. Scientific document to describe M10 radiosonde / manual and automatic : **OK,** Dupont et al., 2020 (DOI: 10.1175/JTECH-D-18-0205.1) and Madonna et al. 2020 (https://doi.org/10.5194/amt-13-3621-2020).
3. One operationnal site (twice a day for TRP & REU): **OK**
4. Dataflow and datacenter: **OK** (https://www.gruan.org/data/measurements/sonde-launches) and AERIS datacenter
5. An established dataset for each site / sonde : **OK,** 20 months for TRP site et 14 months for REU site
6. Review of certification document by GRUAN WG : **review in progress**

Correction and uncertainty strategy (1/8)

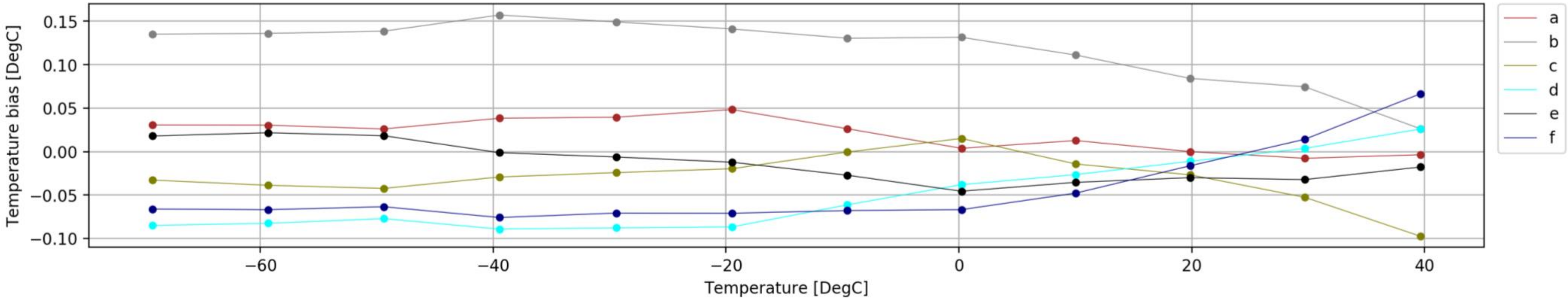
Temperature Calibration tests

- Calibration tests made @LMD/Ecole polytechnique
- Measurements made from +40 -> -70°C per 10°C steps
  - Reference PT100 calibrated u_{ref} 0.09 K k=2
  - Taking into account : linearity, repeatability, reproducibility, resolution, ref repeatability, ref resolution
  - **Result** : **0.228 K** (k=2)

Climatic chamber @ LMD/Ecole Polytechnique



Schematization of climatic chamber, and stabilizing block



Example of mean results for 6 radiosondes, mean on 3 hours of stabilization per steps, taking account 4 steps (2 descents and ascents)

Correction and uncertainty strategy (2/8)

More details in M10 TD
Temperature calibration uncertainties

Following the methodology from Duvernoy et al. 2015 WMO Report n°119

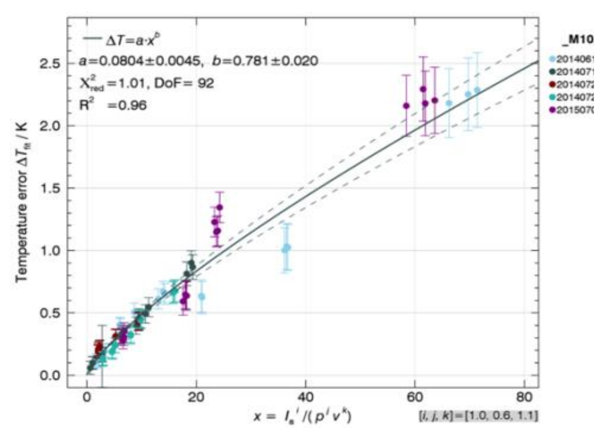
More information in the M10 technical Document (in review)

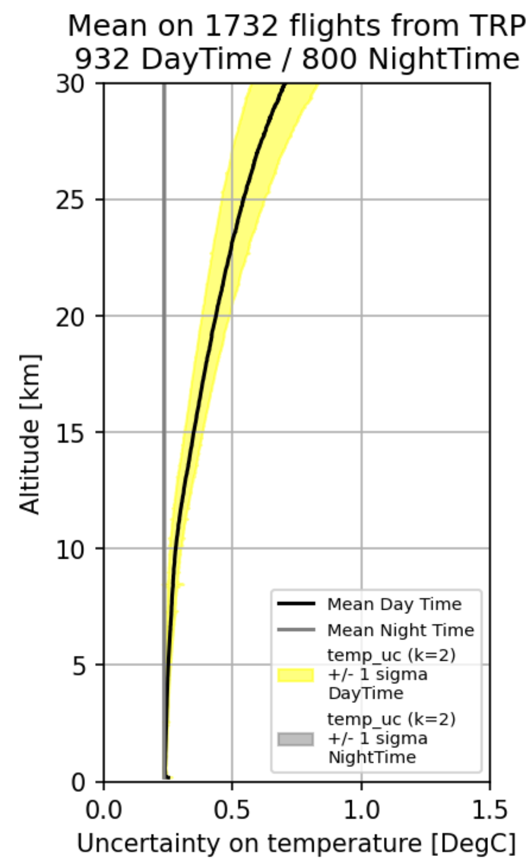
Parameter	Name	Description	Standard uncertainty [°C] k=1	Type	Data field in product
$u(T_{a\text{-}lin})$	Uncertainty of temp_raw linearity	Maximum bias from reference	0.160/√(3)	B	-
$u(T_{a\text{-}repe})$	Uncertainty of temp_raw repeatability	Standard deviation of mean stabilized values	0.015	B	-
$u(T_{a\text{-}repro})$	Uncertainty of temp_raw reproducibility	Maximum standard deviation along all stabilized values	0.082/√(3)	B	-
$u(T_{a\text{-}reso})$	Uncertainty of temp_raw resolution	Minimum difference between two indications	0.040/√(12)	B	-
$u(T_{ref\text{-}cal})$	Uncertainty of Tref calibration	Calibration certificate including the PT100 and the acquisition system	0.045	A	-
$u(T_{ref\text{-}repe})$	Uncertainty of Tref repeatability	Standard deviation of mean stabilized values	0.005	B	-
$u(T_{ref\text{-}reso})$	Uncertainty of Tref resolution	Minimum difference between two indications	<0.001/√(12)	B	-
$u(T_{a\text{-}cal})$	Uncertainty of Ta_raw calibration	Composition of $u(T_{a\text{-}lin})$, $u(T_{a\text{-}repe})$, $u(T_{a\text{-}repro})$, $u(T_{a\text{-}reso})$, $u(T_{ref\text{-}cal})$, $u(T_{ref\text{-}repe})$, $u(T_{ref\text{-}reso})$	0.114	B	temp_cal_uc

Table 4-1: Overview of the uncertainty budget of temp_raw calibration

Temperature correction and uncertainty related

- **Calibration uncertainty** : 0.228K (k=2)
- **Radiative correction**
    - Using pvlib for the solar position (Reda and Andreas, 2008)
    - Using solar radiation equation (OD 0.8, albedo 0.2%)
    - Solar irradiance correction factor determined @ Lindenberg 2014 (former set up) function of the solar irradiance, pressure and vertical speed
    - Uncertainty derived from the uncertainty of the regression terms
- **ARL correction**
    - Interpolation of the first ten seconds of measurement with the Météo France ground measurement

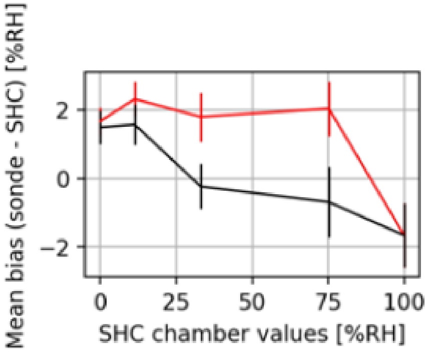


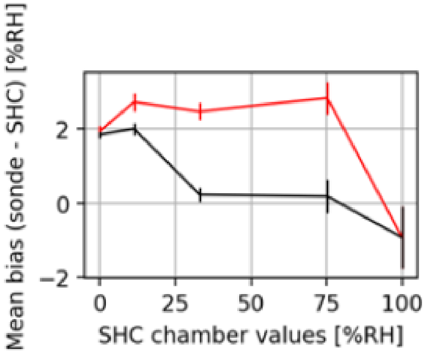


Mean temperature uncertainty
Period : March 2018 -> October 2020
From Trappes Palaiseau - Paris FR

Correction and uncertainty strategy (4/8)

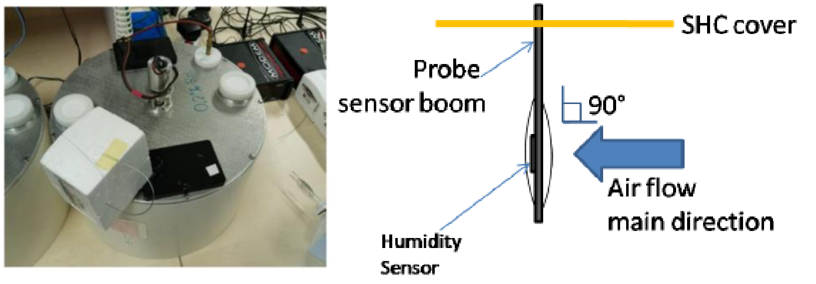
Relative humidity calibration tests





Left, differences between mean 10 raw sonde indications and SHC saturated salt indications
Right, differences between mean 5 times the same sonde indications and SHC saturated salt indications

- Calibration tests made @ Lindenberg
  - Repeatability and reproducibility tested
    - Using 10 different sondes
    - Using 5 times the same sonde
  - Different orientations in the SHC give different results (~ +/- 0.5 %RH) reason ?
  - **Results** : calibration uncertainty = **2.42 %RH** (k=2)



Position and air flow direction chosen for the tests

Correction and uncertainty strategy (5/8)

More details in M10 TD
RH calibration uncertainties

Following the methodology from Duvernoy et al. 2015 WMO Report n°119

More information in the M10 technical Document (in review)

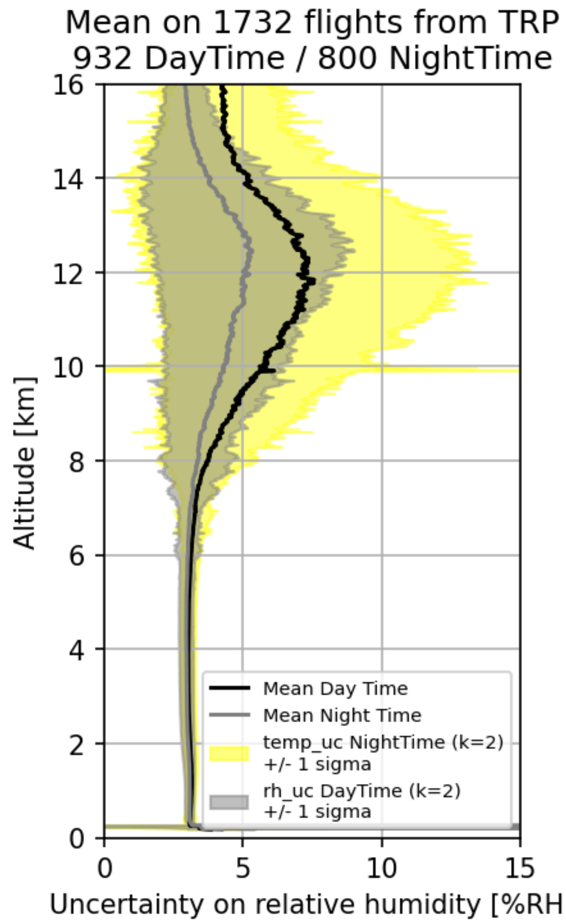
Parameter	Name	Description	Standard uncertainty [%RH] k=1	Type	Data field in product
$u(rh_{repro})$	Uncertainty of rh_rawreproductibilit y	Maximum standard deviation between results	0.60	B	-
$u(rh_{repe})$	Uncertainty of rh_raw repeatability	Standard deviation of mean stabilized values	0.10	B	-
$u(rh_{reso})$	Uncertainty of rh_raw resolution	Minimum difference between two indications	0.01/√(12)	B	-
$u(rh_{hyst})$	Uncertainty of rh_raw hysteresis	Mean hysteresis effect	1.00	B	-
$u(rh_{sensor\_orie})$	Uncertainty of rh_raw sensor orientation	Maximum difference between position	0.5/√(3)	B	-
$u(rh_{cal})$	Uncertainty of rh_raw calibration	Composition of $u(rh_{repro})$, $u(rh_{repe})$, $u(rh_{reso})$, $u(rh_{hyst})$, $u(rh_{sensor\_orien})$	1.21	B	rh_cal_uc

Table 4-4: Overview of the uncertainty budget of rh_raw calibration

Correction and uncertainty strategy (6/8)

Relative humidity corrections and related uncertainties

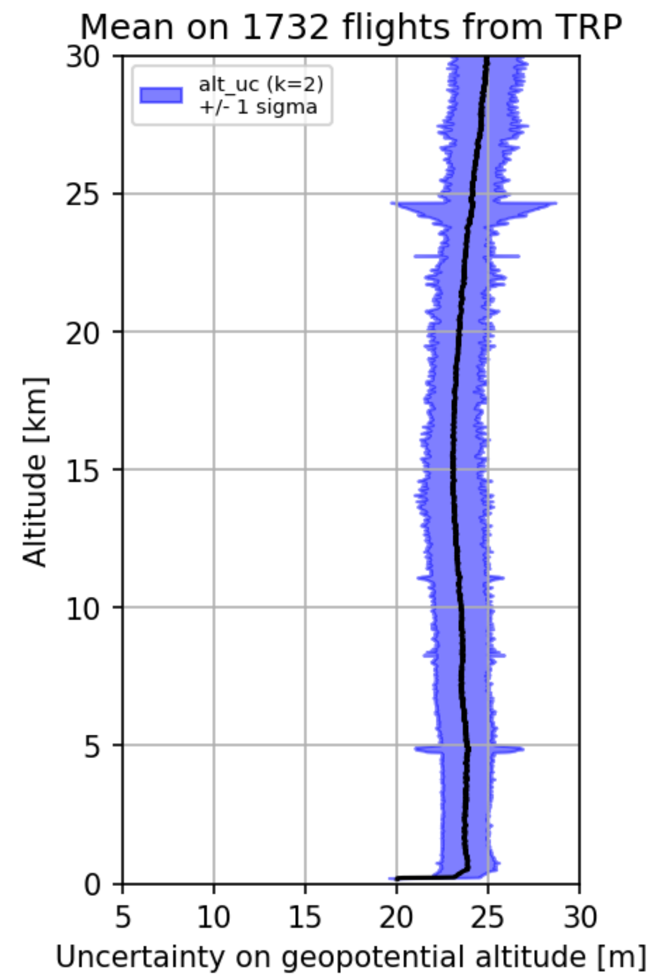
- **Slow regime correction**
  - Correction of a hysteresis-like effect, or memory effect
  - Uncertainty derived from Dupont et al. 2020 = **1.06 %RH** (k=2)
- **Temperature dependence**
  - Correction of relative humidity indication, taking into account temperature difference between the sensor and air
  - Uncertainty derived from Hyland and Wexler 1983 equations, using combined standard uncertainty (eq. 10 JCGM 100:2008, or eq. 2 Immler et al. 2010)
    - Function (thum, thum_uc, temp, temp_uc)
    - Day time from 2 to 4 %RH at tropopause / night time
- **Time-lag correction**
  - Correction of the time-lag as a function to temperature
  - Uncertainty derived from Dupont et al. 2020 which show a +/- 15% error on the determination of time-lag constant, and appling Dirksen et al. 2014 methodology
- **ARL correction**
  - Correction of the relative humidity indication, taking into account the air temperature corrected by the effect of the ARL
  - Uncertainty to be determined



Mean RH uncertainty
Period : March 2018 -> October 2020
From Trappes Palaiseau - Paris FR
Tropopause ~ 11.6 +/- 1.4 (k=1) km

Altitude corrections and uncertainties

- From geometric altitude to geopotential altitude
  - Using equation from GPS manufacturer (function of std gravity and gravity as a function of latitude, Earth radius, geometric altitude)
  - Uncertainty took into account : Manufacturer uncertainty (20 m k=2 without SBAS), repeatability in simulator, and noise estimation
- ARL correction
  - Interpolation of altitude for the first ten seconds after the release, with respect to ground altitude
  - Due to the shadowing effect of the ARL conception (maritime container)



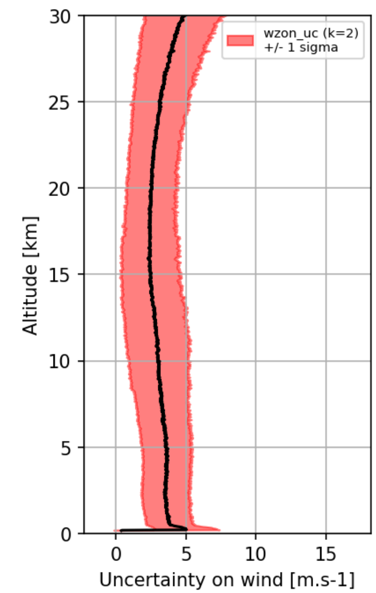
Mean Altitude uncertainty
Period : March 2018 -> October 2020
From Trappes Paris FR

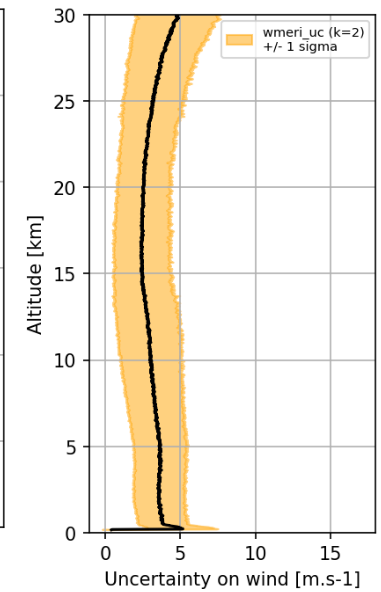
Correction and uncertainty strategy (8/8)

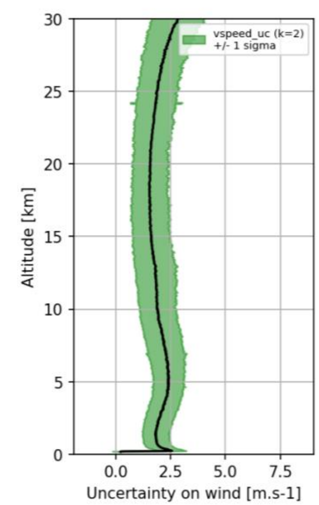
Zonal, meridional, and vertical winds correction and uncertainties

K=2

- <u>Zonal and meridional winds</u> :
    - Pendulum motion using Dirksen et al. 2014 method, gaussian kernel of 11 s length
    - Uncertainty taking into account manufacturer uncertainty (0.2m without SBAS), pendulum motion smoothing uncertainty (Dirksen et al. 2014)
- <u>Vertical wind</u> :
    - Uncertainty taking into account manufacturer uncertainty (20m without SBAS), pendulum motion smoothing uncertainty (Dirksen et al. 2014)







Mean wind components uncertainty

Period : March 2018 -> October 2020 From Trappes Palaiseau - Paris FR

Main features of the GRUAN M10 data processing and data access

The different processing levels of the radiosonde data:

- Level 0 data: original raw data (4 ascii files and 1 proprietary binary file)
- Level 1 data: Preprocessed raw data, converted into netcdf file, no change in the data, the 4 ascii files formatted into one netcdf file (according to GRUAN Lead Center recommendations).
- Level 2 data: GRUAN data product are obtained from the level1 data which are processed, improved and flagged, based on Dupont et al. 2019 and on Meteomodem expertise, netcdf file.

Distributed data: L1, L2

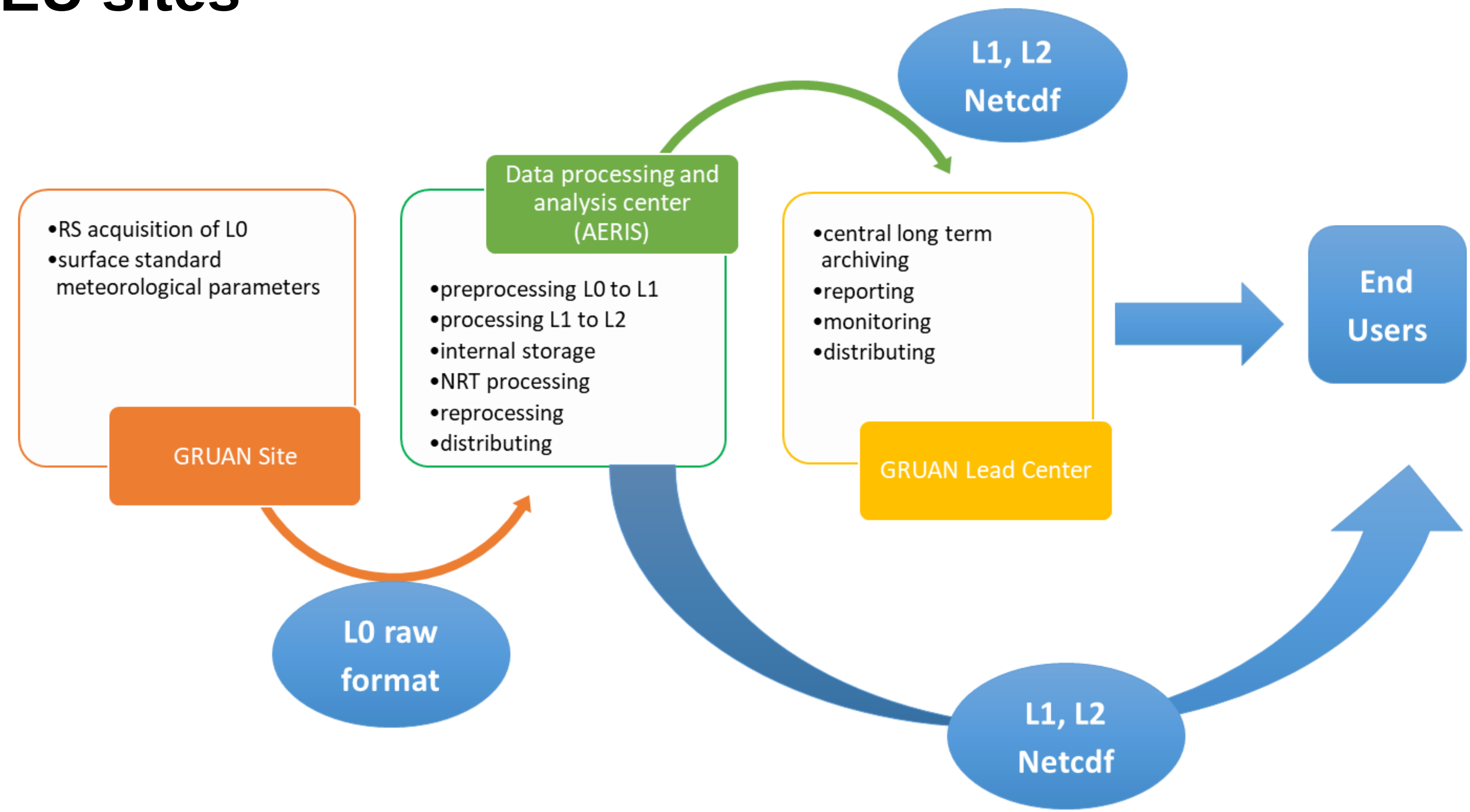
Format of distribution: Netcdf

Data center for the processing : **AERIS**, the French atmospheric data center

Distributor: GRUAN and AERIS

Data flow

Overview of the GRUAN M10 data flow for TRP and REU sites

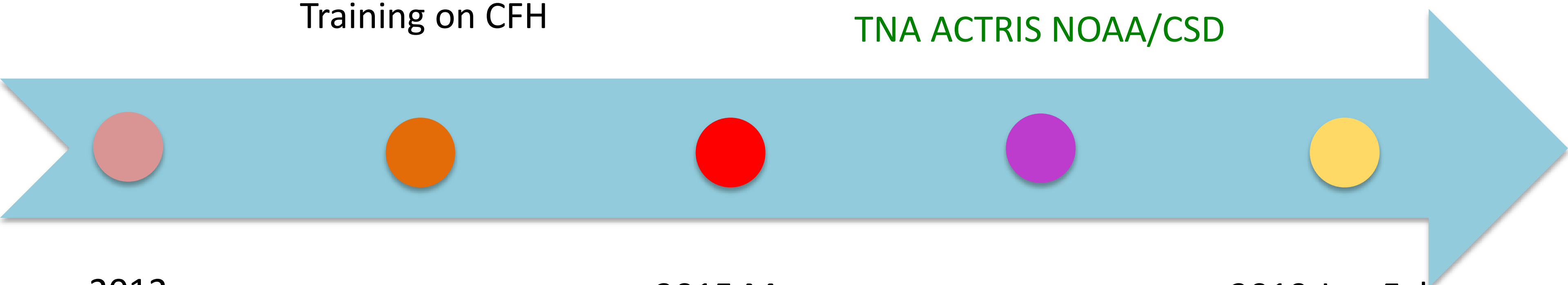


Validations of the results (1/8)

CFH/M10/LIDAR measurements at Maïdo observatory

Nov 2014
Start of GRUAN related activities
Training on CFH

2016
CFH/COBALD/POPS
TNA ACTRIS NOAA/CSD



2012
Opening of Maïdo Observatory (2km ASL)

2015 May
MORGANE
RS92/RS41/M10
CFH/COBALD
LIDARS

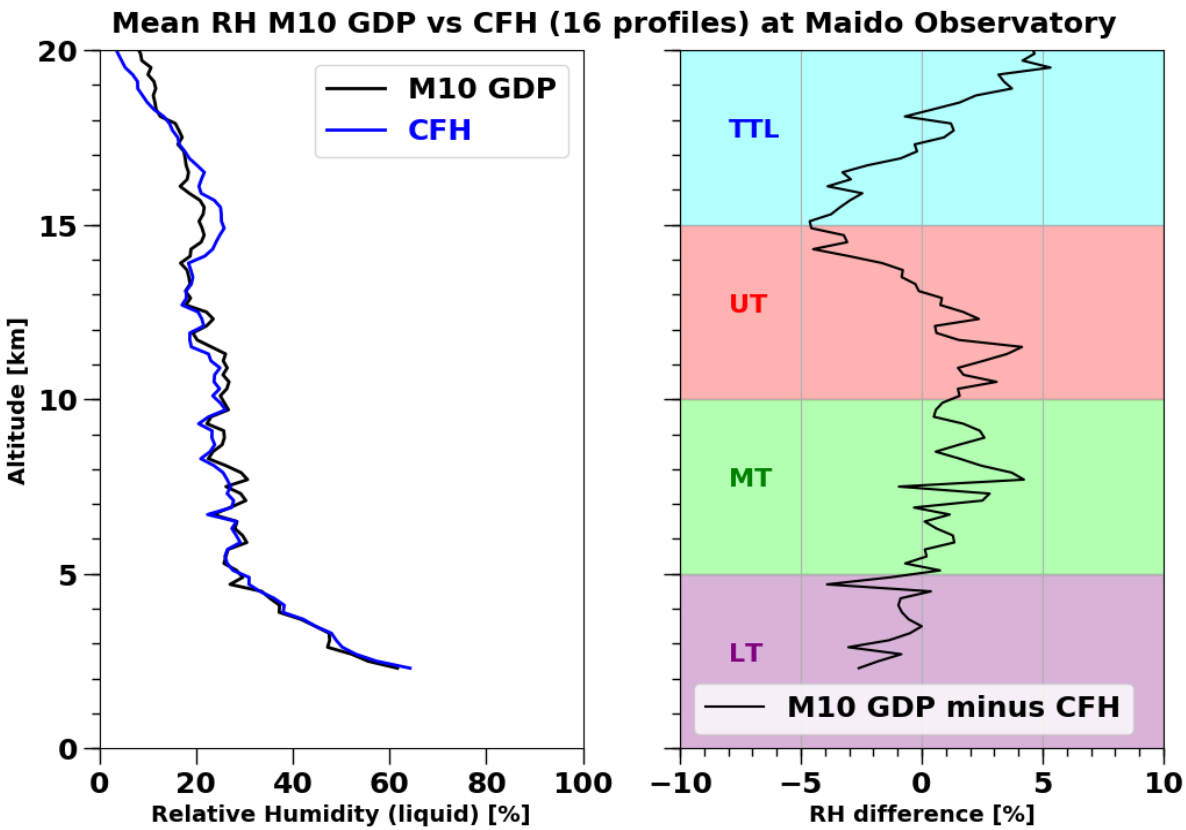
TNA ACTRIS DWD

2019 Jan-Feb
CONCIRTO
RS92/RS41/M10
CFH/COBALD/
Ozone ECC
LIDARS/RADAR

ANR, LACy, DWD, ETHZ, U. Leeds

Validations of the results (2/8)

M10 GDP versus CFH radiosonde comparisons at Maïdo observatory (2014-2019)



Tropical Tropopause Layer: -4.6%

Upper Troposphere: +0.3%

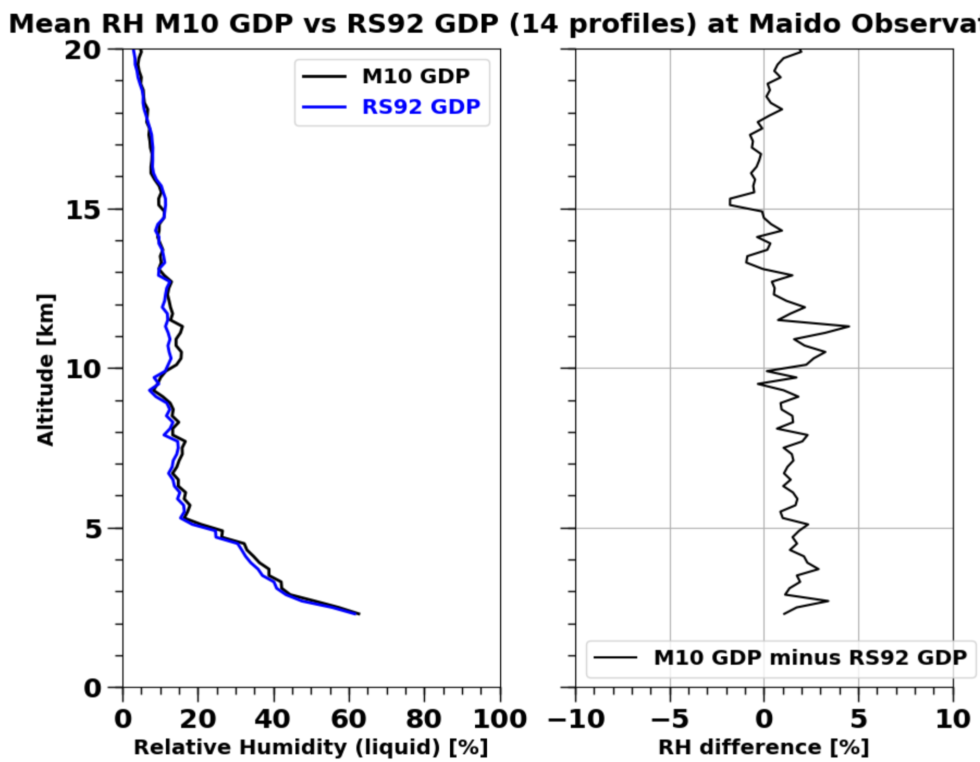
Middle Troposphere: +1.3%

Lower Troposphere: -1.3%

Vertical profiles of mean RH obtained from 16 multiple-payload sounding of CFH&M10 radiosondes. The mean profile of differences in RH is shown on the right panel.

Validations of the results (3/8)

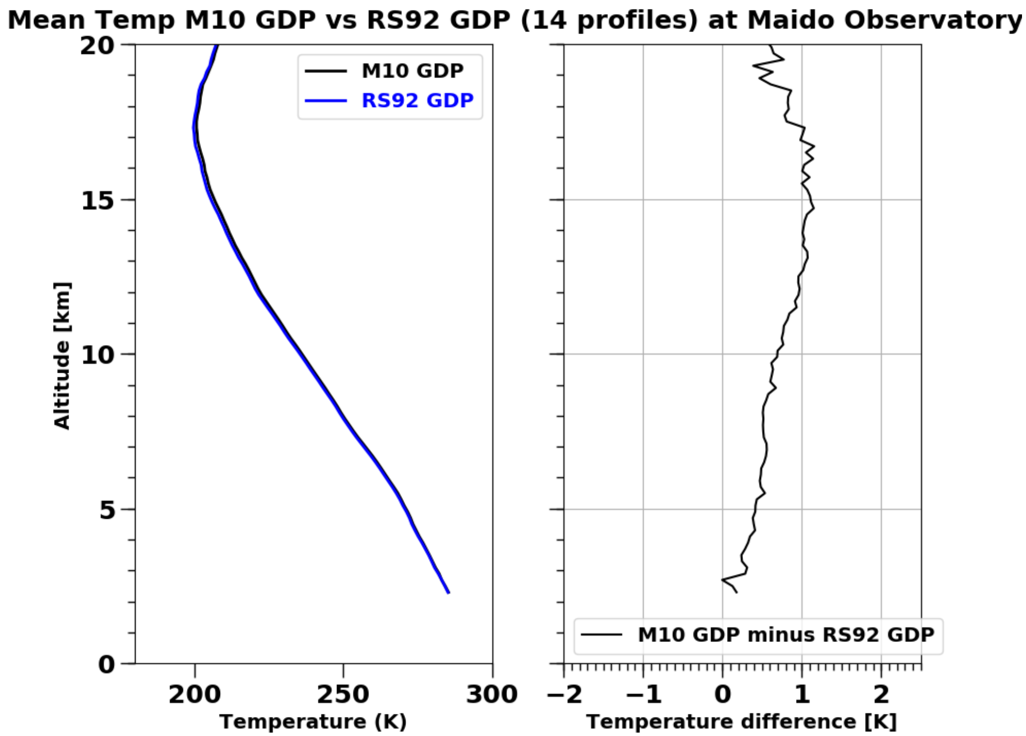
M10 GDP versus RS92 GDP during the MORGANE campaign (May 2015): Relative Humidity



Vertical profiles of mean RH obtained from 14 multiple-payload sounding of M10&RS92 radiosondes (blue and black curves respectively on the left panel) at the Maïdo Observatory during the MORGANE campaign in May 2015. The mean profile of differences in RH is shown on the right panel.

Validations of the results (4/8)

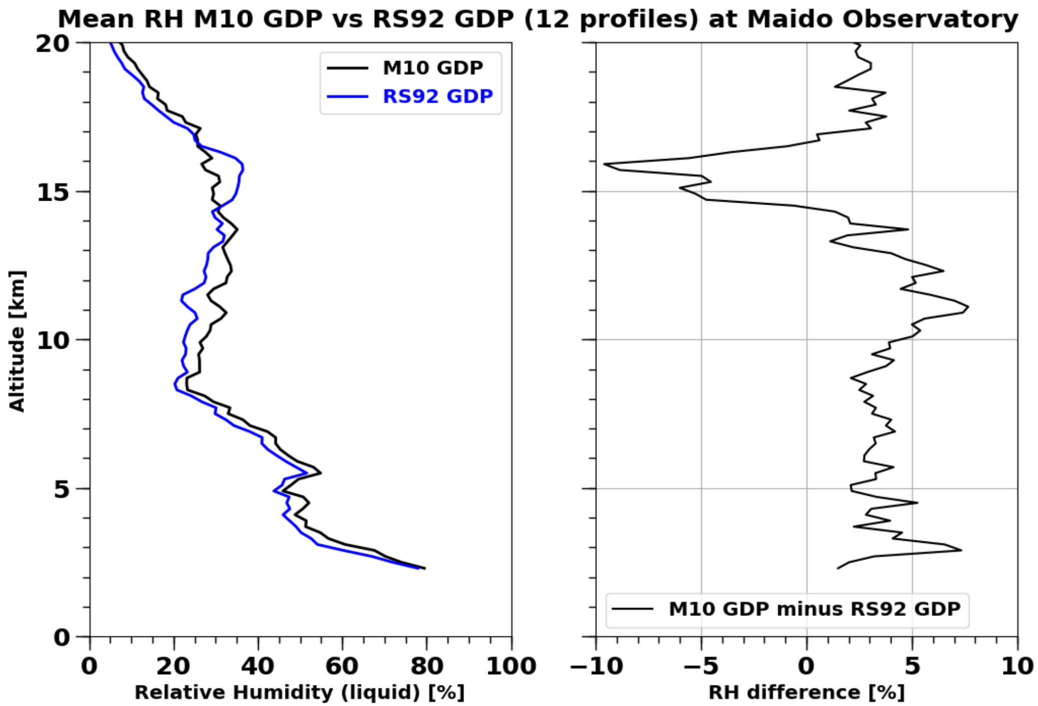
M10 GDP versus RS92 GDP during the MORGANE campaign (May 2015): Temperature



Vertical profiles of mean Temperature obtained from 14 multiple-payload sounding of M10&RS92 radiosondes (blue and black curves respectively on the left panel) at the Maïdo Observatory during the MORGANE campaign in May 2015. The mean profile of differences in temperature is shown on the right panel.

Validations of the results (5/8)

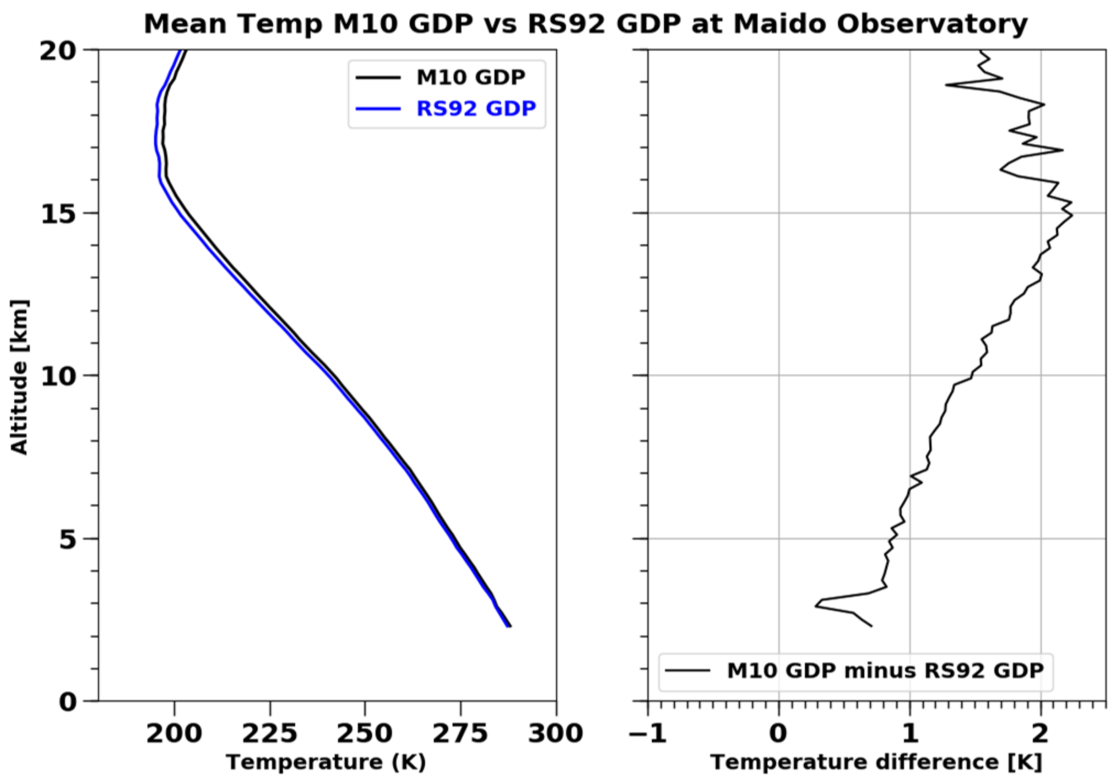
M10 GDP versus RS92 GDP during the CONCIRTO campaign (Jan-Feb 2019): Relative Humidity



Vertical profiles of mean RH obtained from 12 multiple-payload sounding of M10&RS92 radiosondes (blue and black curves respectively on the left panel) at the Maïdo Observatory during the CONCIRTO campaign in January 2019. The mean profile of differences in RH is shown on the right panel.

Validations of the results (6/8)

M10 GDP versus RS92 GDP during the CONCIRTO campaign (Jan-Feb 2019): Temperature



Vertical profiles of mean Temperature obtained from 12 multiple-payload sounding of M10&RS92 radiosondes (blue and black curves respectively on the left panel) at the Maïdo Observatory during the CONCIRTO campaign in January 2019. The mean profile of differences in temperature is shown on the right panel.

Validations of the results (7/8)

M10 GDP versus RS92 GDP versus CFH

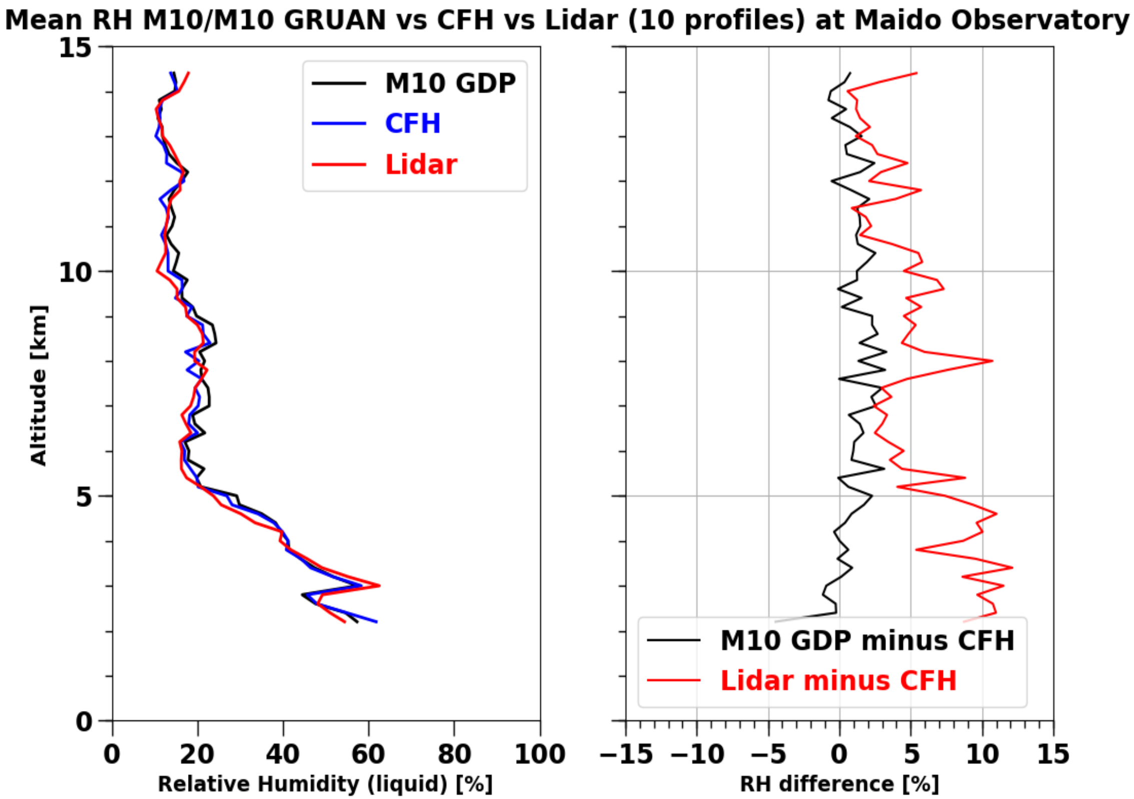
MORGANE	LT (0-5km)	MT (5-10km)	UT (10-15km)	TTL (15-20km)
M10 GDP RH(%)	40.5	14.3	12.2	6.9
RS92 GDP RH(%)	38.6	13.0	11.1	6.9
M10 GDP T(K)	278.4	253.8	220.0	203.4
RS92 GDP T(K)	278.1	253.3	219.1	202.5
CONCIRTO	**LT (0-5km)**	**MT (5-10km)**	**UT (10-15km)**	**TTL (15-20km)**
M10 GDP RH(%)	58.2	36.1	31.3	20.2
RS92 GDP RH(%)	54.4	32.9	27.7	20.3
M10 GDP T(K)	281.1	258.5	222.0	199.1
RS92 GDP T(K)	280.4	257.4	220.2	197.2

Validations of the results (8/8)

M10 GDP versus Raman lidar comparisons

The Lidar RH profiles were computed with the Lidar water vapor mixing ratio and the Intermet iMet-1-RSB temperature using the water vapor pressure equation by Hyland and Wexler (1983).

LIDAR water vapor data are calibrated using GNSS Integrated Water Vapor (Vérrèmes et al., 2019)



Differences between the M10 GDP RH and Lidar RH compared to CFH RH:

- Lower troposphere (<5km altitude): 1% and 9.7%
- Mid-troposphere (between 5 and 10km): 5% and 1.6%
- Upper troposphere (between 10-13km): 3.1 and 1.3%

Question ?

Thanks for your attention