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QUALITY MANAGEMENT IN SURFACE, CLIMATE AND UPPER-AIR OBSERVATIONS IN CHINA

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Summary and Purpose of Document

This paper has attended the characters of China surface, climate and up-air stations which are exchanging data in RA II, including the number of stations, distribution map, instruments upgrade and maintenance, quality control etc. The total number of surface observation stations for exchange in China is 220, the number of up-air stations is 83. Since 2002, the instrument has been upgraded gradually, and now all these stations are AWS. Atmospheric Observing System Operations and Monitoring (ASOM) has been built up for the instruments tracing and maintaining. The operational quality control of meteorological data in China can be divided into real-time and non-real-time quality control in terms of effectiveness for a given period of time. Real-time QC is for the real-time data, non-real-time QC is for the storage and archived data. Many forms of data product have been used in a lot of fields like education, medicine, and agriculture etc.

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1. Introduction

In China, operational meteorological observation network comprises observing facilities on land, at sea, in the air and in outer space. The observation network is used in weather, climate and professional meteorology observation services.

This paper will introduce conventional meteorological surface and upper-air observing networks, the number of stations within RBSN, RBCN, GSN/GUAN and the distribution map. Also discuss the Instruments and sensors' upgrade and maintenance , and quality management of observation data etc.

2. Observation Networks

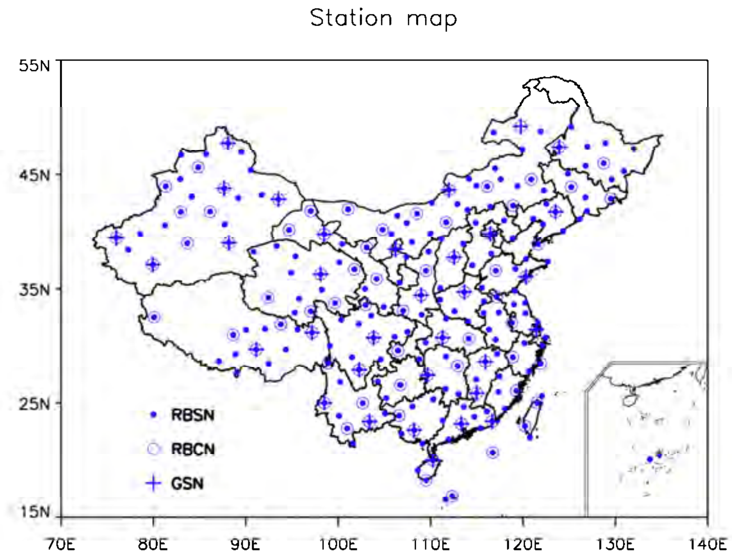
2.1 Surface observation network

The total number of surface observation stations for exchange through the Regional Basic Synoptic Network (RBSN) is 219, and the number of surface stations for exchange through the Regional Basic Climatological Network (RBCN) is 82, out of which 81 (with only exception of the station with the index number 50527) also function as RBSN stations at the same time. The number of surface stations from China participating in the Global Climate Observing System (GCOS) Network (GSN) is 33, which are all RBCN observation stations. All these stations are Automatic Weather Stations (AWS), but such elements as cloud and weather phenomena still rely on manual observations. A list of the stations is given in Table 1; and for their distribution, please see Figure 1.

Table 1 Number of China's surface stations

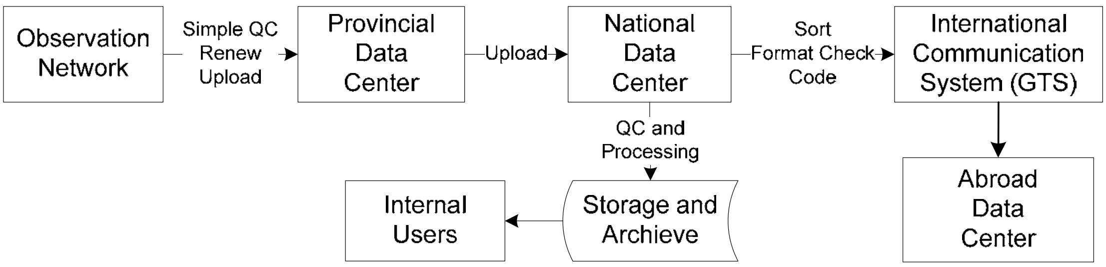
	RBSN	RBCN	GSN	Manned stations	AWS
Number	219	82	33	/	220

Figure 1 Distribution of China's surface stations



The transmission frequency of China's SYNOP reports for exchange via RBSN is 4 times per day, i.e. at 00, 06, 12, 18 UTC respectively. Normally each transmission will be completed 30 minutes after each synoptic observation hour. China's surface CLIMAT messages for exchange through RBCN are transmitted once a month, i.e. the message transmission is made at 06 UTC on the 4th day of each month. The work flows for transmitting both SYNOP and CLIMAT reports are identical, i.e. real-time data acquisition by observing station network, logging in AWS data files immediately after automatic quality control, automatic coding, human interventions by adding manual observations of such elements as weather phenomena and clouds, transmission to a provincial data centre, retransmission to the National Meteorological Data Centre, report sorting at the National Meteorological Data Centre, format checking, and dissemination via GTS to other relevant international centers. All observational data and reports transmitted to the National Data Centre shall be archived. A flow diagram is given in Figure 2.

Figure 2 Flow diagram for data transmission



2.2 Upper-air observation network

The total number of China's upper-air sounding stations for exchange through the Regional Basic Synoptic Network (RBSN) is 82; the number of upper-air stations that participate in regional exchange via the Regional Basic Climatological Network (RBCN) is 43, in which 42 (except station number 50527) are functioning as RBSN stations as well. The total number of the China's upper-air stations that have been included in the Global Climate Observing System (GCOS) Network (GUAN) is 7, which are all RBCN stations. All these stations are automatic ones. The number of upper-air sounding stations in China is listed in Table 2, and their distribution is shown in Figure 3.

Table 2 Number of China's upper-air sounding stations

	RBSN	RBCN	GUAN	Manned stations	Automated system stations
Number	82	43	7	/	83

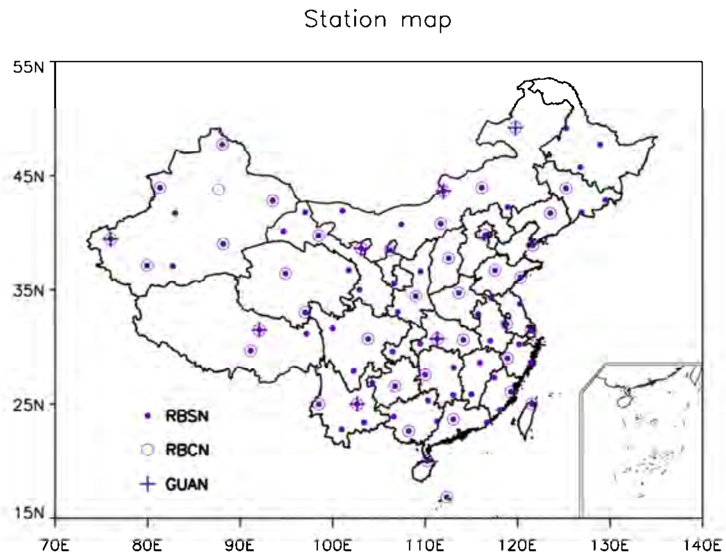


Figure 3 Distribution of China's upper-air sounding stations

The transmission frequency of China's TEMP reports for exchange through RBSN is twice per day, i.e. at 00 and 12 UTC respectively. Under normal conditions, each observation will be coded and transmitted within 30 minutes after a synoptic hour. The CLIMAT TEMP messages for exchange through RBCN are transmitted once a month, i.e. at 06 UTC on the 4th day of every month. The transmission procedure is identical to that for transmission of SYNOP reports.

3. Instruments and sensors' upgrade and maintenance

3.1 upgrade

In the past few years, all national surface station has installed the AWS by the CMA. The observations contain parameters such as wind direction and speed, temperature (atmospheric, ground and grass), atmospheric pressure and humidity; amount of precipitation; radiation automatically. But the weather phenomena, amounts, types and height of clouds, visibility are still observed by human as supplement. The observing data quality is needed to improve. The technique of the cloud, visibility and weather phenomena observation automatically is planned to develop.

Since 1950's, the instruments of up-air sounding has renew 2 times. First, type 49 had been replaced by type 59-701. Second, L band electronic radiosonde and windfinding radar sounding system as a new generation sounding system to replace the old sounding system (Type 59-701 Mechanical Radiosonde and Secondary Windfinding Radar). By 2010, April, almost all up-air stations have been replaced by L band sounding system.

3.2 Maintenance

A near real-time monitoring system of China meteorological observation network has been built up, named as Atmospheric Observing System Operations and Monitoring (ASOM). It monitors national surface observation system and upper-air sounding system. ASOM contains several subsystems, including equipments operation monitoring, observation data monitoring, equipment maintenance management, logistic management and observation site management.

3.2.1 Equipments operation monitoring

Based on parameters and certain model, equipment operation monitoring will show some indexes by processing and judging operational status, such as normal, alarm and so on, and it will display these statuses in many ways. Real-time monitoring can directly show the equipment status by overlapping on the Chinese electrical map with some special flags with a updating period of 1 hour for AWS. Historical monitoring figures can show the equipment operational status in any time or any period with time series. Station synthetically displaying can gather figures, parameters and alarm information, which is benefit for analyzing both equipment status and products quality.

3.2.2 Equipment maintenance management

Equipment maintenance management can realize life management and it can also offer supporting platform to improve maintenance level by archived the life time of the equipment from registration. It contains equipments maintain management, equipments repairing, maintenance and repairing experiences and knowledge management and things. In this subsystem, the uniform equipment ID is taken the module function chain, the equipment's maintaining and repairing status can be traced by the ID. When the equipment is down, all processes are filled in the form, and the different people from different sections will fill the same form in one accident. The national and the province center can collector these repairing experiences to form the knowledge database and sharing it so as to convenient for the following equipments maintenance and repairing work.

3.2.3 Logistic management

Logistical management realizes the meteorological equipments, meteorological apparatuses' lifetime tracing and management using the uniform equipment's ID number. Logistic management includes calibration and license modules. Calibration module establishes a database for supervising instrument calibration valid periods, which has alarm, and statistics function. Logistics management realized plan, stock, supply and storage in the internet. On the basis of operation and consumption, it can form stock plan and submit report by corresponding approval procedure then carry out stock in the internet and issue storage status at the same time. License module has realized declaration, experimentation, approval and search information management and has standardized management flow. Technology rules, regulations, criterions, database and information searching platform were established.

It will also generators some evaluation results, such as the consumption of the different equipments, the number of the stock and warehousing in one time and the top 10 purchase and so on.

3.2.4 Observation site management

Observation site management includes the management of the people, all equipments and the whole site environment in China meteorological observing network. It supplies this foundation information for the other subsystems. It has some basic information about stations, equipment types, numbers, observation items and update information about the sensors.

4. Quality Control

The operational quality control of meteorological data in China can be divided into real-time and non-real-time quality control in terms of effectiveness for a given period of time. In the whole process from data collection to data sending, storing and archiving (see Figure 2), real-time quality control should ensure the timeliness of data. Simple quality control methods can be used to achieve automated processing without manual intervention. Non-real-time quality control is targeted at monthly data or accumulated real-time data reported by stations. It uses more comprehensive quality control techniques, which is mainly based on computers and supplemented by manual intervention, combines both manual intervention and computers.

4.1 Real-time quality control

Real-time quality control is first made at the station level. The data will be sent, via provincial data center, to National Data Center. In this process, at the provincial level, real-time quality control is not made for data uploaded from stations to National Data Center. At the national level, real-time quality control is made so that these data are provided to domestic users and sent to overseas data centers through international communication system GTS after sorting, coding, and format checking.

4.1.1 Real-time quality control at the station level

Observing stations collect data in a real-time manner, and check the data against climatic extreme and element allowance range (B-QC), check element continuity (E-QC) and element consistency. Then, the results of these checks are written into AWS data collection files. In the process of data quality control, it is necessary to identify whether quality control is made on sampling instantaneous value and instantaneous meteorological value, as well as the results of quality control. This identification is used to qualitatively describe data confidence. The specifications of the identification are given in Table 1.

Table 3 Data quality control identifiers

ID code	Description
0	"Right": the data does not exceed a given limit.
1	"Doubtful": not credible.
2	"Wrong": erroneous data that exceeds a given limit.
3	"Inconsistent": one or more parameters are inconsistent; the relationship between different elements does not meet the required standards.
4	"Checked": Raw data that are identified as doubtful, wrong or inconsistent and that are reconfirmed as right using other verification procedures.
8	"Missing": Data are missing.
9	"Not checked": the variable has not been checked for quality control purpose.
N	No sensors. No data.
Note: If instantaneous meteorological values lack measurement data due to collectors or telecommunication, directly give "missing" when the terminal commands a data output, and the corresponding quality control is identified as "8". If data are available, which are judged as wrong by the quality control, and when the terminal commands a data output, their values are still given, and the corresponding quality control is identified as "2", but the erroneous data can not participate in subsequent computing or accounting.	

4.1.2 National real-time quality control

4.1.2.1 Ground

The quality of data for regular observation messages in national real-time ground observation data is controlled. Elements under quality check include air pressure, temperature, dew point temperature, wind direction and speed, and precipitation. Quality control includes:

(1) Limiting value or allowable values of climate

First of all, elements are checked against the limiting value or allowable values of climate according to Table 4. If the value of an element exceeds the limit or allowable values of climate, then it is wrong. The quality control code is set to be 2;

Table 4　Limiting values of climate of elements

Element	Climatic limiting values or allowable values of elements
Air pressure	1100 hpa——400 hpa
Air temperature	60℃—— -60℃
Dew point temperature	50℃—— -70℃
Precipitation	0－600mm
Wind direction	0－50 m/s
Wind speed	0-360 degrees

(2) Extreme value check at station

Determine whether air pressure, air temperature, wind speed and precipitation at the station go beyond the scope of each corresponding extreme value of the station. If yes, the data are doubtful, and the quality control code is set to be 1.

(3) Internal consistency check

Determine the consistency of related elements like sea level pressure and the station pressure, temperature and dew point temperature, wind speed and direction, and 1, 3, 6, 12 and 24-hour precipitation.

For example, the dew point temperature is equal or lower than temperature. When this relationship is not met, the two elements are doubtful, and the quality control code is set to be 1. The internal relationship of temperature should be 24-hour minimum temperature ≤ temperature ≤24-hour maximum temperature. When this relationship is not met, the two elements are doubtful, and the quality control code is set to be 1. Precipitation of different periods should meet the following relationship: 1-hour ≤ 3-hour ≤ 6-hour ≤ 12-hour ≤ 24-hourprecipitation, otherwise, precipitation during a relevant period is doubtful, and the quality control code is set to be 1.

4.1.2.2 Upper air

The quality of standard layer (US, UL, UP, UG) of the upper-air observational data will be checked, whose elements mainly include air pressure, geopotential height of the standard layer, temperature, dew point temperature, wind direction and wind speed. The quality control includes:

(1) The allowable value check

For example: in case of 0°≤wind direction≤360°, if it is found wrong in the checking, individual elements will be recorded as wrong, with corresponding quality code set to be 2.

(2) The climatological threshold value check

From the perspective of climatology, those climatological threshold values that can not appear (including values that couldn’t be measured by current measurement techniques) are called climatological threshold values for various elements. Those data beyond climatological threshold values for various elements is wrong (i.e. MQC=2).

(3) Internal consistency check

Checking whether certain physical relationship is met by different elements or items of the station is called internal consistency check. Upper-air data refers to multi-layer data extending vertically in the space. The consistency of related elements in the same layer is checked only in the quality control scheme, not involving in elements of many layers. For example, for the air temperature and dew point temperature, if the air temperature is lower than the dew point temperature in the same layer, then at least one item of the air temperature and dew point temperature is wrong, with the quality control code set to be 1 respectively for the two elements.

Through the aforementioned real-time quality control, statistics is taken for quality check results of international exchange stations from Jan. to Jun. 2010, with erroneous data accounting for 0.01% of the total data. The percentage of various types of errors is shown in Table 5.

Table 5 error type and percentage of quality control of real-time data

Error type	Percentage
Equipment failure	44.44%
Operation failure	37.04%
Unexplained	18.52%

4.2 Message format check

Once the real-time observational data from observation network is uploaded to the National Data Centre, the format of the message will be checked. The checking includes integrity of the bulletin (mainly checking the starting line, end line, correctness of the bulletin length), header (checking the bulletin header format, the correctness of time group), bulletin content (checking the bulletin formats of various kinds of data according to the WMO *Manual on Codes* (WMO-No.306). For ground report FM12, upper-air report FM35, ground monthly report FM71, upper-air monthly report FM75, etc., the format of each set of data and each report will be checked. After format checking, the correct data will be sorted and coded, and sent to overseas data centre by GTS.

4.3 Non-real-time quality control

For monthly report or accumulated real-time data from stations, more comprehensive quality control techniques are applied to non-real-time quality control, which is mainly based on computer and supplemented by manual intervention, and combines both manual intervention and computer. At present, an operational flow consisting of a three-level quality control system has been established for monthly and annual reports from ground AWSs and manual stations. The operational flow of the three-level quality control system is given in Figure 4, which includes station QC, provincial QC and national QC. The station QC means that stations make quality inspection and preliminary examination of data using station-level quality control software and submit those qualified data to provincial data processing center. Provincial QC means that the said data files are collected from stations within the province during specified time of each month. The data file will undergo quality inspection and man-computer interactive examination with provincial quality control software, while the information on quality inspection will be fed back to stations. The data will be submitted to National Meteorological Information Center after it is confirmed to be qualified through re-inspection. National QC means that data files are collected from provinces during specified time of each month. With national quality control software, rolling format examination and quality inspection will be conducted for the data files, while data check and processing will be made with human-computer interactive interface. Meanwhile, information on final quality control will be fed back to provinces, which will be kept in the archives of the Data Office of the National

Meteorological Information Center after it is confirmed to be qualified.

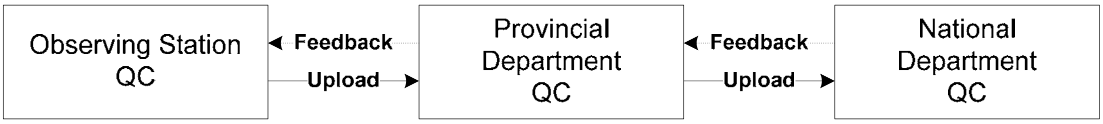


Figure 4 Flow chart of three-level quality control system

In the three-level quality control system, quality control is the core of the system as a whole. National and provincial QC processes are shown in Figure 5. The QC process at the station level is similar to Figure 6 but without spatial consistency check. In Figure 6, all links from format check to consistency check are automatically controlled by software.

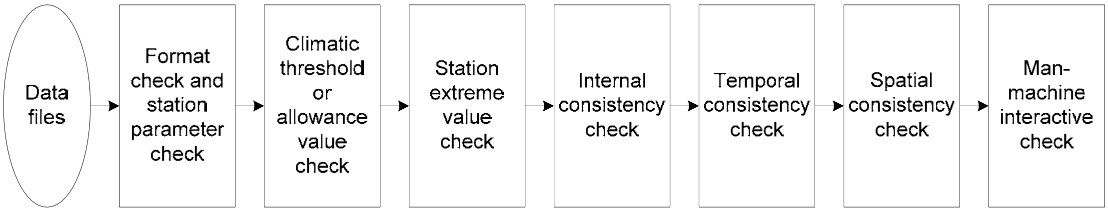


Figure 5 The flow chart of QC process

Fully automated quality control cannot solve all problems of data quality. For some special cases or problems, manual check is used as a supplement to make judgment. Manual check can be done at any level of quality control, which is the man-machine interactive quality control carried out on suspicious or erroneous data after automatic control mentioned above. According to data comparison, graphical analysis, inquiry stations, neighborhood stations comparison and manual analysis judgments, it is ultimately determined whether to modify or revise data, and determines quality control code corresponding to element value.

Following the quality control process, each data must be marked with quality-control flag, quality-related information has to be archived for reference of data processors and users. In monthly report, intervals have been set for storing information on data quality which contains quality-control codes and data amendments.

Quality control code representing quality status of observational data, according to the operational process, can be divided into three levels: station level, provincial and national level. Quality control code is represented by an integer of three digits, with one digit standing for national level, tens digit for provincial level, and hundred's digit for station level. The meaning of quality control code at all levels is as follows:

0 : Data correct
1 : Data suspicious
2 : Data error
3 : Data with corrected value
4 : Data has been corrected
8 : Lack Measured Data
9 : Data without quality control

In the quality control process, it is allowed to correct doubtful data and data lacking measurement. Data correction includes data revising and data modification. Data revising refers to doubtful data or lacking of measured original observational data, a kind of data calculated and estimated through a given statistical method. This data does not replace the original data in observational data, only recording its revised data in data correction information. Data modification means that the original observational data is wrong, confirming the correct data after inquiries, which replaces the original data in observational data, while recording its modification status in data correction information. The corrected quality control codes are 3 or 4.

5. Training Activities

Training centers have been established in both national and provincial meteorological departments, which bear the responsibility for training employees at all levels of meteorological departments on basic meteorological knowledge, station network maintenance, forecasting operation, observation and detection technology, quality control technology. What's more, an integrated observing training/practice base was established to carry out online distance training. Through training, the operational personnel would deeply understand practice of meteorological observations and detection, master methods and operational requirements of meteorological observations and detection, and grasp basic principles of quality inspection and automatic quality control software operation. This will improve the operational capacity of meteorological technical personnel at all levels, ensure the quality of uploaded data, so as to meet the requirements for meteorological data in operational service and scientific researches.

6. Data Statistics and Application

6.1 The Climate standard value

WMO recommends that all the countries collate and prepare statistics for climate data taking 30 years as the standard, so as to facilitate WMO to issue a global climate standard value and to provide services for the national governments. Many member countries of WMO including China also stipulate that the climate standard value will be updated every ten years, in order to describe the average pattern of climate in 30 years, which is also regarded as the reference object for current climate condition. Meanwhile, climate standard value can be used to divide regional climate, providing extensive support to such areas as basic residential environment, agriculture, natural vegetation, energy utilization, transportation, tourism and environment research. China’s 30-year (i.e. 1951-1980, 1961-1990, and 1971-2000) meteorological data have been collated and compiled for three times (Figure 9). At present, preparations are underway to collate and compile the fourth 30-year (i.e. 1981-2010) meteorological data.

6.2 Data homogenization

Regarding data homogenization, studies on homogeneous verification and correction for data from surface and upper-air sounding stations nationwide are being carried out. Homogeneous verification for daily and monthly series of temperature, precipitation and upper-air temperature has been preliminary completed (see Figure 6).

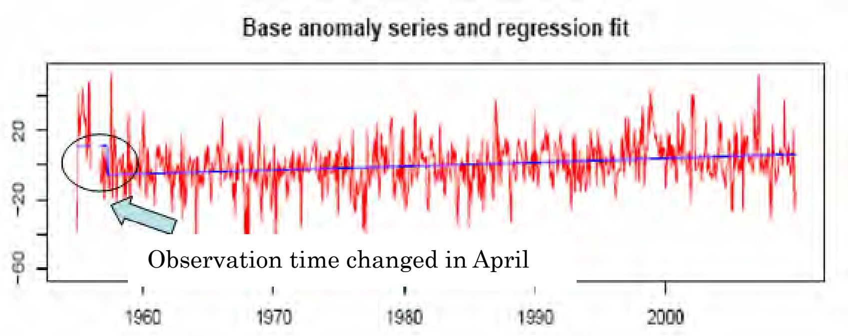


Figure 6　Verification of data homogenization

6.3 Application of meteorological data to various sectors

As meteorology is related to all aspects of national economy and scientific research, there are extensive and urgent needs for meteorological data. Meteorological data are applied to many sectors such as education, scientific research, government, agriculture, forestry, water conservancy, military, pharmacy, ocean, railway, public security, media and environment protection. Figure 7 presents a distribution chart of user groups based on statistics by sectors. Evidently, major user groups are from scientific institutions, colleges and universities followed by meteorological sectors, while the rest users are from earth science, agricultural science, bio-science, water engineering, and medicine and health sectors. All of them are professional staff involving in national scientific and technological projects, such as 863, 973 and the Natural Science Foundation, etc.

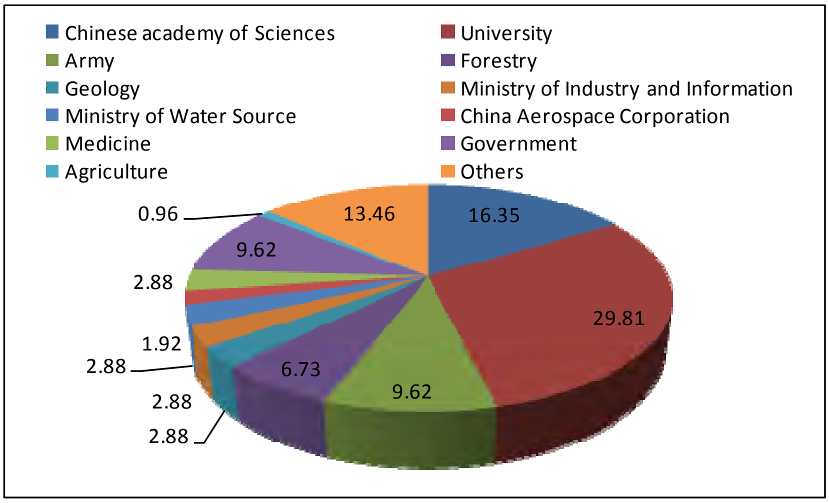


Figure 7　Sectors applying meteorological data

7. Existing problems and future plan

The improvement of observation data quality is needed. Although the electronic radiosonde in use has obviously been improved compared to mechanical ones, the stability and accuracy should further be increased to meet the requirements of climate observation. The high accuracy sensor of the pressure, temperature and humidity is planned to develop.

Quality control schemes need to be improved, and quality control is not used effectively for all observing elements. For example, quality control schemes are not developed for significant level, surface layer and L-band minute-level data for upper-air sounding data. Therefore, more efforts should be made to develop quality control schemes and put them into operation.

Metadata are limited, and a large amount of metadata are still archived in different stations, leading to uncertainties in judgment of data breakpoints, since it is hard to identify whether breakpoints are caused by natural variability or by other factors such as observing methods, changing of instruments. In this regard, cooperation should be enhanced with stations to collect metadata as much and soon as possible.

It is necessary to improve capabilities of data observers and recorders, allowing them to comprehensively and scientifically understand physical meaning and algorithm of observing elements, strengthening, meanwhile, operational practices to reduce or avoid data quality problems caused by human factors as far as possible.

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