The progression of GTH3 GDP and laboratory characterization

（task：GCOS-262）

GUO Qiyun, Luo Haowen, Han Zhongqiang&Zhang Peng

Meteorological Observation Centre, CMA

gqyaoc@cma.gov.cn/feng_cloudy@163.com

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Outline

01 Background

02 The implementation progress of ICM-15's GA3

03 The three sets of laboratory equipments developing

1. Background

atmospheric temperature and relative humidity measurements $\Lambda^{\delta}_{\sigma(\delta)\pm\epsilon}$

		Atmospheric temperatue [K]				Relative humidity [%RH]			
		PBL	FT	UTLS	MUS	PBL	FT	UTLS	MUS
GTH3	Day	$0.18^{-0.05}_{0.17}\pm0.03$	$0.12^{+0.05}_{0.11}\pm0.04$	$0.09^{+0.01}_{0.08}\pm0.02$	$0.27^{-0.22}_{0.16}\pm0.10$	$7.00^{-5.43}_{4.41}\pm0.74$	$8.75^{-3.50}_{8.02}\pm0.60$	$7.73^{-1.55}_{7.58}\pm0.40$	$1.69^{+1.48}_{0.82}\pm0.46$
	Night	$0.38^{-0.18}_{0.34}\pm0.05$	$0.15^{+0.02}_{0.15}\pm0.02$	$0.12^{+0.06}_{0.10}\pm0.05$	$0.10^{-0.03}_{0.10}\pm0.02$	$4.72^{+0.74}_{4.66}\pm0.15$	$6.41^{+2.16}_{6.03}\pm0.11$	$6.82^{+3.70}_{5.74}\pm0.26$	$1.71^{+1.54}_{0.74}\pm0.28$

The night valuer of the GTH3 s slightly larger than that of the day, and the temperature value is smaller than that of other radiosondes, so the GTH3 has better temperature detection performance

		Geopotential height [m]				Pressure [hPa]			
		PBL	FT	UTLS	MUS	PBL	FT	UTLS	MUS
GTH3	Day	×	$5.9^{+2.0}_{5.5}\pm1.8$	$13.2^{+10.0}_{8.6}\pm3.8$	$29.5^{+23.4}_{17.9}\pm4.2$	×	$0.4^{-0.0}_{0.4}\pm0.1$	$0.4^{-0.3}_{0.2}\pm0.1$	$0.3^{-0.2}_{0.1}\pm0.0$
	Night	×	$5.8^{+0.4}_{5.8}\pm0.4$	$11.5^{+7.7}_{8.6}\pm3.4$	$26.7^{+20.7}_{16.8}\pm4.2$	×	$0.5^{+0.1}_{0.5}\pm0.2$	$0.3^{-0.1}_{0.2}\pm0.1$	$0.1^{-0.1}_{0.1}\pm0.0$

The geopotential height and the pressure measurement error is small and at the average level

		Wind (horizontal) direction [°]				Wind (horizontal) speed [ms^{-1}]				Wind (horizontal) vector [ms^{-1}]			
		PBL	FT	UTLS	MUS	PBL	FT	UTLS	MUS	PBL	FT	UTLS	MUS
GTH3	Day	×	$3.6^{-0.4}_{3.6}\pm0.2$	$2.5^{-0.2}_{2.5}\pm0.3$	$6.1^{-0.4}_{6.1}\pm0.2$	×	$0.2^{-0.0}_{0.2}\pm0.0$	$0.2^{-0.0}_{0.2}\pm0.0$	$1.3^{-0.0}_{1.3}\pm0.0$	×	$0.3^{+0.2}_{0.1}\pm0.0$	$0.3^{+0.2}_{0.2}\pm0.0$	$1.5^{+0.3}_{1.5}\pm0.0$
	Night	×	$2.6^{-0.2}_{2.6}\pm0.2$	$2.4^{-0.1}_{2.4}\pm0.1$	$4.5^{-0.6}_{4.4}\pm0.2$	×	$0.2^{-0.0}_{0.2}\pm0.0$	$0.2^{+0.0}_{0.2}\pm0.0$	$0.2^{-0.0}_{0.2}\pm0.0$	×	$0.2^{+0.2}_{0.1}\pm0.0$	$0.2^{+0.2}_{0.1}\pm0.0$	$0.4^{+0.3}_{0.3}\pm0.0$

The GTH3 wind accuracy is high and stable

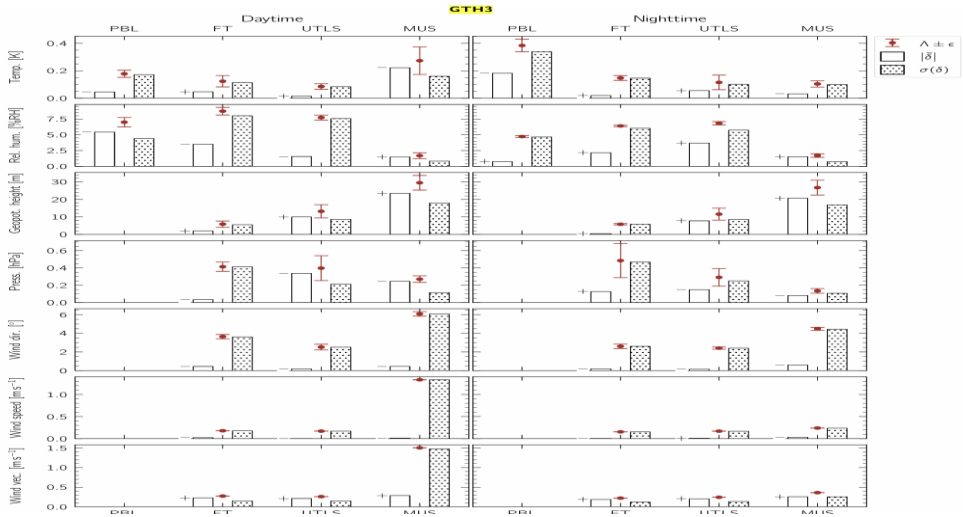
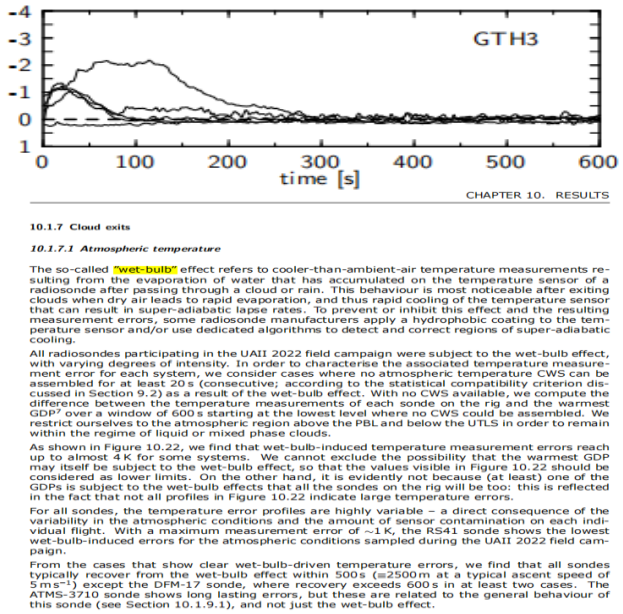


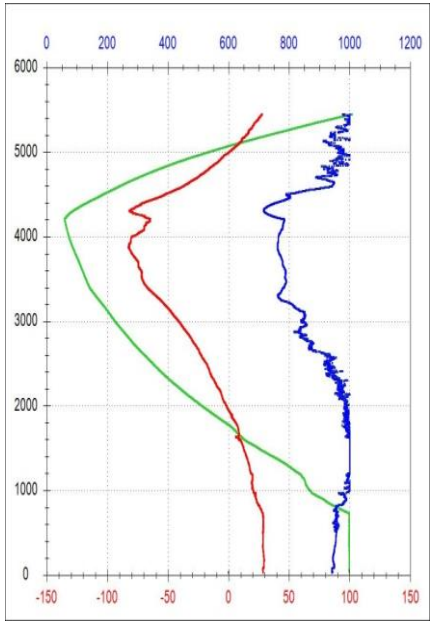
Figure 10.3: Measured values of the ORUC assessment function $\Lambda_{\mathcal{C},\mathcal{L}}$ (red dots, with error bars extending $\pm\epsilon_{\mathcal{C},\mathcal{L}}$) for all geophysical variables and atmospheric layers considered in this analysis, for the ATMS-3710 radiosonde. For each case, columns indicate the values of $|\bar{\delta}|_{\mathcal{C},\mathcal{L}}$ and $\sigma(\delta)_{\mathcal{C},\mathcal{L}}$, of which $\Lambda_{\mathcal{C},\mathcal{L}}$ is being comprised of (see Section 10.1.5.2 for details). The sign of the mean measurement error $\bar{\delta}_{\mathcal{C},\mathcal{L}}$ is indicated explicitly next to the top of the corresponding (white) column.

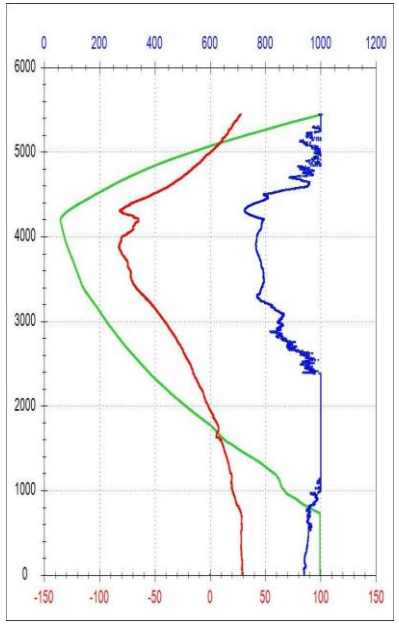
◆*Why develop GTH3 GDP?*

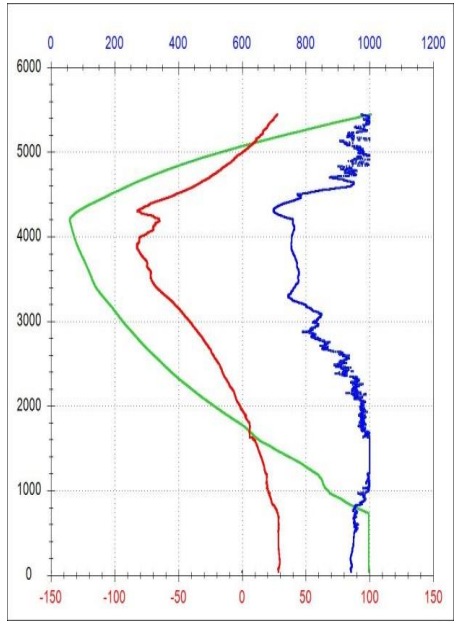
- represented *CMA's operational sounding* to participate in UAII2022
- assessed to be suitable for applications in many aspects (aeronautic meteorology, near/ultra-short term forecasting, NWP, etc)
- confirmed with international standards(*based on OSCAR requirement uncertainty criterion assessment profile*)

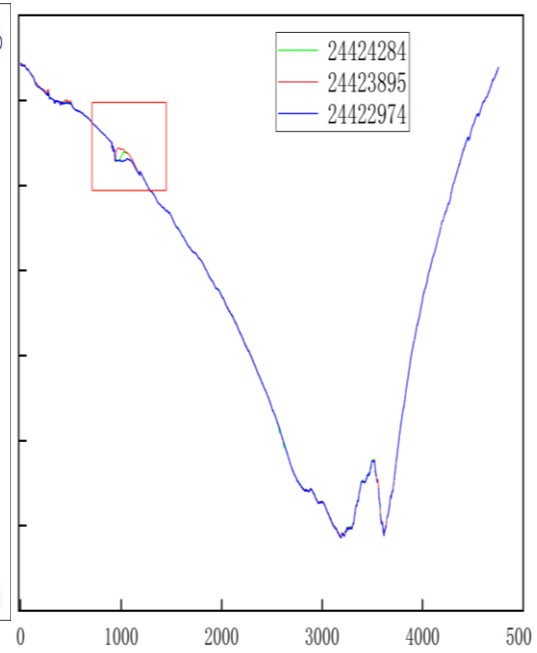
1. Background











"Wet-bulb" effect of Atmosphere temperature in UAII 2022

24423895 and 24424284 (apply hydrophobic coating to the temperature sensor)

24422974(no hydrophobic coating)

the consistency of temperature

◆*Is there some improvement of GTH3 after UAII2022?*

- *hydrophobic coating to temperature sensor* was applied to improve the "*Wet-bulb*" effect
- the launch of *same balloon with three GTH3s was compared*, two hydrophobic and one no-hydrophobic coating
- hydrophobic coating works effectively, and *"Wet-bulb" effect had been significantly improved*

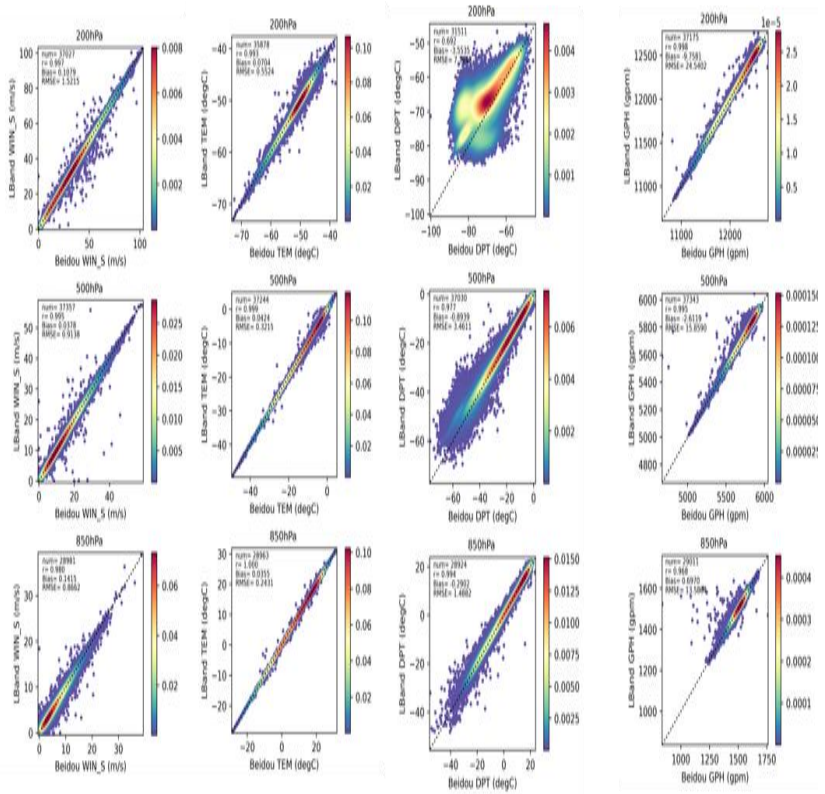
1. Background

L-band radar sounding system

L-band Secondary Radar sounding System
(2002–2025)

Beidou Sounding System

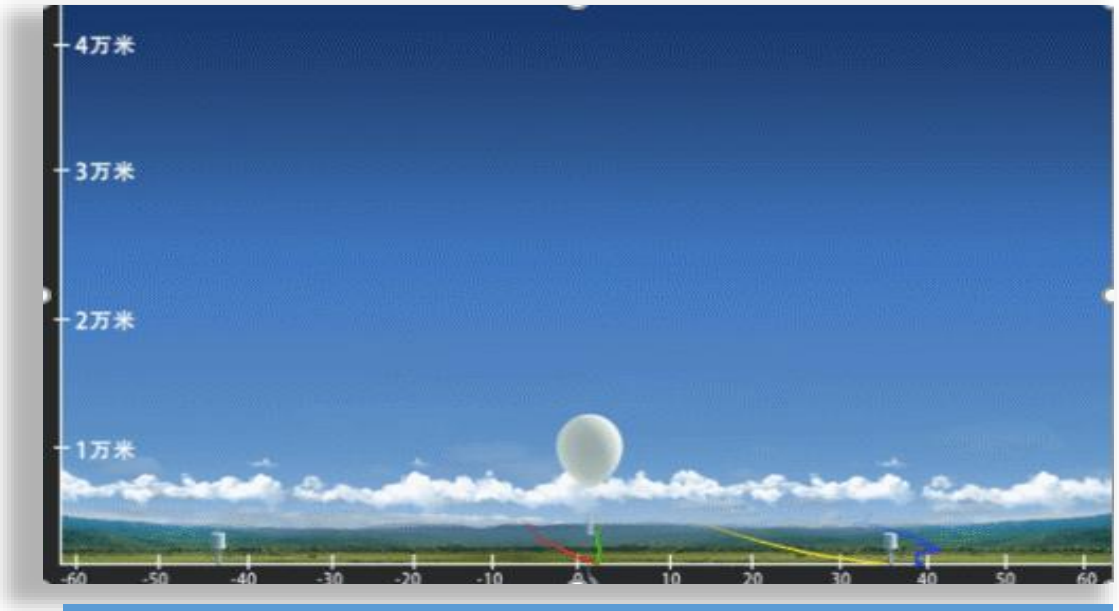
Beidou sounding system(2025-)



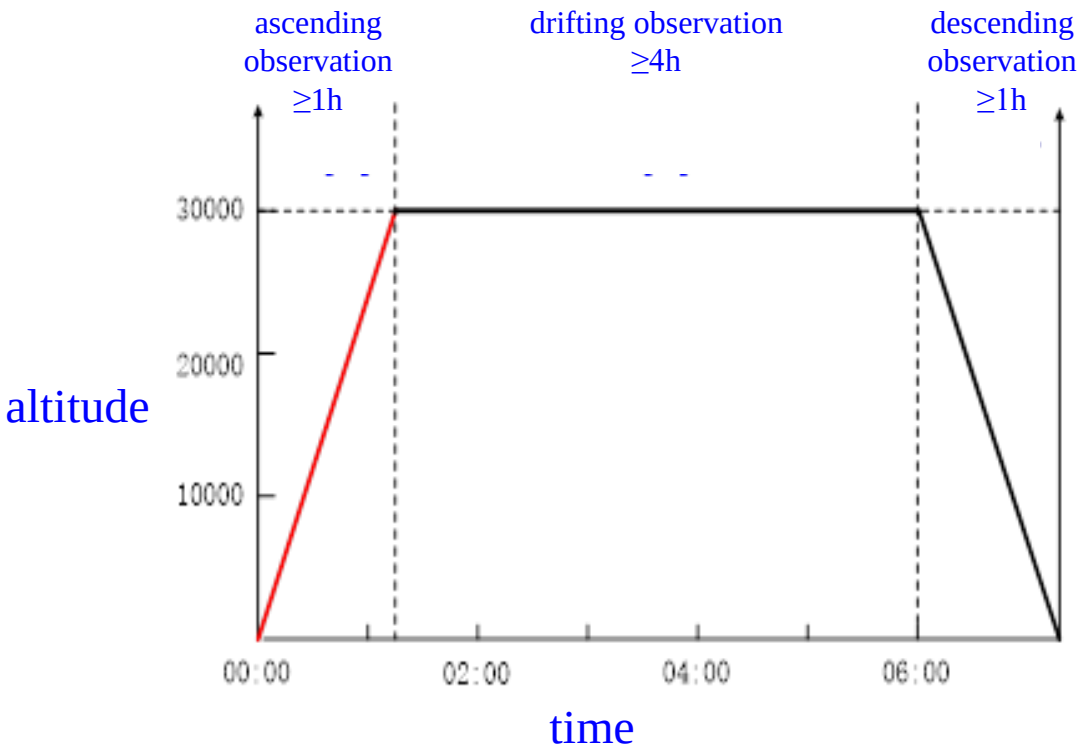
◆ *CMA finished radiosounding operation transition in 2025*

- *one-year parallel comparison* between L-band radar and Beidou (BD) sounding system were carried out
- *BD sounding system transforms into opertion* by the end of September 2025
- six type radonsonde*(GTH1, GTH2, GTH3, GTH4, GTH5, GTH6)* were put into operaton

1. Background



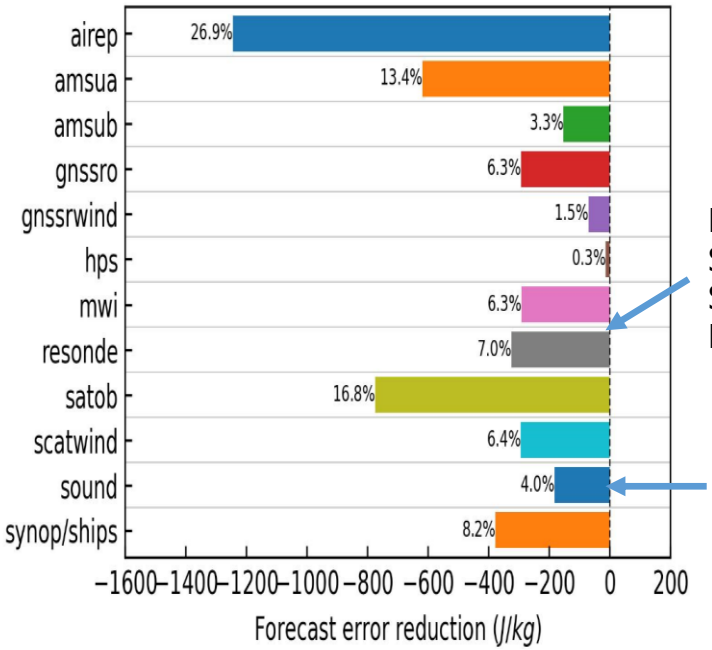
Beidou ascent-drift-descent Sounding system
(*24-28 km Altitude, 24-hour Floating Limit*)



◆ *BD's new technology development*

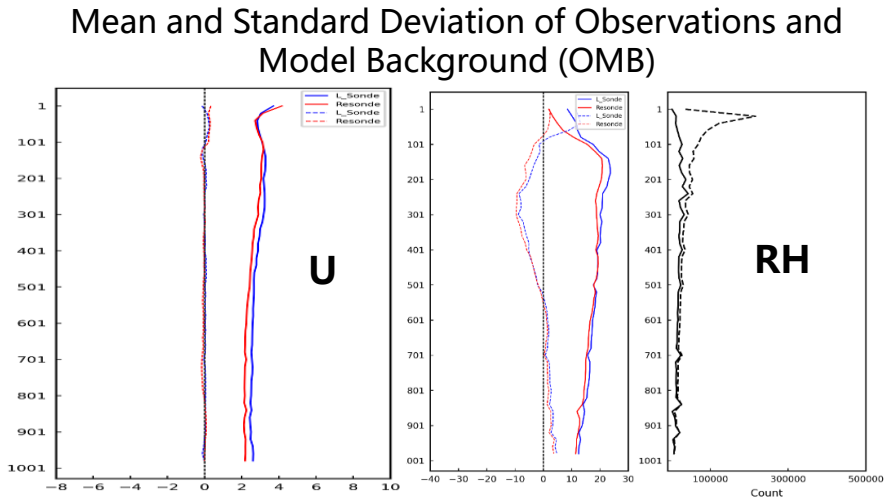
- based on *BD sounding technology* and employing *P-band frequency* for net-work communication
- *three-stage (ascent-drift-descent)* radiosonde system has been developed
- enabling high-temporal-resolution monitoring of severe weather events (*now only 4 site in Guangdong Provice*)

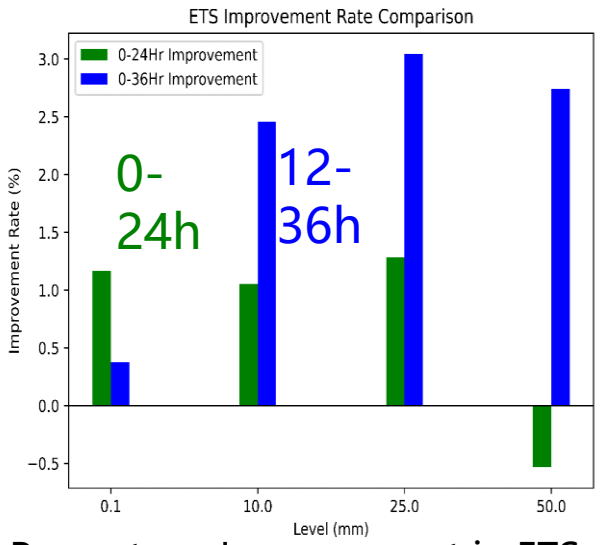
1. Background



Beidou Sounding Second-Level Dat

Other Sounding Systems





Percentage Improvement in ETS

◆ *Assimilation and Impact in CMA GFS and MESO(by Earth System Numerical Prediction Center of CMA)*

- ***GFS*:** O-B standard deviations of wind and humidity were *smaller than* L-band. FSO show assimilating BD second sounding data *reduces 24-hour forecast errors more effectively than conventional assimilation methods*
- ***MESO***:Compared to L-band, 0-24h accumulated precipitation forecast skill were *improved* by approximately *1%*, while the 12-36h accumulated precipitation forecast scores were *increased* by an average of *2%*

Outline

01 Background

02 The implementation progress of ICM-15's GA3

03 The three sets of laboratory equipments developing

II. The implementation progress of ICM-15's GA3

◆ *Overall situation of the task of ICM-15's GA3?*

- *three tasks of the GTH3 GDP* should be developed before ICM16(*GCOS-262*)
- *good correspondence with scheme of GDP* and processing steps (*from LC*) and Outlined in *GRUAN TN-1 & TN-4*

a.Technical document with full description of the data processing
b.Peer-reviewed paper on the data product
c.Measurement System employed within GRUAN
- Characterisation and correction of measurement errors
- Measurement uncertainty

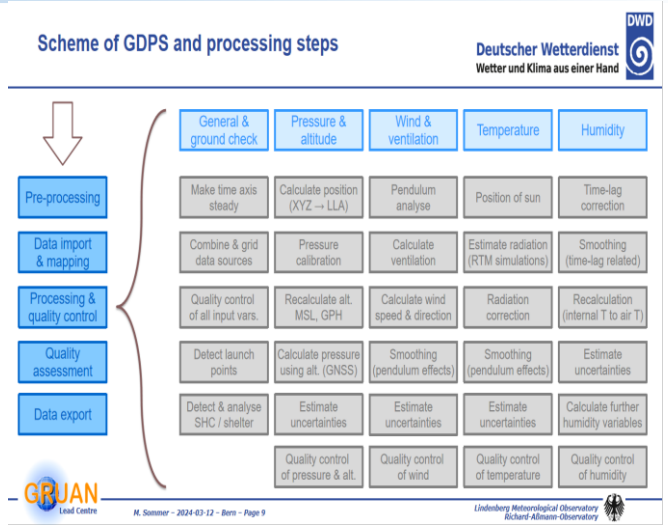
d.Central data-processing facility
e.Existing operational data stream
f.Review (validation) of the data stream(by LC)

1.Drafting TD and peer-reviewed paper

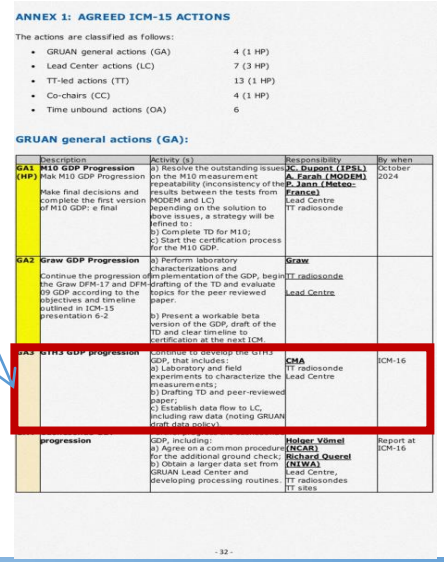
3.Laboratory and field experiments to characterize the measurements

2.Data flow to LC, including raw data (noting GRUAN draft data policy)

Outlined in GRUAN TN-1 & TN-4



Scheme of GDPS and processing steps (from GRUAN-LC)


ANNEX 1: AGREED ICM-15 ACTIONS

The actions are classified as follows:

- GRUAN general actions (GA) 4 (1 HP)
- Lead Center actions (LC) 7 (3 HP)
- TT-led actions (TT) 13 (1 HP)
- Co-chairs (CC) 4 (1 HP)
- Time unbound actions (OA) 6

GRUAN general actions (GA):

	Description	Activity (s)	Responsibility	By when
GA1 (HP)	M10 GDP Progression Mak M10 GDP Progression Make final decisions and complete the first version of M10 GDP: e final	a) Resolve the outstanding issues on the M10 measurement repeatability (inconsistency of the results between the tests from MODEM and LC) depending on the solution to above issues, a strategy will be defined to : b) Complete TD for M10; c) Start the certification process for the M10 GDP.	JC. Dupont (LPSL) A. Farah (MODEM) P. Jann (Meteo-France) Lead Centre TT radiosonde	October 2024
GA2	Graw GDP Progression Continue the progression of the Graw DFM-17 and DFM-09 GDP according to the objectives and timeline outlined in ICM-15 presentation 6-2	a) Perform laboratory characterizations and implementation of the GDP, begin drafting of the TD and evaluate topics for the peer reviewed paper. b) Present a workable beta version of the GDP, draft of the TD and clear timeline to certification at the next ICM	Graw TT radiosonde Lead Centre	
GA3	GTH3 GDP progression	Continue to develop the GTH3 GDP, that includes: a) Laboratory and field experiments to characterize the measurements; b) Drafting TD and peer-reviewed paper; c) Establish data flow to LC, including raw data (noting GRUAN draft data policy)	CMA TT radiosonde Lead Centre	ICM-16
	progression	GDP, including: a) Agree on a common procedure for the additional ground check; b) Obtain a larger data set from GRUAN Lead Center and developing processing routines.	Holger Vömel (NCAR) Richard Querel (NLWA) Lead Centre, TT radiosondes TT sites	Report at ICM-16

- 32 -

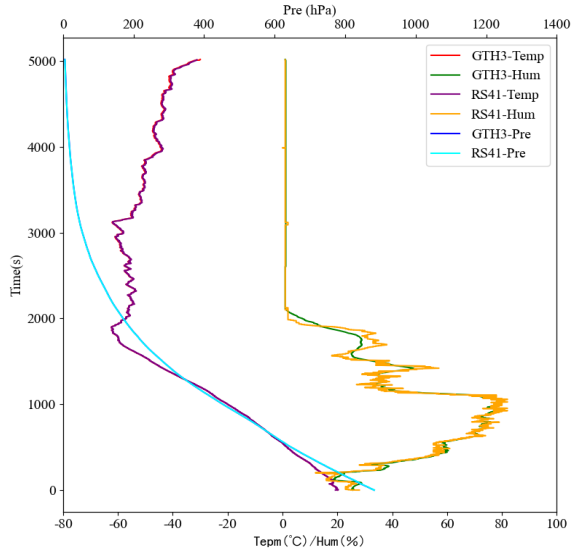
System	Data processor	Centralized processor facililty	GRUAN documentation (TD)	Peer reviewed paper	GRUAN certification	Topics covered by paper
GTH3	in progress	in progress	in progress	in progress		GTH3&RS41 twins sounding

II. The implementation progress of ICM-15's GA3

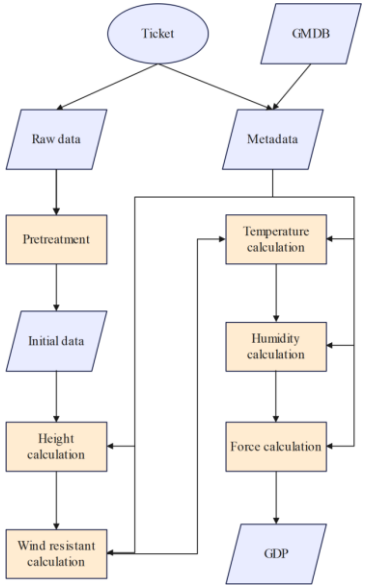
2.1 Drafting *TD* and peer-reviewed paper

- *preliminary version* of technical document (according to TN-2, TD-5 and TD-8,) to be completed soon
- *chapter 1*-introduction, *chapter 2*-instrument and *chapter 3*-reference measurement of TD have been completed
- *other chapters to be completed* in 2026
- peer-reviewed manuscript submitted in 2025

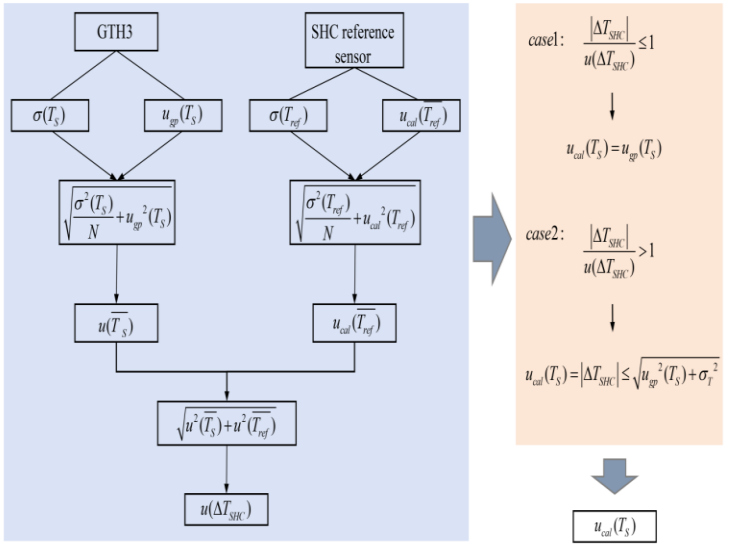
GTH3 radiosonde



GTH3 and RS41 temperature, humidity and pressure data matching results



Data processing process of GTH3 type sounding instrument GRUAN

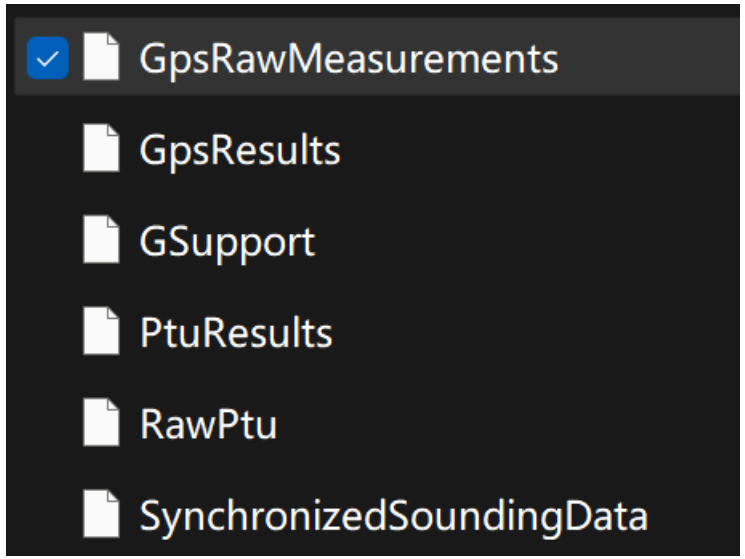


Calculation logic of temperature uncertainty

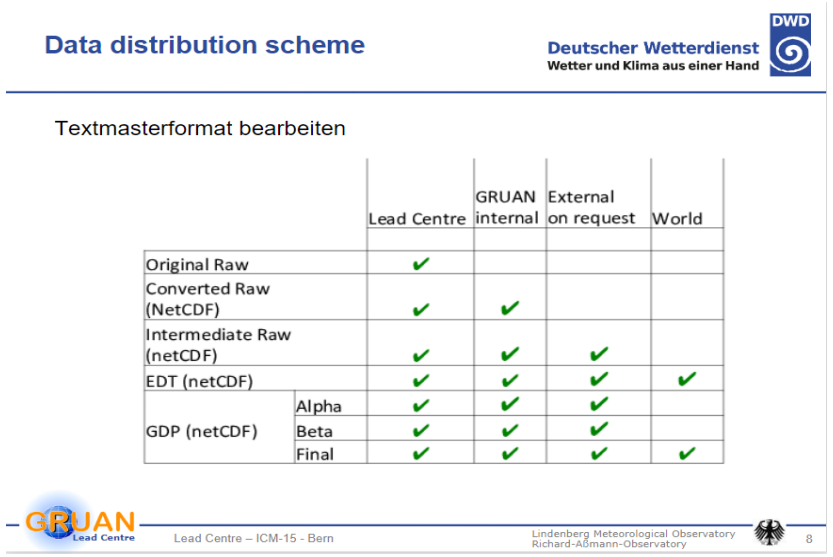
II. The implementation progress of ICM-15's GA3

2.2 Establishing *data flow* to LC

- T,U and P of database and meta data are *establishing in data processing center*
- confirm with LC about the key's raw data of GTH3 and sample of XIL
- disscuss condition of use *RsLaunchClient* to upload GTH3 data
- GTH3's central data-processing facility *switch to any format raw data* (now referred to *RS41*)



GTH3 raw data(.mwx)



		Lead Centre	GRUAN internal	External on request	World
Original Raw		✔			
Converted Raw (NetCDF)		✔	✔		
Intermediate Raw (netCDF)		✔	✔	✔	
EDT (netCDF)		✔	✔	✔	✔
GDP (netCDF)	Alpha	✔	✔	✔	
	Beta	✔	✔	✔	
	Final	✔	✔	✔	✔

GRUAN draft data policy

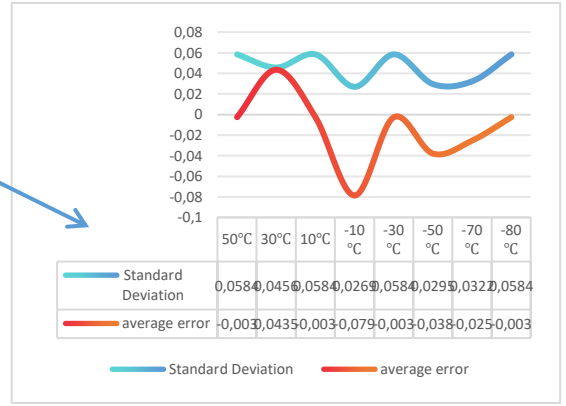
II.The implementation progress of ICM-15's GA3

2.3 *Laboratory and field experiments* to characterize the measurements

a. Review the existing correction of T, U and P of GTH3

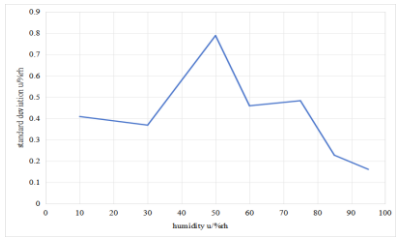
- ***T:*** calibrate *eight temperature points from -80℃ to +50℃*, checking accuracy of *calibration curve*
- ***U:*** carry out orderly from low to high, checking its deviation at each calibration point control
- ***P:*** refine temperature deviation elimination method of the *pressure* sensor(static error of pressure reducing from 1hPa to 0.3hPa)

calibration chamber

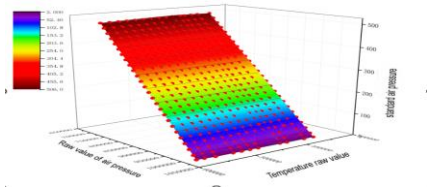


Thermistor calibration(Until October 2024, 1067 in total, including the 8 batches and 640 sets in 2023; from 5 batches and 427 sets in 2024.)

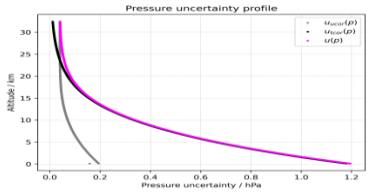
GRZ5100 humidity verification device



Manufactured calibration uncertainty of the humidity sensor (k = 1)



Multi-temperature and pressure point fitting correction to eliminate error caused by temperature



pressure correction algorithm for GTH3

II. The implementation progress of ICM-15's GA3

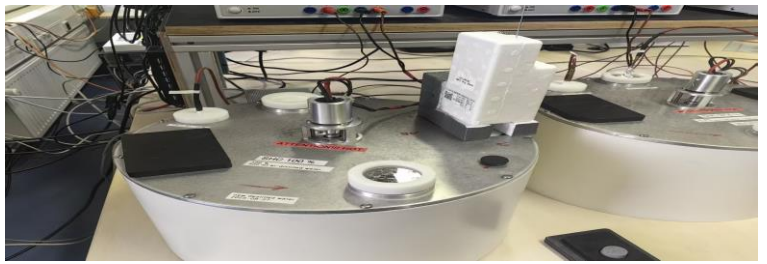
2.3 Laboratory and field experiments to characterize the measurements

b.Measurement uncertainty of GTH3 in *LC*

- technicians went to LC for *field experiments* of GTH3 and RS41(October 13-17, 2025)
- carried out ground check(100% SHC) test, and *characterized the measurements* of GTH3 radiosonde
- technical exchanges to be carried out on *laboratory verification*, including data flow from XIL to LC
- uncertainty validation to be performed through repeated technical experiments in LC until June 2026

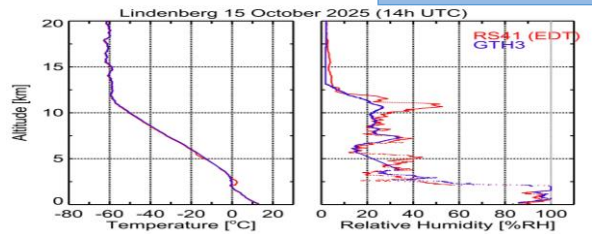
eight sets of GTH3 radiosonde system (excluding radiosondes, balloons and other consumables)

The GTH3 radiosonde system receiver equipment is ready



Ground check-100%SHC

field experiments of GTH3 and RS41 dual-sounding



T and U comparison profile of GTH3 radiosonde and RS41 radiosonde

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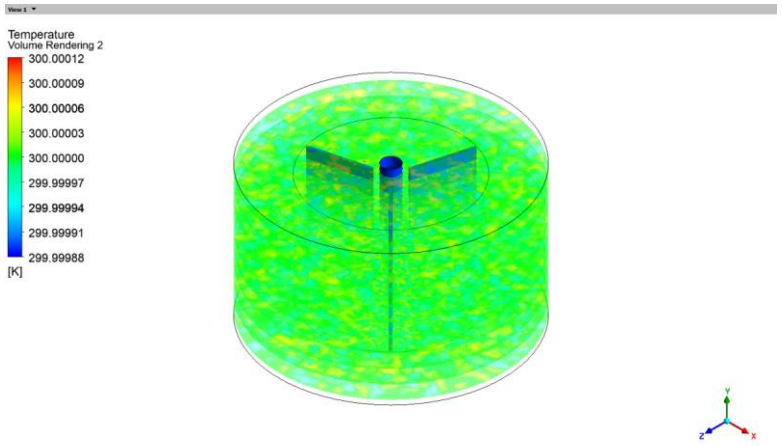
III. The three sets of laboratory equipments developing

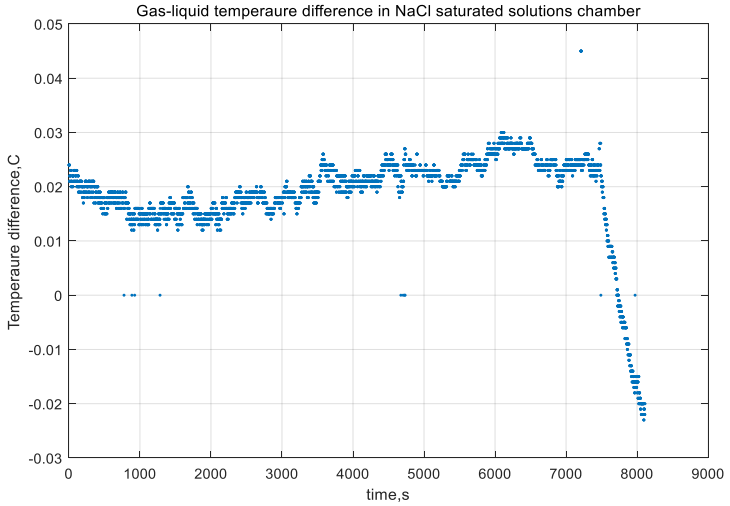
3.1 Standard Humidity Chamber(SHC)

- ***principle***:referenced to LC, stable humidity environment of *0%,11%,33%,75%,97%,100%* generated in *six chambers*, respectively by desiccant, saturated salt solutions of four type(LiCl, $MgCl_2$,NaCl,K_2SO_4) and water
- ***ventilation effect***: air circulates at 6m/s in the chamber, *mimicking the ventilation during ascent*
- ***prototype***: engineering *prototype* has recently been developed, *and to be deployed in 2026*



Simulated temperature distribution contour map in SHC
And the measured temperature uniformity is less than 0.1℃

6m/s ventilation measured



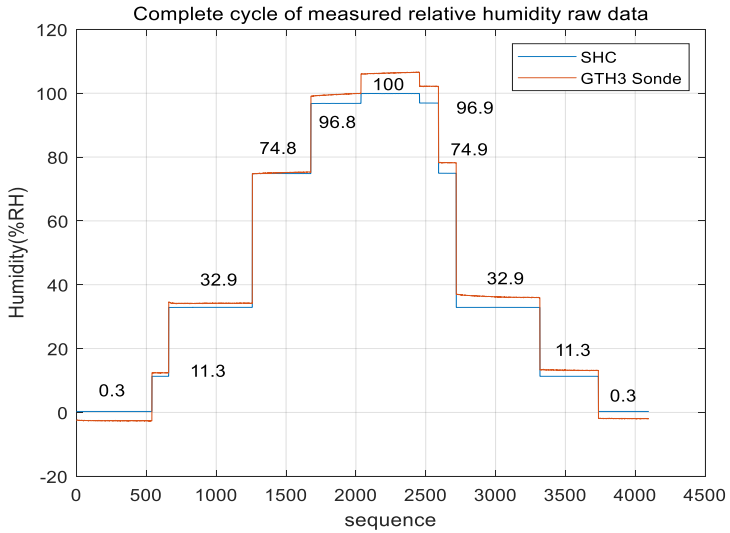
Gas-liquid temperature difference in NaCl solution chamber in near 3 hours

III. The three sets of laboratory equipments developing

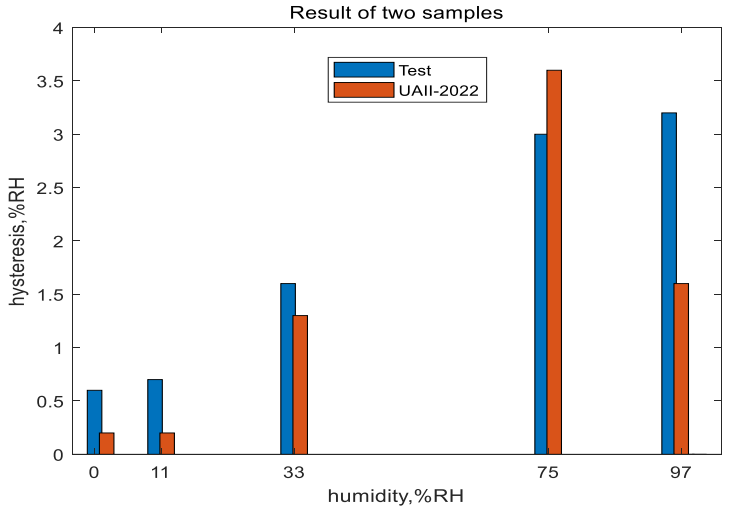
3.1 Standard Humidity Chamber(SHC)

- ***Progress***:*tests* related to *uniformity* of temperature, humidity, ventilation, and humidity accuracy *conducted humidity sensor of GTH3* radiosonde of *preliminary tests*(hysteresis results) were conducted
- ***Effect***: test results shows *SHC performance* has basically *achieved the design goal*
- ***Follow-up***: uncertainty analysis of temperature and humidity measurement to be involved in next steps

GTH3 radiosonde tested in SHCs



Complete cycle measurement of GTH3 radiosonde humidity

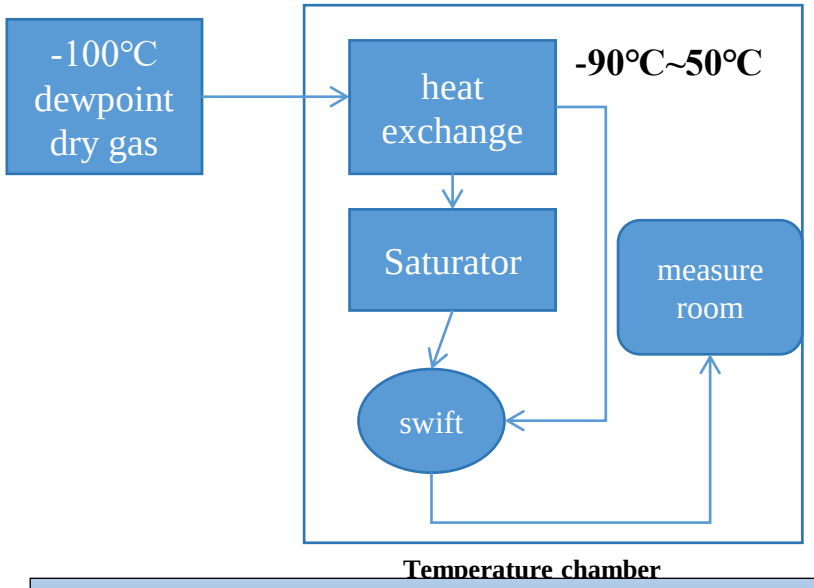


Hysteresis results was close to LC's test UAII 2022 of GTH3 radiosonde

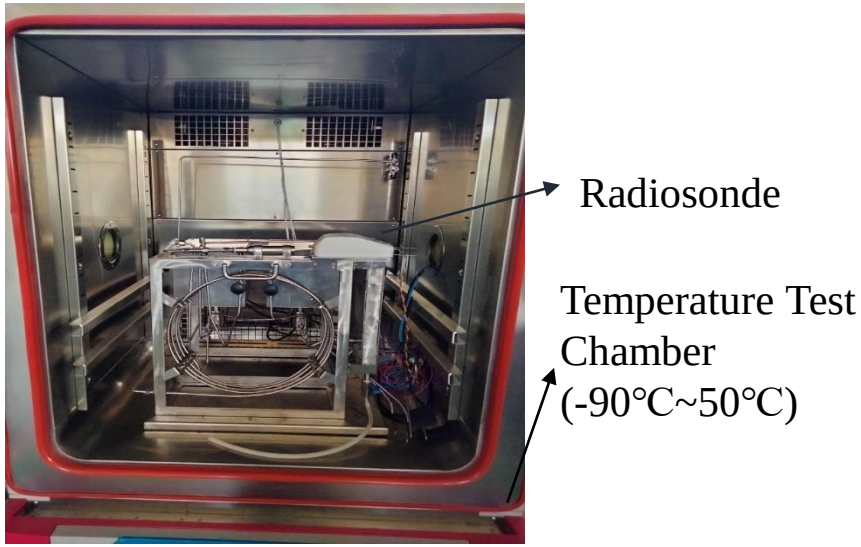
III. The three sets of laboratory equipments developing

3.2 Response time measurement of humidity sensor (URTM)

- ***prototype :***thanks to technical guidance and support from *LC and experts*, engineering prototype developed
- ***principle:***dry gas divided into *two paths* after being introduced into temperature chamber, and one path is directed to humidity saturator to generate wet gas. The dry or wet gas path is quickly controlled by a switch to flow into the testing chamber for creating a humidity step change, and the response time of sensor measured



Principle block diagram of humidity sensor response time measurement

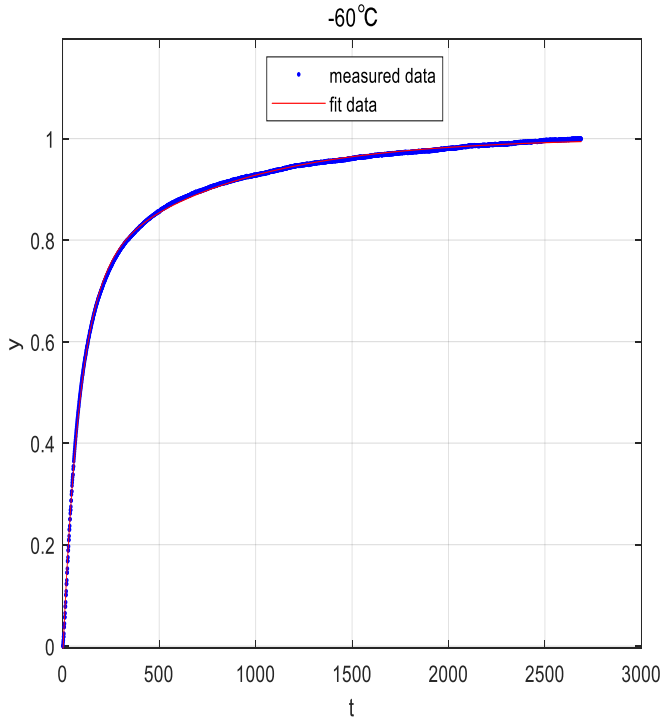


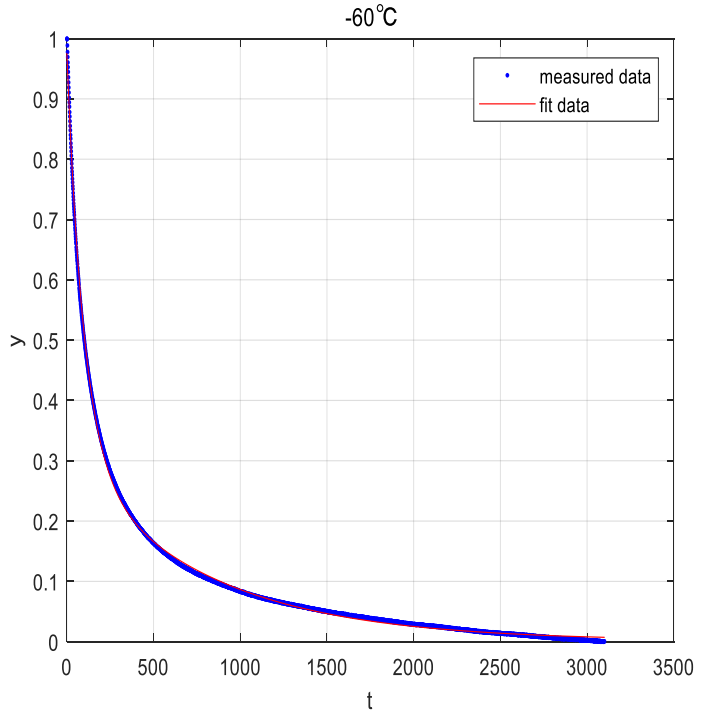
The physical picture of the engineering prototype

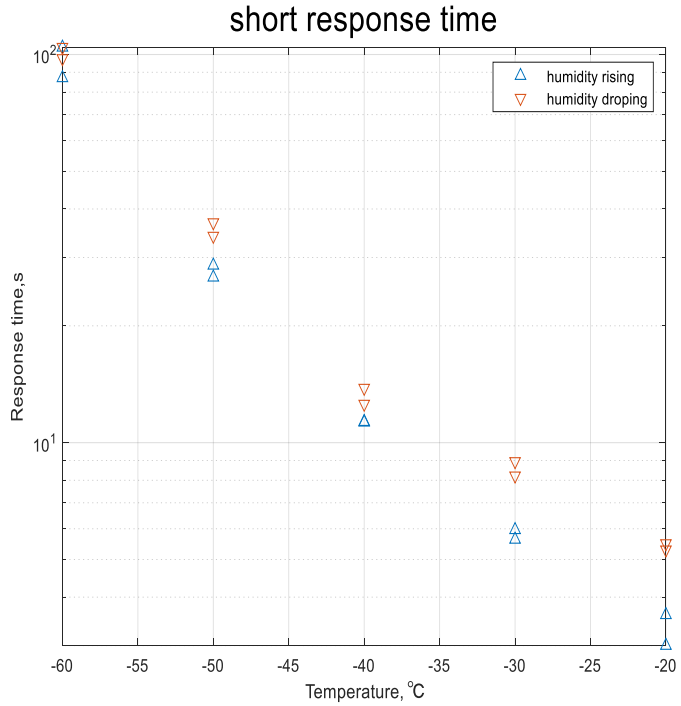
III. The three sets of laboratory equipments developing

3.2 Response time measurement of humidity sensor(URTM)

- ***Progress:***preliminary tests of humidity sensor of *GTH3 without cap* (at *-20℃, -30℃, -40℃, -50℃, and -60℃*) conducted *double decay model* used to fit testing data:**$U(t)=U(\infty)-(U(\infty)-U(0))(p*\exp(-t/\tau_1)+(1-p)*\exp(-t/\tau_2))$**
- ***Follow-up***: select short response time τ_1 as humidity sensor response time, *and the result close to UAII2022*







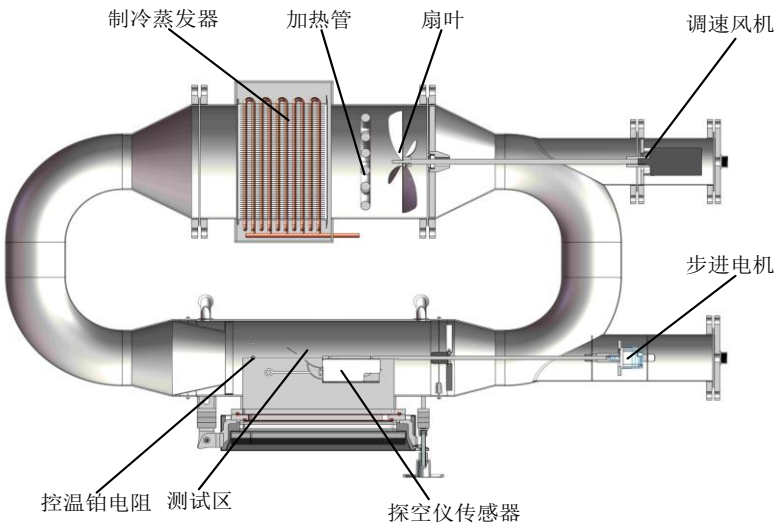
the humidity data were scaled to 0~1 to fit example of -60℃ test results, and the left humidity was from low to high， while the right was inverse

Process result of τ_1 at different temperature

III. The three sets of laboratory equipments developing

3.3 The low temperature-low pressure and solar radiation combined simulation equipment

- ***Principle***:*re*ferenced to LC, a similar equipment developed to *reproduce complex meteorological conditions* providing a *realistic and controllable environment* for studying the impact of solar radiation on temperature measurements at high altitudes, thereby enhancing the precision of solar radiation corrections
- ***Follow-up***: engineering *prototype* of the equioment developed, and currently undergoes debugging and performance verification, and to *be deployed in 2026*



The equipment components

Subsystem	Technical indicators
Temperature control system	Measurement range: -70℃ to 20 ℃ Resolution: 0.01 ℃ Maximum allowable error: ±0.1 ℃ Annual drift of the temperature control system: ≤0.1℃; Test area stability: ≤0.1℃/min; Uniformity of the test area: ≤0.1 ℃.
Wind tunnel control system	Simulate wind speed under different environmental conditions Wind speed range: 0-7m/s;
Air pressure control system	Measurement range: 3 hPa to 1100 hPa; Resolution: 0.1 hPa Maximum allowable error: ±0.3 hPa; Annual drift of the air pressure control system: ≤0.3hPa.
Radiation system	Spectral range: 350-1100nm, AM1.5G solar spectrum; Irradiation intensity: 1000W/m ^{2} Radiation area: 2X2in(50X50)

Summary：

GTH3 GDP's certification has been promoted in accordance with the requirements

GTH3 data flow will be established under the technical guidance of LC

Next step:

to deliever disscussed format data from XIL to LC

to compare test and comparion of GTH3 in LC to meet the GDP certification requirements

to be in trail operation of the three sets of laboratory equipments

to complete TD with verification by the three sets of uncertainty equipment

That's all.

Thanks again!