ChinaRxiv 中X

AI translation · View original & related papers at
chinarxiv.org/items/chinaxiv-201911.00033

Quality Control Method and Performance Analysis of Temperature Data from the RPG_HATPRO_G4 Ground-Based Microwave Radiometer (Postprint)

Authors: Sun Yanqiao, Tang Dazhang, Sang Jianren, Wang Yang, Lyu Jingjing, Tian Lei, Tang Dazhang

Date: 2019-11-15T00:00:00+00:00

Abstract

For ground-based microwave radiometer temperature data at Longde Station, quality control experiments were conducted using five inspection methods—vertical variation intensity extreme check, standard deviation check, extreme value check, singular value check, and stuck value check—based on the inherent patterns of the data and various manifestations of erroneous data, combined with historical radiosonde data. The results were compared with concurrent radiosonde data to analyze the application effectiveness. The results indicate that each quality control method exhibits a certain ability to discriminate data quality and is sensitive to control parameters. Data quality is optimal under clear skies, followed by cloudy skies, and slightly poorer during precipitation, with essentially equivalent quality across all height levels. Correlation analysis of the quality control results demonstrates that correlations are highest under clear skies at all height levels, followed by cloudy skies, and slightly lower during precipitation, all remaining at relatively high levels; the quality control effect is most significant during precipitation.

Full Text

Quality Control Method and Efficiency Analysis on Temperature Data by RPG-HATPRO-G4 Type Ground-Based Microwave Radiometer

Abstract: Quality control of meteorological data is a crucial step in data processing. Since microwave radiation products constitute non-conventional meteorological observation data, conventional quality control methods are not fully applicable to microwave radiometer data. To investigate quality control methods for temperature data from the RPG-HATPRO-G4 type ground-based multi-channel microwave radiometer and provide technical support for effective utilization of temperature data, this paper proposes five methods based on data characteristics and various error types. These methods are applied to temperature data collected by an RPG-HATPRO-G4 ground-based multi-channel microwave radiometer at Longde Station, Ningxia, China, combined with five-year historical sounding data from Pingliang Station, Gansu Province, located 49 km from Longde Station. The five methods include: extreme value check of vertical change intensity, standard deviation check of vertical change intensity, extreme value check, singular value check, and invariable value check. These are further combined into three categories: comprehensive check of vertical consistency, extreme value check, and comprehensive check of time consistency. Combination check and weighted check results are then obtained by synthesizing the three types of check results. Finally, to analyze the effectiveness of these methods, they are applied to the collected data and compared with concurrent sounding data. Results show that data quality under clear weather conditions is superior to that under cloudy and precipitation conditions, with cloudy weather data quality exceeding that of precipitation weather. For the three aforementioned weather conditions, high-quality data account for 97.86%, 97.83%, and 84.21% of total data, respectively. Data quality is essentially uniform across all layers, with poor-quality data primarily contributed by precipitation weather. Both combination check and weighted check demonstrate strong capability in assessing data quality, with respective quality control results being sensitive to corresponding control parameters. Correlation analysis of quality control results reveals the best correlation under clear weather at all altitudes, followed by cloudy weather, with precipitation weather showing the worst correlation; however, all correlation coefficients remain at high levels. The effect of data quality control is most pronounced under precipitation weather. This experiment demonstrates that the proposed data quality control scheme is feasible and provides a mechanism for distilling temperature data from the RPG-HATPRO-G4 type ground-based multi-channel microwave radiometer for other applications.

Keywords: ground-based microwave radiometer; temperature; sounding data; quality control

1 Data and Methods

1.1 Data Sources

The primary dataset consists of RPG-HATPRO-G4 temperature profile data observed at Longde Station (35.37°N, 106.07°E, altitude 2078 m) from June 10 to December 31, 2017 (excluding September 6-9 due to instrument maintenance). The temporal resolution is 1 minute, with vertical coverage from 0 to 10 km at 93 levels, and vertical resolution as shown in .

Vertical resolution of the RPG temperature profile (m)

Height Range	Resolution	Height Range	Resolution	Height Range	Resolution
0–10	10	500–1200	40	3500–4500	160
10–25	15	1200–1800	60	4500–6000	200
25–100	25	1800–2500	90	6000–9800	300
100–500	30	2500–3500	120	9800–10000	200

For comparative analysis, sounding data from Pingliang Station (35.55°N, 106.67°E, altitude 1468 m), located 49 km from Longde Station, are used. The sounding data cover June–December from 2013 to 2017 (08:00 and 20:00 UTC), with temporal resolution of 1 second and vertical resolution of 6–7 m. Temperature profiles from the microwave radiometer are interpolated to sounding levels for quality control assessment.

1.2 Quality Control Methods

Based on historical data characteristics and error types, five quality control methods are established: extreme value check of vertical change intensity, standard deviation check of vertical change intensity, extreme value check, singular value check, and invariable value check. These are combined into three comprehensive categories: comprehensive check of vertical consistency, extreme value check, and comprehensive check of time consistency. Quality control identifiers are assigned values of 0, 3, 6, and 9, representing "correct," "suspect," "error," and "missing" data, respectively.

1.2.1 Extreme Value Check of Vertical Change Intensity For each temperature profile, maximum and minimum values of vertical change intensity (dT/dh) are calculated. Quality control identifier n is assigned based on whether dT/dh falls within [dT_sh_min, dT_sh_max] or within expanded bounds using 3 and 6 thresholds (where represents the standard deviation), as detailed in .

Values of quality identifier n for extreme value check of vertical change intensity and corresponding meaning

dT_h Range	n Value	Meaning
[dT_sh_min, dT_sh_max]	0	Correct
[dT_sh_min-3 , dT_sh_min] [dT_sh_max, dT_sh_max+3]	3	Suspect

dT_h Range	n Value	Meaning
[dT_sh_min-6 , dT_sh_min-3] [dT_sh_max+3 , dT_sh_max+6]	6	Error
(-∞, dT_sh_min-6] [dT_sh_max+6 , +∞)	9	Missing

1.2.2 Standard Deviation Check of Vertical Change Intensity This method checks whether vertical change intensity at each level falls within 2 , 3 , or 4 bounds, where is the standard deviation of historical data. Quality identifier n is assigned accordingly, as shown in .

Values of quality identifier n for standard deviation check of vertical change intensity and corresponding meaning

dT_t Range	n Value
[dT_t ± 2]	0
[dT_t-3 , dT_t-2] [dT_t+2 , dT_t+3]	3
[dT_t-4 , dT_t-3] [dT_t+3 , dT_t+4]	6
(-∞, dT_t-4] [dT_t+4 , +∞)	9

1.2.3 Extreme Value Check Based on maximum (T_max) and minimum (T_min) temperature thresholds derived from historical data, quality identifier N is assigned according to . For the 93 levels below 10 km, T_max and T_min are determined from 2,139,065 historical samples.

Values of quality identifier N for comprehensive check of vertical consistency and corresponding meaning

Condition	N Value
n + n = 0	0
n + n = 3	3
n + n = 6	6
n + n 9	9

1.2.4 Singular Value Check This method identifies temperature values that deviate significantly from historical ranges. Quality identifier N is assigned based on whether temperature falls within [T_min, T_max] or expanded bounds using 3t and 6t thresholds (where t represents the time variation parameter), as shown in .

Values of quality identifier N for extreme value check and corresponding meaning

T Range	N Value
[T_min, T_max]	0
[T_min-3t, T_min] [T_max, T_max+3t]	3
[T_min-6t, T_min-3t] [T_max+3t, T_max+6t]	6
(-∞, T_min-6t] [T_max+6t, +∞)	9

1.2.5 Invariable Value Check This method checks for consecutive identical values over time. Quality identifier N is assigned based on the duration of invariable values, as detailed in .

Values of quality identifier N for comprehensive check of time consistency and corresponding meaning

Condition	N Value
n + n = 0	0
n + n = 3	3
n + n = 6	6
n + n 9	9

1.3 Combination Check and Weighted Check

The three comprehensive check results (N , N , N) are synthesized through combination check and weighted check. For combination check, the final quality identifier N is calculated as the product: N = N × N × N , where N = 0 indicates correct data and N > 0 indicates suspicious or erroneous data. For weighted check, the final score F is calculated as the sum: F = N + N + N , where F = 0 represents the highest quality data, with increasing F values indicating decreasing quality.

2 Results and Analysis

2.1 Statistical Analysis of Quality Control Results

Applying the five quality control methods to the RPG-HATPRO-G4 temperature data yields the distribution of quality identifiers shown in . For data below 500 m, over 50% receive N = N = N = 0 (highest quality). The weighted check method flags 84.21% of data as high quality (F = 0), demonstrating effective identification of problematic data.

Corresponding data number and frequency of weighted check result F (N +N +N) in different weather conditions

Weather Condition	F=0 (%)	F=3 (%)	F=6 (%)	F 9 (%)
Clear	811,859 (90.192)	56,846 (6.315)	4,409 (0.045)	17 (0.004)
Cloudy	436,926 (91.439)	14,930 (1.659)	698 (0.078)	3 (0.001)
Precipitation	301,201 (92.166)	14,076 (1.564)	94 (0.010)	1 (0.000)

2.3 Parameter Sensitivity Analysis

The standard deviation thresholds ( ) for n and n checks significantly impact quality control results. Analysis shows that when Δ (the relative change in) ranges from -25% to +25%, the percentage of data flagged as high quality (F = 0) varies by less than 2.5%, indicating robust performance. However, when Δt' exceeds thresholds, n > 0 and n > 0 increase substantially, leading to more data being flagged as suspicious.

2.4 Correlation Analysis with Sounding Data

Comparison with 9,679 concurrent sounding profiles reveals significant improvement in data quality after applying the quality control procedures. Before quality control, correlation coefficients between radiometer and sounding temperatures are 0.967 (clear), 0.934 (cloudy), and 0.880 (precipitation). After weighted check (F = 0), these improve to 0.992, 0.981, and 0.965, respectively, with the most pronounced improvement occurring in precipitation conditions [Figure 1: see original paper].

[Figure 1: see original paper] Variation of correlation coefficients (R) along with height before and after quality control of weighted check method (F) in different weather conditions

3 Conclusions

(1) The five quality control methods effectively identify different types of errors in RPG-HATPRO-G4 temperature data. Data quality is highest under clear weather conditions, followed by cloudy weather, with precipitation weather producing the lowest quality data. High-quality data account for 97.86%, 97.83%, and 84.21% of observations under these three conditions, respectively.

(2) Both combination check and weighted check demonstrate strong capability in assessing data quality, with results being sensitive to control parameters. The correlation analysis confirms that quality-controlled data show significantly improved agreement with sounding data, particularly in precipitation conditions where the quality control effect is most obvious.

(3) The proposed quality control scheme is feasible and provides a robust mechanism for distilling reliable temperature data from the RPG-HATPRO-G4 ground-based microwave radiometer for meteorological applications.

References

[1] ZAHUMENSKY I, SHMIJ. Guidelines on quality control procedures for data from automatic weather stations[S]. World Meteorological Organization, 2004.

[2] TIAN Lei, SUN Yanqiao, HU Wendong, et al. Preliminary analysis of the characteristics of atmospheric water vapor and cloud liquid water in Yinchuan area[J]. Plateau Meteorology, 2013, 32(6): 1774-1779.

[3] LIU Xiaoning, REN Zhihua. Progress in quality control of surface meteorological data[J]. Meteorological Science and Technology, 2005, 33(3): 199-203.

[4] WANG Bomin. A study on synthetic differentiation method for basic meteorological data quality control[J]. Journal of Applied Meteorological Science, 2004, 15(Suppl.): 50-58.

[5] REN Zhihua, LIU Xiaoning, YANG Wenxia. Complex quality control and analysis of extremely abnormal meteorological data[J]. Acta Meteorologica Sinica, 2005, 63(4): 526-533.

[6] LI Qing, HU Fangchao, CHU Yanli, et al. Consistency analysis and correction of the brightness temperature data observed with a ground-based microwave radiometer in Beijing[J]. Remote Sensing Technology and Application, 2014, 29(4): 547-556.

[7] HUANG Jianping, HE Min, YAN Hongru, et al. A study of liquid water path and precipitable water vapor in Lanzhou area using ground-based microwave radiometer[J]. Chinese Journal of Atmospheric Sciences, 2010, 34(3): 548-558.

[8] CHEN Tianyu, CHEN Qian, DING Ruijin. Relationship between atmospheric vapor content monitored by ground-based microwave radiometer and rain intensity in Zhangye Prefecture[J]. Arid Land Geography, 2007, 30(4): 501-506.

[9] ZHAO Weizhong, SUN Yanqiao, SANG Jianren, et al. Remote measuring water vapor distribution of Ningxia atmosphere with ground-based dual-channel microwave radiator[J]. Ningxia Engineering Technology, 2011, 10(1): 7-11.

[10] ZHANG Qiuchen, GONG Dianli, FENG Junjie. Analysis and evaluation of retrieval products of RPG-HATPRO-G3 ground-based microwave radiometers[J]. Journal of Marine Meteorology, 2017, 37(1): 104-110.

[11] LIU Hongyan, WANG Yingchun, WANG Jingli, et al. Preliminary analysis of the characteristics of precipitable water vapor measured by the ground-based 12-channel microwave radiometer in Beijing[J]. Chinese Journal of Atmospheric Sciences, 2009, 33(2): 388-396.

[12] YAO Junqiang, YANG Qing, HAN Xueyun, et al. Analysis on daily variation of water vapor and its relationship with rainfall in Urumqi in summer[J]. Arid Zone Research, 2013, 30(1): 67-73.

[13] ZHANG Qiuchen, GONG Dianli, FENG Junjie. Applicability analysis of air temperature and humidity data retrieved from a RPG-HATPRO microwave radiometer[J]. Journal of Applied Meteorological Science, 2017, 28(2): 209-217.

[14] GUO Lijun, GUO Xueliang. Verification study of the atmospheric temperature and humidity profiles retrieved from the ground-based multi-channels microwave radiometer for persistent foggy weather events in northern China[J]. Acta Meteorologica Sinica, 2015, 73(2): 368-381.

[15] ZHU Yuanjing, HU Chengda, ZHEN Jinming, et al. The role of microwave radiometer in weather modification research[J]. Acta Scientiarum Naturalium Universitatis Pekinensis, 1994, 30(5): 597-606.

[16] LEI Hengchi, WEI Chong, SHEN Zhilai, et al. Microwave radiometric measurement on water vapor and cloud liquid water before rainfall[J]. Quarterly Journal of Applied Meteorology, 2001, 12(Suppl.): 73-79.

[17] HUANG Zhiyong, XU Guirong, WANG Xiaofang, et al. Applications of ground-based microwave radiation data to short-term rainstorm and potential forecast[J]. Quarterly Journal of Applied Meteorology, 2013, 24(5): 576-584.

[18] DANG Zhangli, ZHANG Jingpeng, QU Zongxi, et al. The application of microwave radiometer observation data on precipitation forecast[J]. Journal of Arid Meteorology, 2015, 33(2): 340-343.

[19] WANG Xiaokang, XU Guirong, YUAN Kun. Different characteristic analysis of inversion parameters for heavy rainfall and weak rainfall by microwave radiometer data[J]. Torrential Rain and Disasters, 2016, 35(3): 227-233.

[20] ZHANG Wengang, XU Guirong, LIAO Kewen, et al. Impact of precipitation on the retrieval deviation of ground-based microwave radiometer[J]. Torrential Rain and Disasters, 2013, 32(1): 70-76.

[21] LIU Hongyan. The temperature profile comparison between the ground-based microwave radiometer and the other instrument for the three years[J]. Acta Meteorologica Sinica, 2011, 69(4): 719-728.

[22] LIU Jianzhong, HE Hui, ZHANG Qiang. Evaluation and analysis of retrieval products of ground-based microwave radiometers at different times[J]. Meteorological Science and Technology, 2012, 40(3): 332-339.

[23] HAN Juejing, CHEN Fei, ZHANG Zhen, et al. Assessment and characteristics of MP-3000A ground-based microwave radiometer[J]. Meteorological Monthly, 2015, 41(2): 226-233.

[24] ZHU Yayu, WANG Zhenhui, CHU Yanli, et al. Comprehensive quality control and efficiency analysis on brightness temperature data by ground-based

microwave radiometer[J]. Journal of the Meteorological Sciences, 2015, 35(5): 621-628.

[25] FU Xinshu, TAN Jianguo. Quality control of temperature and humidity profile retrievals from ground-based microwave radiometer[J]. Journal of Applied Meteorological Science, 2017, 28(2): 209-217.

[26] COLLINS W G. The operational complex quality control of radiosonde heights and temperatures at the national centers for environmental prediction[J]. Journal of Applied Meteorology, 2001, 40(2): 152-168.

[27] DURRE I M, VOSE R S, WUERTZ D B. Robust automated quality assurance of radiosonde temperatures[J]. Journal of Applied Meteorology and Climatology, 2008, 47(8): 2081-2095.

[28] XIONG Anyuan. Quality control of meteorological observational data in Nordic countries[J]. Meteorological Science and Technology, 2003, 31(5): 314-320.

[29] ZHANG Zhifu. Quality control schemes for hourly soil moisture from automatic weather stations in China[J]. Arid Land Geography, 2013, 36(1): 101-108.

[30] AO Xue, WANG Zhenhui, XU Guirong, et al. Study on the quality control of brightness temperature data observed with ground-based microwave radiometer[J]. Journal of the Meteorological Sciences, 2013, 33(2): 130-137.

[31] LI Jianqiang, LI Xinsheng, DONG Wenxiao, et al. Applicability analysis of air temperature and humidity data retrieved from a RPG-HATPRO microwave radiometer[J]. Journal of Meteorology and Environment, 2017, 33(6): 89-95.

[32] LIU Zengqiang, ZHENG Yuping, LI Jinglin, et al. Temperature inversion characteristics of low-atmosphere of Urumqi City[J]. Arid Land Geography, 2007, 30(3): 351-356.

[33] HUANG Runheng, ZOU Shouxiang. Remote sensing of total water vapor and liquid content of cloudy atmosphere by two-wavelength microwave radiometry[J]. Scientia Atmospherica Sinica, 1987, 11(4): 397-403.

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv —Machine translation. Verify with original.