The achievements, benefits and recognition of GRUAN

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Outline

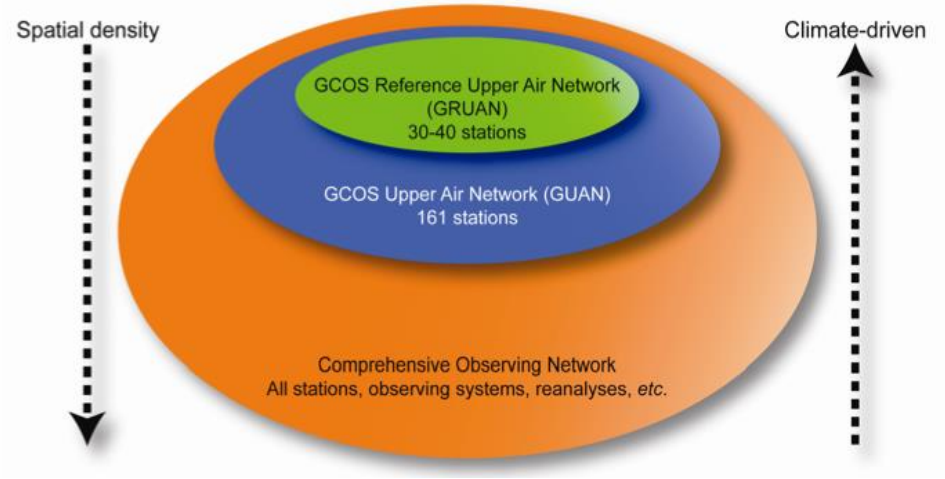
Ⅰ Important achievements of GRUAN

Ⅱ Benefit of GRUAN (For example: CMA)

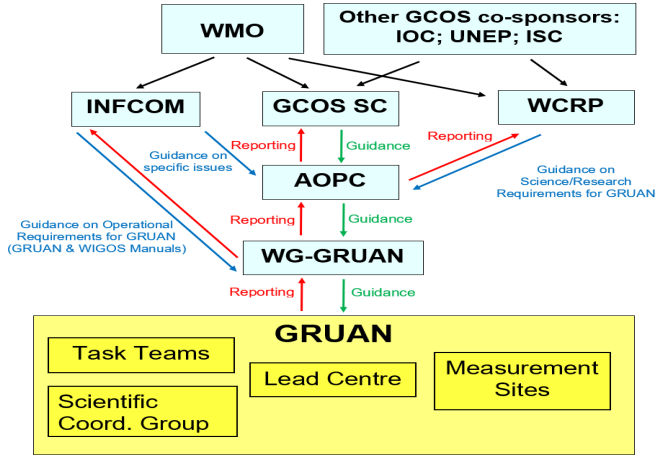
Ⅲ Recognition of GRUAN (future thought?)

I. Important achievements of GRUAN

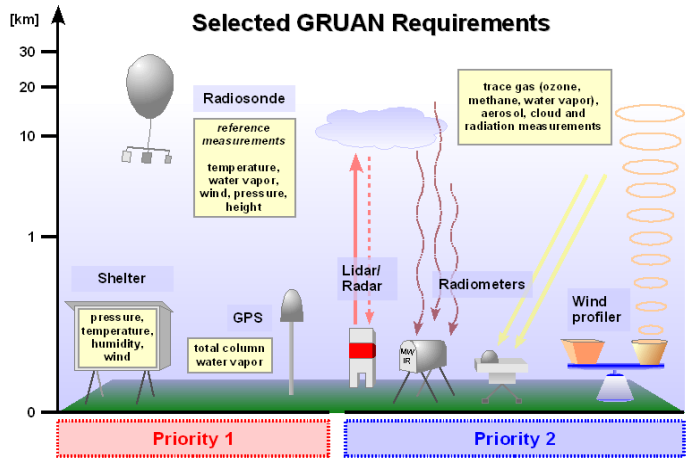
◆ Why GRUAN is so important?



Global Upper-Air Station : Reference, Climate, Meteorological



Schematic outline of the structure of GRUAN

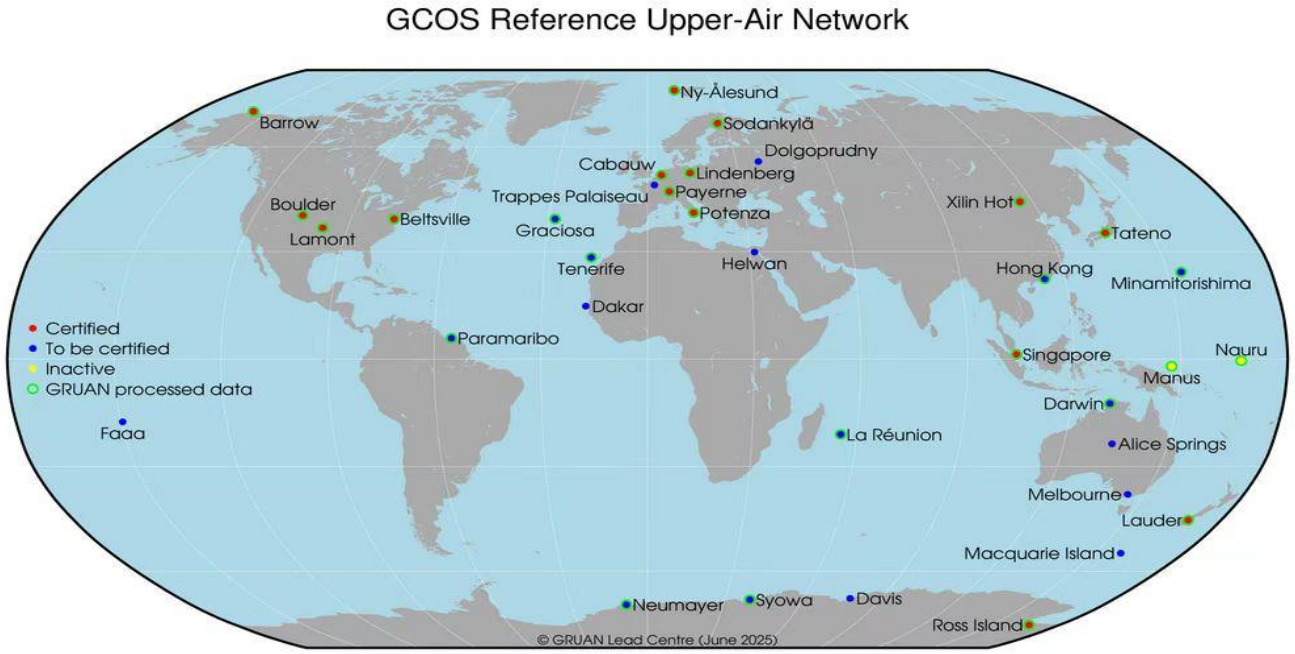


GRUAN Requirements

- ***Network:*** a GCOS Refrrence Upper-Air Network (GRUAN, *30-40 sites*)
- ***Variables:*** ***l****ong-term* observation of Fundamental Climate Variables (*FCVs*) of the vertical atmospheric
- ***Data:*** "*high accuracy, stability, reliability, and continuity*", *validating* of global meteorological *satellite observations*, and imposeing quality constraints on data from the global observing system

I. Important achievements of GRUAN

◆ How many certification of GRUAN sites approved?



GRUAN network

GRUAN site Certificated(16)

No	Site	certified	Country
1	Barrow	2022	United States
2	Beltsville	2016	United States
3	Boulder	2014	United States
4	Lamont	2019	United States
5	Ny-Ålesund	2013	Norway
6	Sodankylä	2015	Finland
7	Cabauw	2016	Finland
8	Lindenberg	2014	Germany
9	Payerne	2015	Switzerland
10	Potenza	2015	Italy
11	Tateno	2018	Japan
12	Singapore	2019	Singapore
13	Lauder	2015	New Zealand
14	Rossisland	2021	Antarctica
15	Tenerife	2025	Spain
16	Xilinhot	2025	China

- ***Number***(*maybe unaccurate*) **:**By November 2025, there are sixteen GRUAN sites certified in the world
- ***By what:****most of* GRUAN sites certified by RS41, RS92, iMS-100 etc

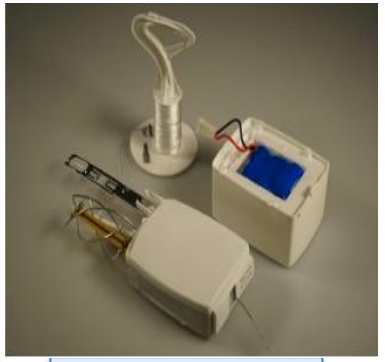
I. Important achievements of GRUAN

◆ How many certification of GRUAN Data Products (GDPs) approved?

GRUAN Data Product Certification

No	Type	GDP	GRUAN Data Processing Centre	certified	Coverage Sites
1	sounding	Finland RS92	Lindenberg Meteorological Observatory	2012	15
2		Finland RS41		2023	22
3		Japan RS-11G	Japan Meteorological Agency	2019	4
4		Japan iMS-100		2022	5
5		Germany DMF-09	Lindenberg Meteorological Observatory	Scheduled for 2026	2
6		Germany DMF-17		Scheduled for 2026	2
7		France M10	Institut Laplaces Environnement (France)	Scheduled for 2025?	2
8		France M20		Scheduled for 2025?	2
9		China GTH3	CMA MOC	Scheduled for 2027	40
10	ground-based	GNSS/PWV	Helmholtz Centre Potsdam (Germany)	2016	17
11		Lidar	NASA Jet Propulsion Center	In the process	/

RS41探空仪



RS92探空仪

iMS-100探空仪

DMF-17探空仪

M10探空仪

GTH3探空仪

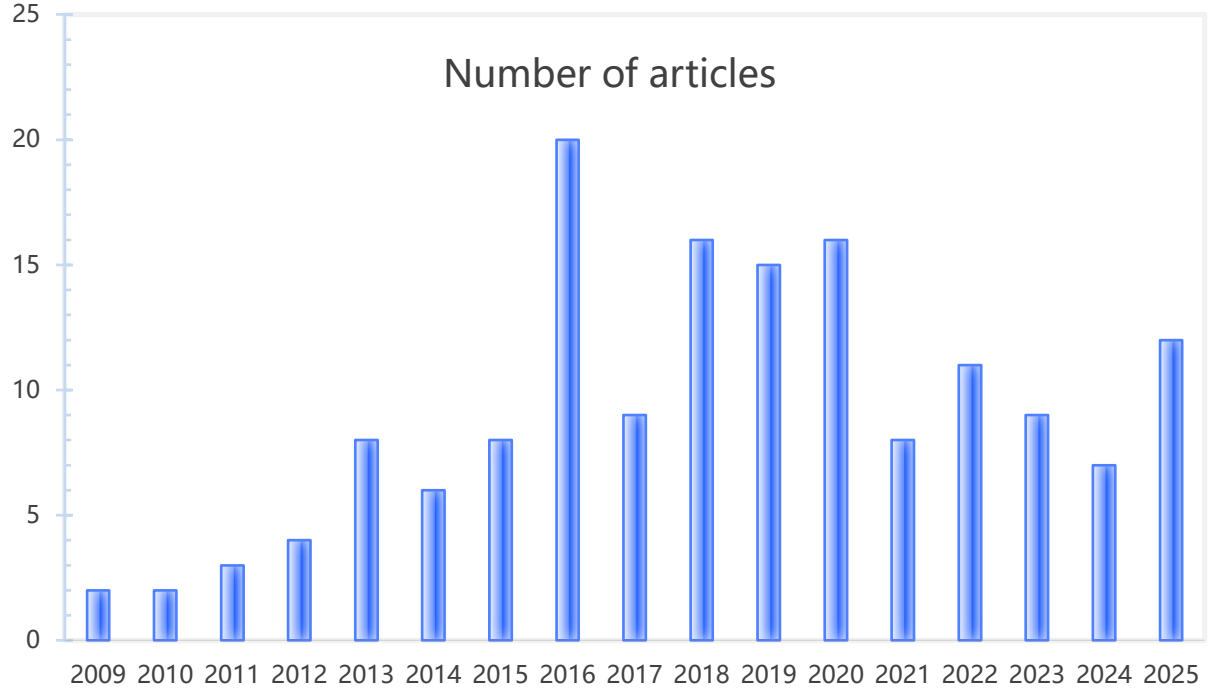
- ***Sounding***(*maybe unaccurate*)***:***GDP certification of radiosondes *approved four, and approving five*

  M10, M20,DMF-17,DMF-09,GTH3 approving; ozonesonde/CHF/FPH is ongoing...

- ***remote sunsing***(*maybe unaccurate*)***:***GDP certification of ground-based remote sensing *approved is GNSS/PWV, and approving is Lidar; MWR/FITR* is ongoing ...

I. Important achievements of GRUAN

◆ Promoting development through academic achievements



Category	Number
Satellite validation & calibration development	31
Field and intercomparison campaigns	29
GRUAN product development	21
Operational developments	17
Validation for ground-based instruments	17
Assessment of the measurement record	14
Modelling; model evaluation and calibration	12
Network design	9
Others (mainly science)	6
Total	156

- ten articles every year on average from 2009 to 2025
- the category with the largest proportion: *satellite validation & algorithm development, with 31 items*
- the most research papers in the past four years: *satellite validation and algorithms development*

Outline

Ⅰ Important achievements of GRUAN

Ⅱ Benefit of GRUAN (For example: CMA)

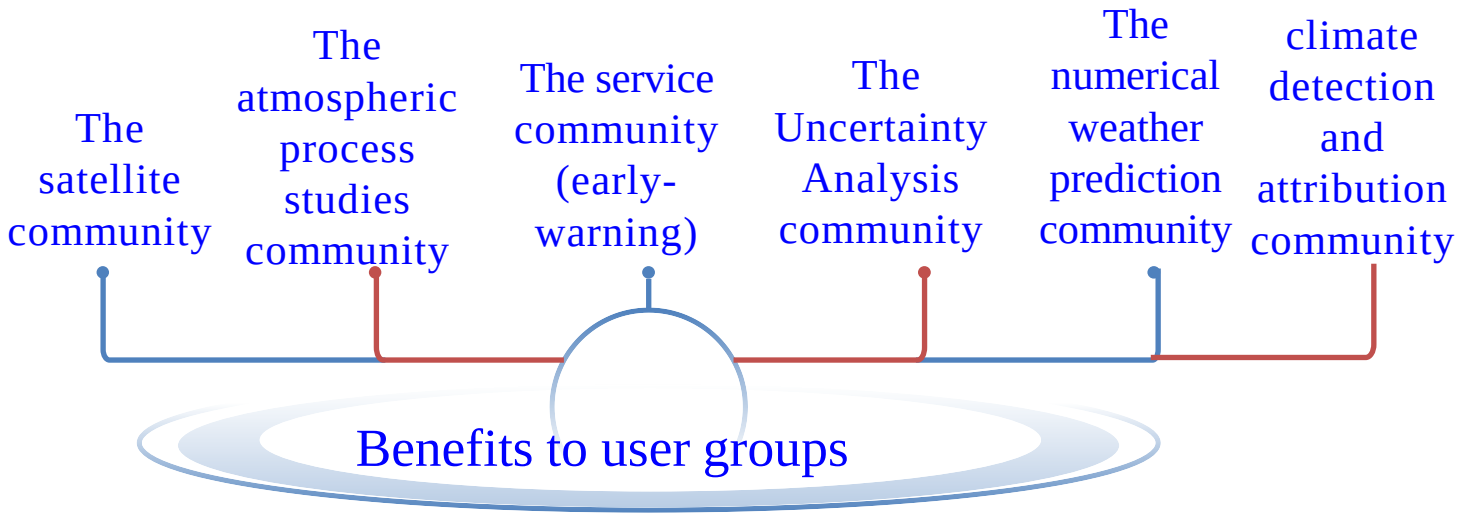
Ⅲ Recognition of GRUAN(future thought?)

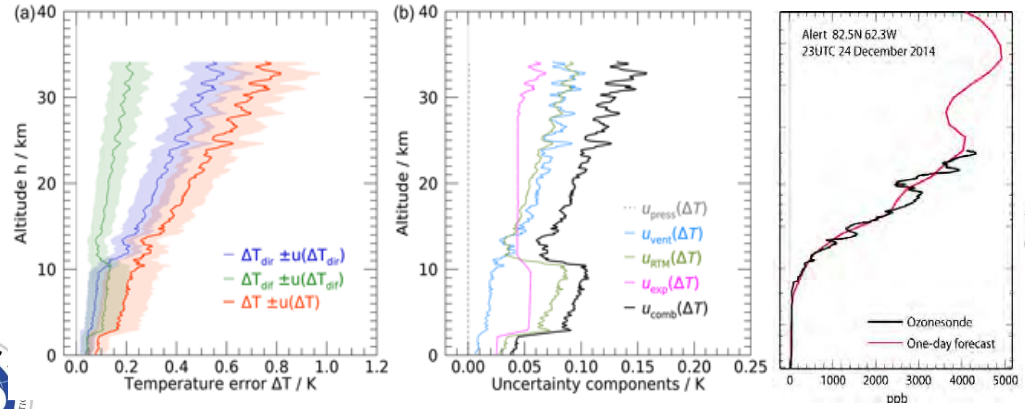
II. Benefit of GRUAN(For example: *CMA*)

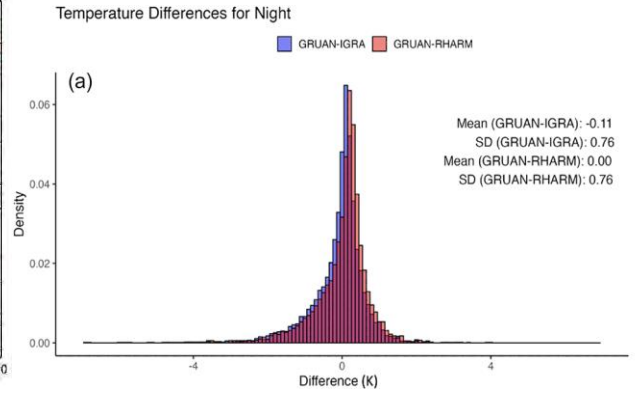
◆ *Benefits to other OBS systems and user groups*

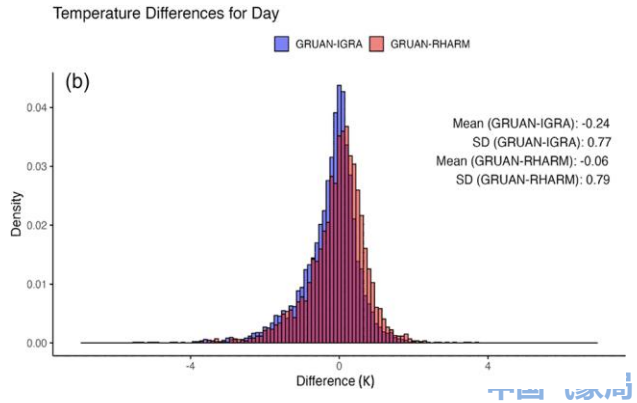
Benefits to other OBS systems

1. Important roles in Satellite Cal & Val
2. Validation for ground-based instruments
3. Profile /Precipitation / Radar /.../ fusion
4. Pioneer in defining and making reference observations
5. Improving operational radiosondes



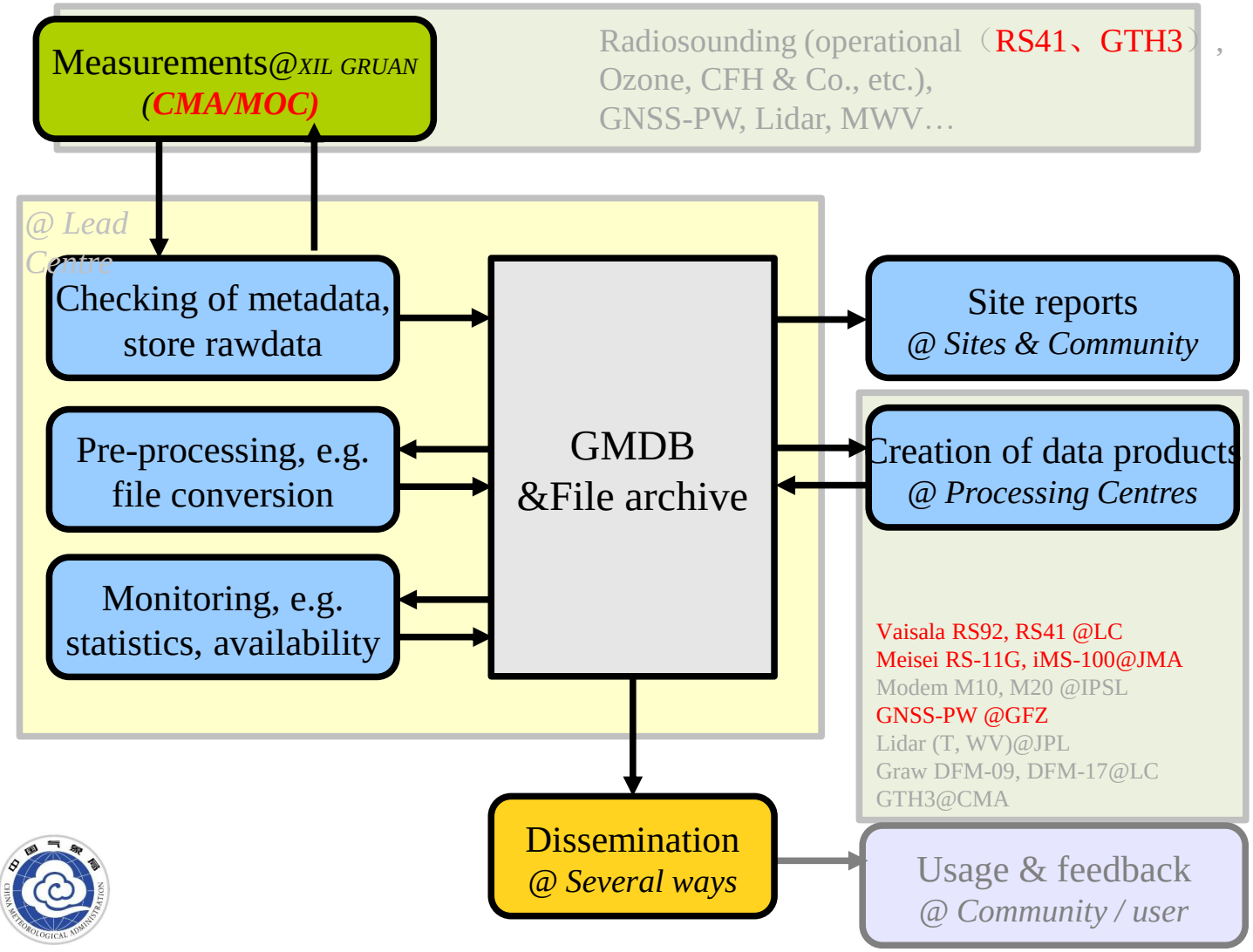




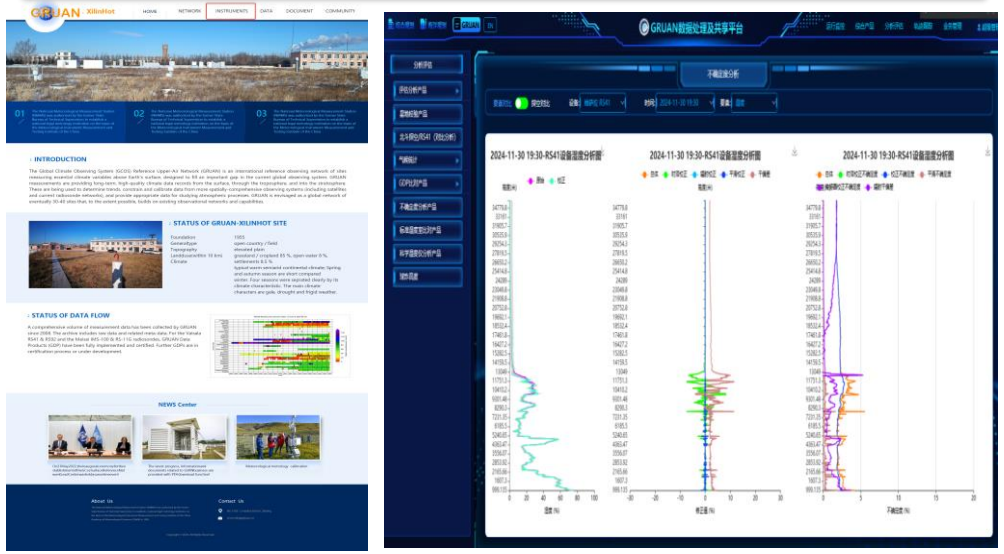


II.Benefit of GRUAN(For example: *CMA*)

◆ *Data processing capacity* of XIL GRUAN



GRUAN Data Center of CMA



- provide *GDP* to CMA's operational and scientific users referred to LC
- promote coordinated development Air-Space-Ground observation in CMA
- promote the value of GRUAN in CMA

II.The benefit of GRUAN(For example: *CMA*)

◆ *Sounding metrology capacity* of XIL GRUAN

Manufacturer

radiosonde Uncertainty Verification Laboratory

Per Batch

radiosonde

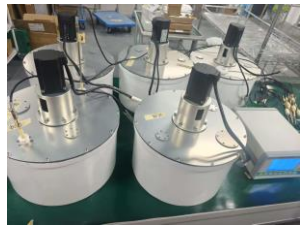
Per year

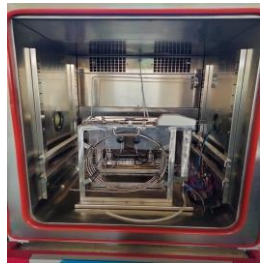
Each radiosonde

Factory sampling inspection of radiosondes.（T/U/P/W）

Laboratory intercomparison of domestic radiosondes（T/U/P/W）

Uncertainty assessment of radiosondes（T/U/P）





Implementation

Upper-Air Observation stations carry out observations（131 stations in China）

Evaluation

XIL Station Field ComparisonL station（T/U/P/W）

XIL upper-air observation（T/U/P/W）

➢To perform data validation.
➢To establish methods for data processing and uncertainty analysis of vertical profiles of atmospheric temperature, humidity, and pressure from the GTH sonde.

To achieve precise, stable, reliable, and continuous observations of Essential Climate Variables (ECVs) within the atmospheric vertical column

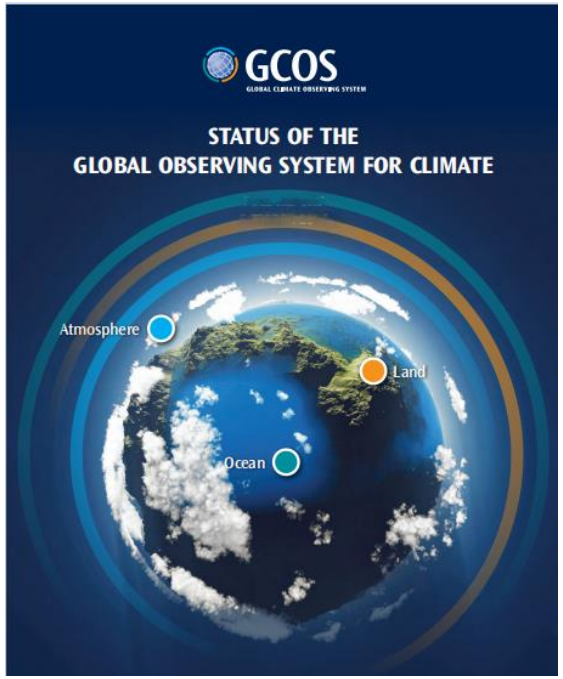
➢the three sets of laboratory equipments in *trial operation in 2026*

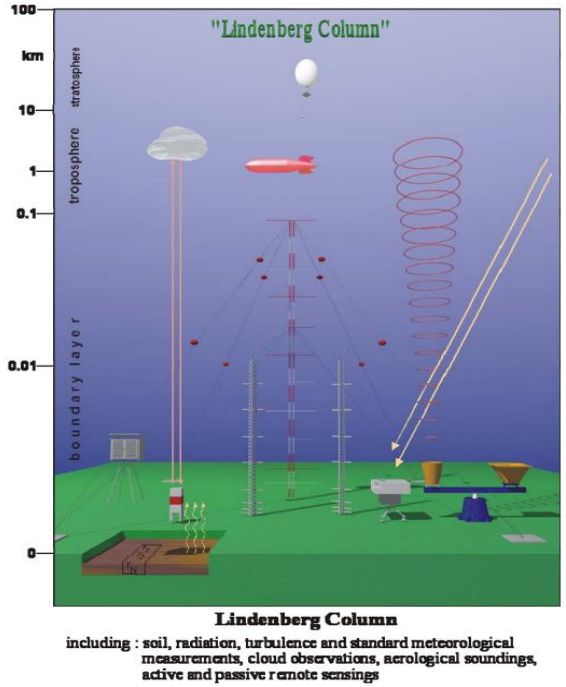
➢provide sounding *metrology service* to *six types of radiosondes* of CMA at 131 sites

➢impose quality constraints on data from the global observing system for data exchange by GTS

II.Benefit of GRUAN(For example: *CMA*)

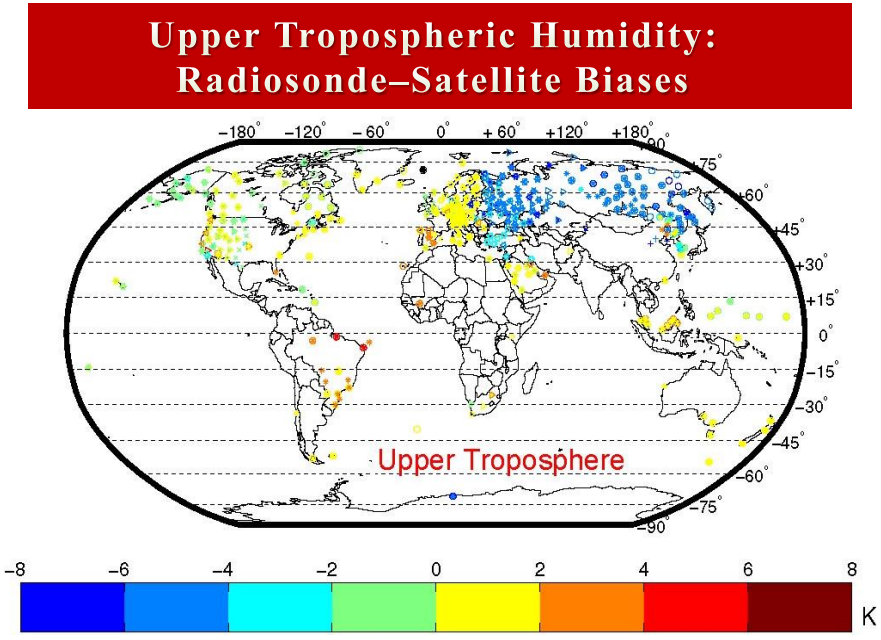
◆ *Climate monitoring service* of XIL GRUAN





Lindenberg Column

including : soil, radiation, turbulence and standard meteorological measurements, cloud observations, aerological soundings, active and passive remote sensings



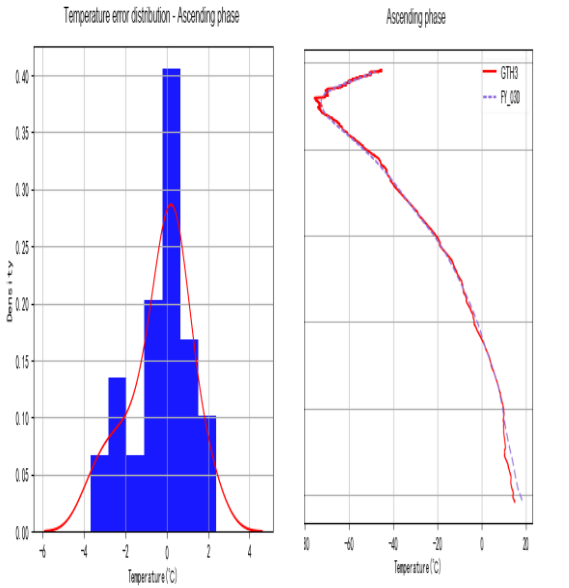
Moradi et al. JGR

- obtain *long-term, high-accuracy vertical atmospheric data*, serving both the ecologically fragile grassland areas of China and the critical pathways of cold air outbreaks

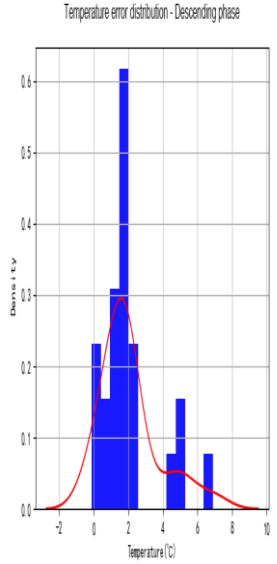
- serve as a regional *benchmark* for upper-air and provid a *reliable reference* for global observation

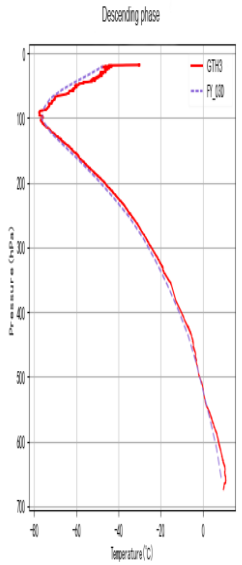
II.The benefit of GRUAN(For example: *CMA*)

◆ *Evaluation capacity* of meteorological Satellite by XIL GRUAN

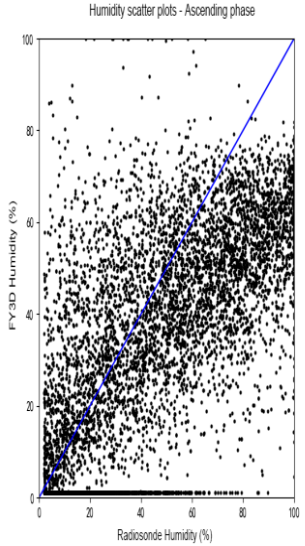


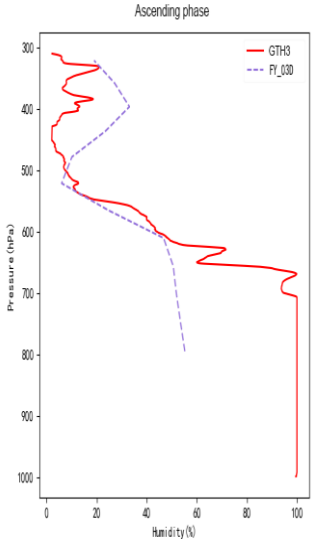
Temperature Profile Validation During Ascent



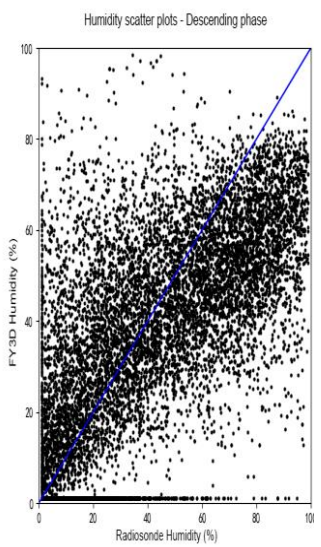


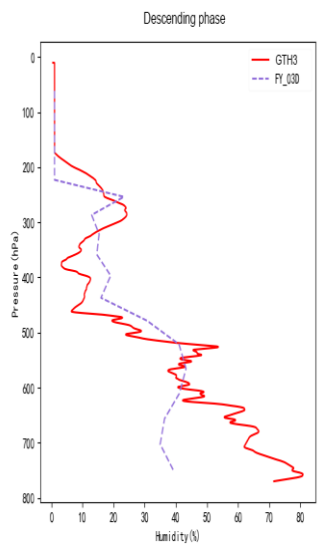
Temperature Profile Evaluation During Descent





Validation of Humidity Profiles During Ascent





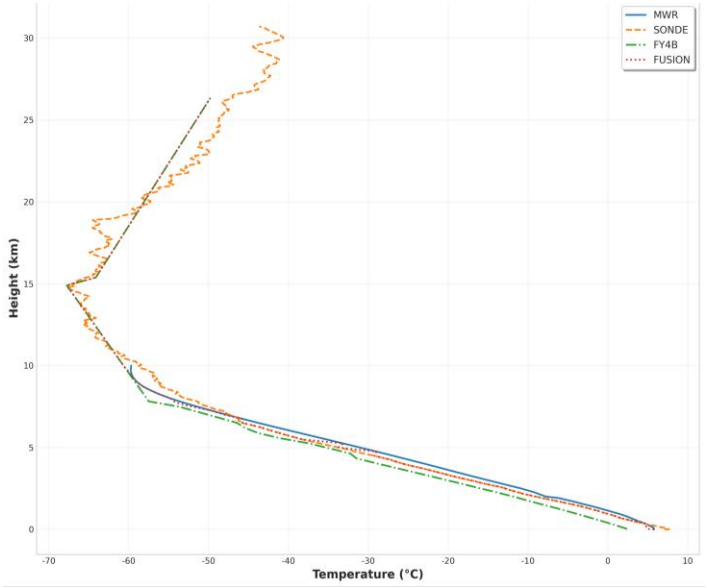
Validation of Humidity Profiles During Descent

- Evaluation temperature and humidity profile of FY meteorological satellite by GTH3 observations in XIL GRUAN shows that *the error is relatively small, and separately within 2℃ and 15%*.

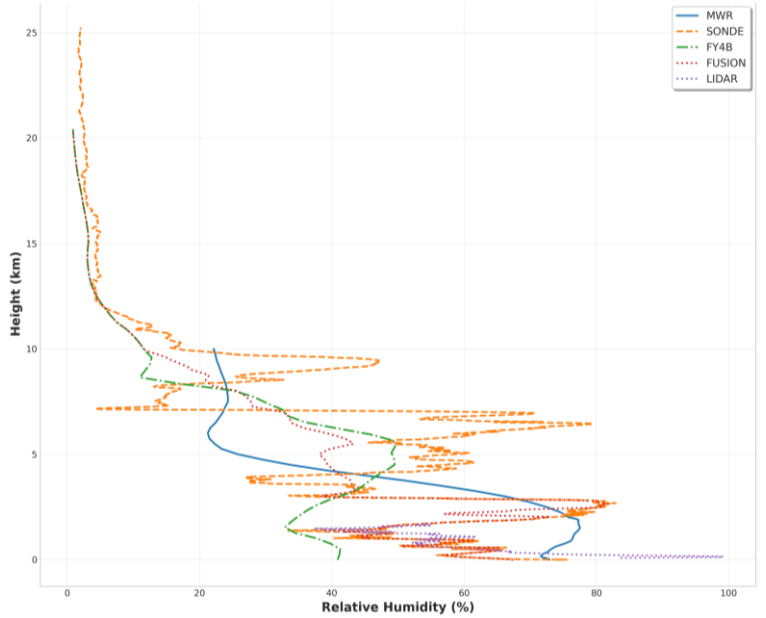
II.Benefit of GRUAN(For example: *CMA*)

◆ *Data fusion* based on Air-Space-Ground observation in XIL GRUAN

- a satellite temperature and humidity profile *fusion algorithm* was developed based on observation in XIL
- the algorithm integrated temperature/humidity from *FY-4B/GIIRS, microwave radiometor and radiosonde*
- the fused profiles *enhanced accuracy*， and demonstrate improvement over both the original satellite, radiosonde and ground-based data sources.



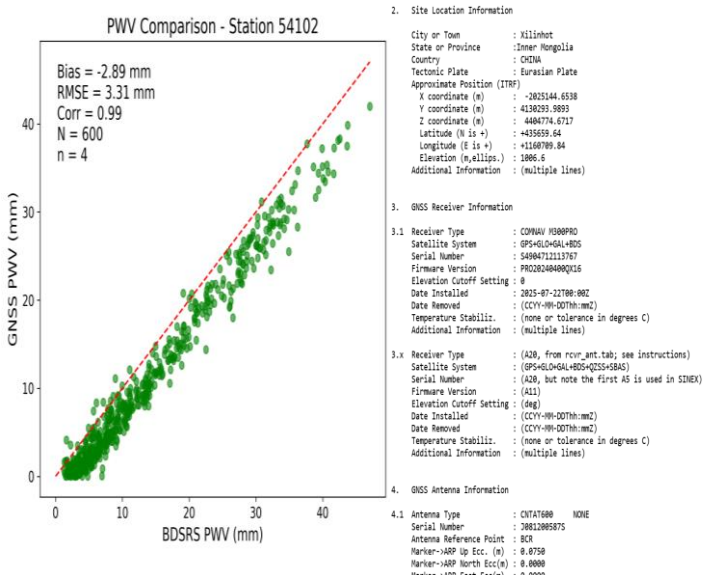
20251027120000 Temperature Profile Comparison



20251029120000 Relative Humidity Profile Comparison

II.Benefit of GRUAN(For example: *CMA*)

◆ *Other GDPs*(GNSS/MET, Ozonesonde, ...) *development* in XIL GRUAN



2. Site Location Information

City or Town : Xilinhot
State or Province :Inner Mongolia
Country : CHINA
Tectonic Plate : Eurasian Plate
Approximate Position (ITRF)
X coordinate (m) : -2025144.6538
Y coordinate (m) : 4130293.9893
Z coordinate (m) : 4404774.6717
Latitude (N is +) : +435659.64
Longitude (E is +) : +1160709.84
Elevation (m,ellips.) : 1086.6
Additional Information : (multiple lines)

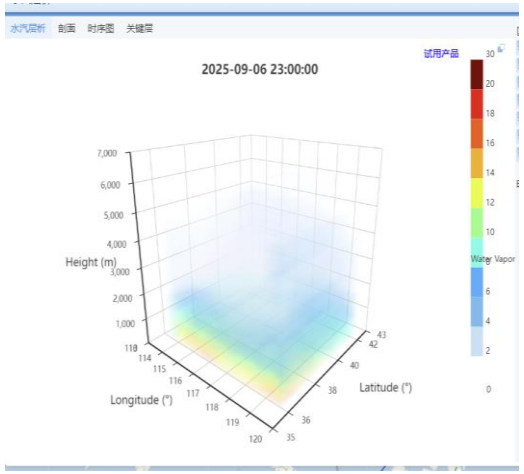
3. GNSS Receiver Information

3.1 Receiver Type : COMNAV M300PRO
Satellite System : GPS+GLO+GAL+BDS
Serial Number : 5490471211376?
Firmware Version : PRO20240400QX16
Elevation Cutoff Setting : 0
Date Installed : 2025-07-22T00:00Z
Date Removed : (CCYY-MM-DDThh:mmZ)
Temperature Stabiliz. : (none or tolerance in degrees C)
Additional Information : (multiple lines)

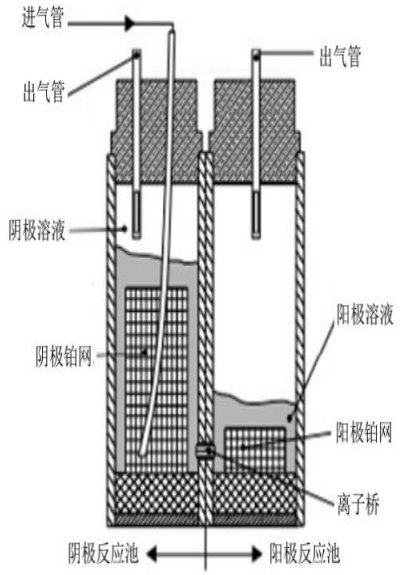
3.x Receiver Type : (A20, from rcvr_ant.tab; see instructions)
Satellite System : (GPS+GLO+GAL+BDS+QZSS+SBAS)
Serial Number : (A20, but note the first A5 is used in SINEX)
Firmware Version : (A11)
Elevation Cutoff Setting : (deg)
Date Installed : (CCYY-MM-DDThh:mmZ)
Date Removed : (CCYY-MM-DDThh:mmZ)
Temperature Stabiliz. : (none or tolerance in degrees C)
Additional Information : (multiple lines)

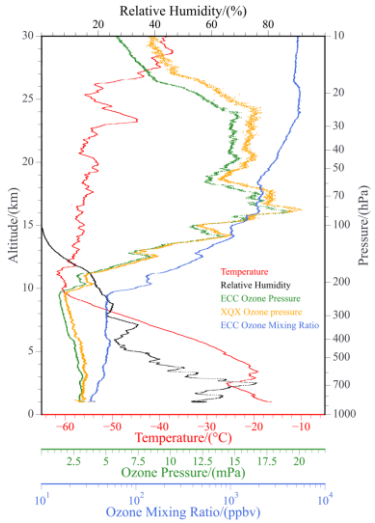
4. GNSS Antenna Information

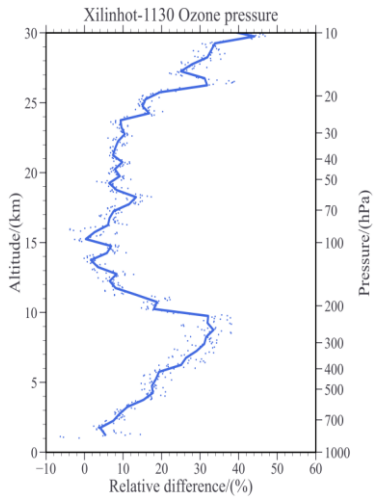
4.1 Antenna Type : CNTAT600 NONE
Serial Number : 30812005875
Antenna Reference Point : BCR
Marker->ARP Up Ecc. (m) : 0.0750
Marker->ARP North Ecc(m) : 0.0000



The technical roadmap for GNSS metadata development has been submitted to the chair of the GNSS Water Vapor Technical Group







Schematic Diagram of the Dual-Cell Ozone sounding and Ozone sounding Intercomparison Results

- **GNSS/PWV**:to undertake postprocess of the GNSS observations from 2024 to 2025 to produce the new ZTD and PWV time series.
- **Ozonesonde:**Since November 2023, XIL has conducted weekly ozonesonde observations at 06 UTC on Wednesday, establishing a continuous dataset. GDP of Ozonesonde has been initiated, with certification procedures to be implemented progressively.

Outline

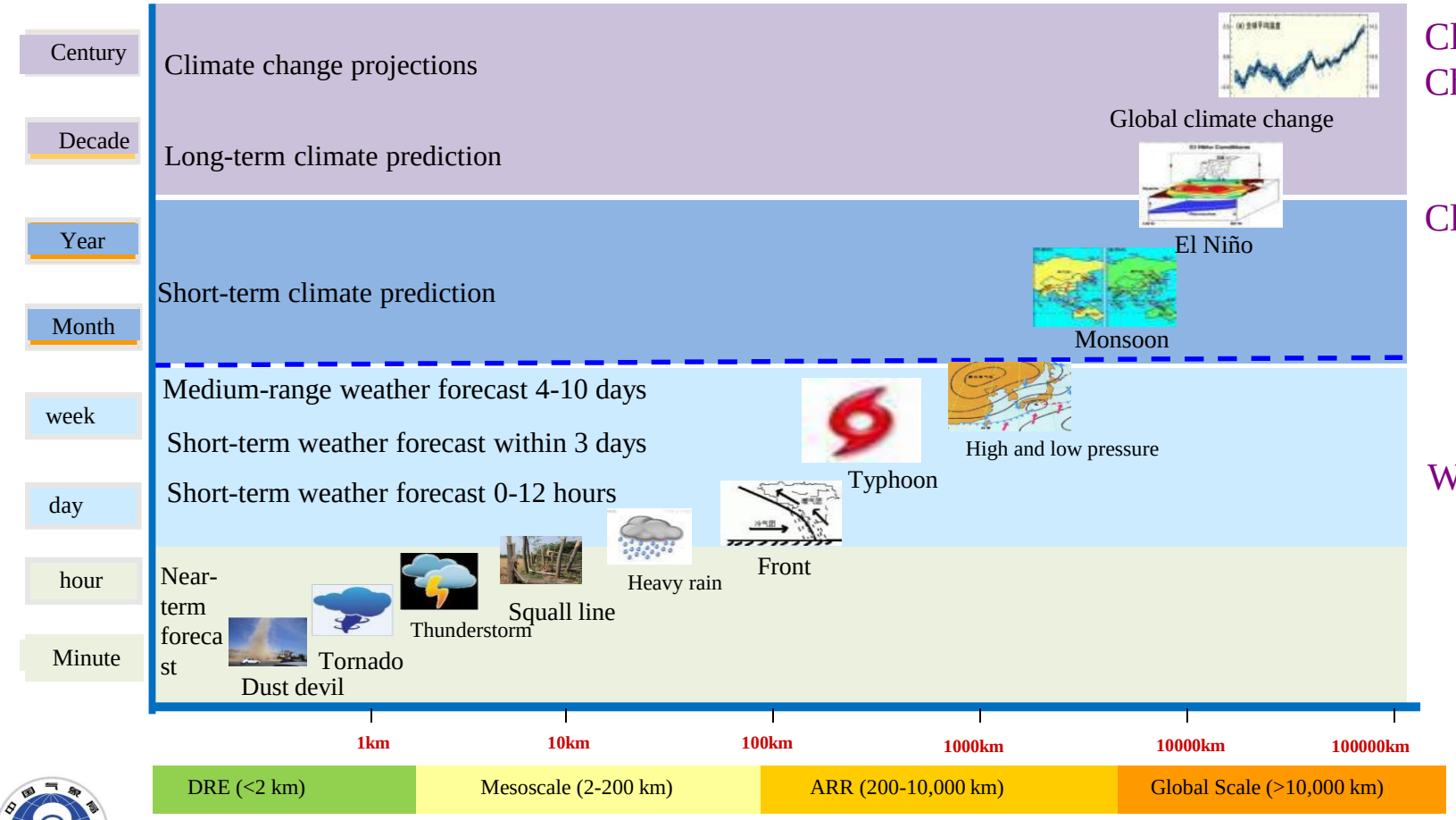
Ⅰ Important achievements of GRUAN

Ⅱ Benefit of GRUAN (For example: CMA)

Ⅲ Recognition of GRUAN (future thought？)

The requirementsin GRUAN site for "high accuracy, stability, reliability, and continuity" remain never changed(QA/QC is basic requirement)

◆ The scales(*time/space*) of weather, climate and climate change



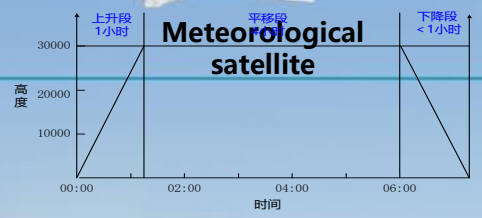
- Weather: Atmospheric conditions occurring over a short period (from minutes to days), such as thunderstorms, hail, typhoons, heavy rain, cold waves, and strong winds.
- Climate: The average or statistical state of the atmosphere over a long period (months, seasons, years, or decades), primarily reflecting the fundamental characteristics of a region, such as its temperature, warmth, dryness, and humidity.
- Climate Change: Significant changes in the climate system over a longer period (decades to centuries or more). This typically includes changes in averages, the frequency and intensity of extremes, and variability.

Should we develop new observation methods in GRUAN site?

(data from higher altitude and longer time by zero-pressure/over-pressure/stratosphere balloon for example, XIL uses the 1600/3000gram balloon to reach 5hPa/2hPa, and sometimes it can reach 1hPa.)

MUS 17~50km

Balloon sounding



Meteorological satellite

1600/3000g balloon

Solar Activity, Sunspot, Solar Flare,Coronal Mass Ejection (CME), Ionospheric Scintillation, Ionospheric Gradient, Ionospheric Electromagnetic Absorption,Earth's Magnetic Field / Geomagnetic Field,Magnetic Disturbance, Cosmic Ray

Nearly 10 items such as temperature, humidity, air pressure, wind direction, wind speed, ozone, atmospheric charge, radiation, etc.

UTLS 7~17km

Meteorological aircraft

More than 20 items such as temperature, humidity, air pressure, wind direction, wind speed, cloud base, cloud top, cloud particle radius, particle concentration, phase state, water content, aerosol, ozone, greenhouse gases, reactive gases, lightning location, lightning density, polarity, precipitation echo intensity, velocity, and spectrum width

FT 2~12km

Temperature, humidity, air pressure, wind direction, wind speed, precipitation, visibility, surface temperature, grass temperature, evaporation, sunshine duration, total radiation, net all-wave radiation, scattered radiation, reflected radiation, direct radiation, permafrost, snow depth, weather phenomena, cloud cover, cloud height, greenhouse gases, aerosols, reactive gases, ground-level ozone, acid rain, precipitation chemistry, atmospheric deposition, atmospheric optical thickness, atmospheric precipitable water, zenith total delay, vegetation, phenology, crop growth stage, agrometeorology, flux, and more than 40 other items

PBL 0~2km

Weathe r radar

Wind Profiler Radar

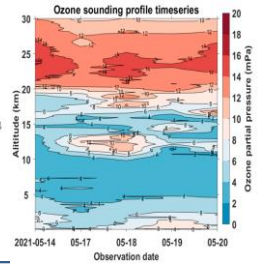
Cloud radar

More than 10 items such as temperature, humidity, air pressure, wind direction, wind speed, precipitation, visibility, sea surface wave height, wave period, and sea surface temperature

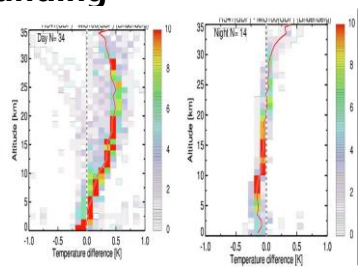
水汽

Should we develop other element sensor technologies in GRUAN site?

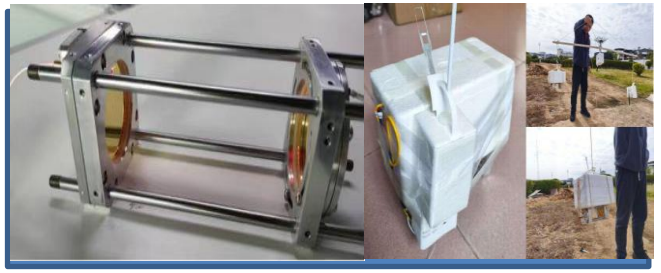
(adding other new element observation: humidity, *cloud Particle, atmospheric radiation, atmospheric electrical characteristics, etc***)**



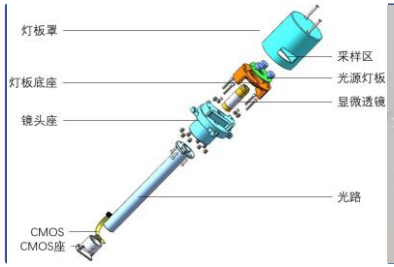
Dual-cell electrochemical ozone sounding

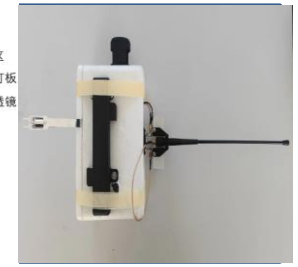


Low-temperature dew point/frost point hygrometer radiosonde



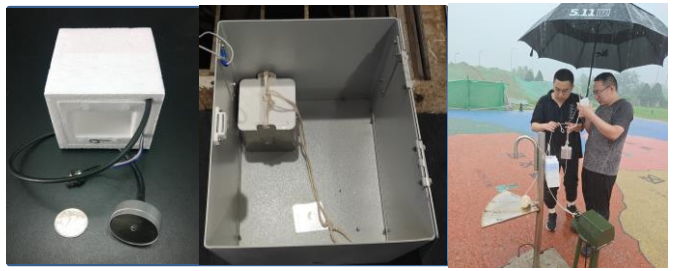
Integrated TDLAS Humidity Sounding





Cloud Particle Sounding

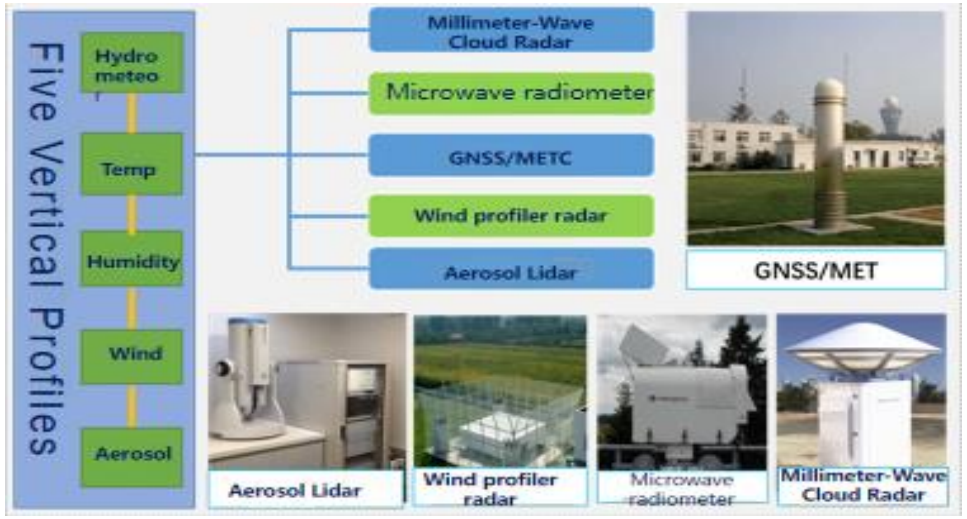
Atmospheric Radiation Sounding



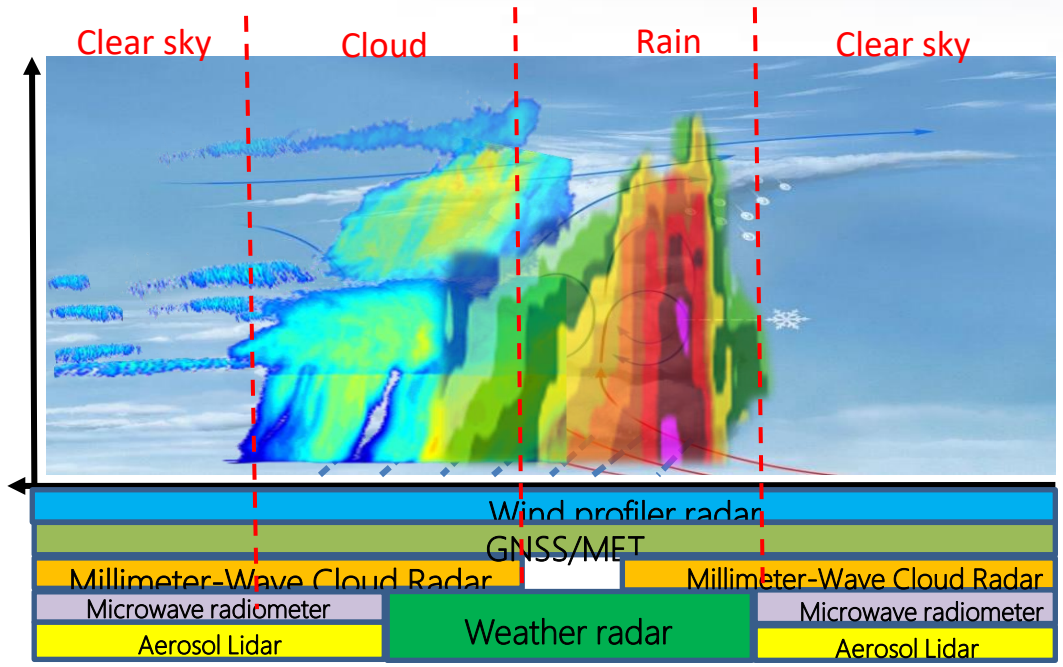
MEMS Atmospheric Electric sounding

- Based on the existing basic variables (PCVs), expand the research on atmospheric physical conditions (temperature, pressure, wind, humidity, *cloud Particle, atmospheric radiation, atmospheric electrical characteristics, etc).*

How we develop ground-based remote sensing in GRUAN site or reach unGRUAN site? (radiosonde of encryption of time and space)



System Composition: 5 types of observation equipment + 1 integrated system



- obtain *vertical profiles of T, U, P ,D,W,... from the ground up to 10 km(even hgher)* within troposphere
- achieve *continuous monitoring from clear-sky conditions to weather processes* involving cloud and rain
- reveal the *thermodynamic and dynamic processes of precipitation* weather systems, as well as the formation and dissipation mechanisms of haze and fog events

This is merely my little recognition,and it might be some shortcomings.

That's all. Thanks you for your attention!