Study of Quality Control and Assimilation of Ground-based GPS ZTD in North China

ZHONG Jiqin[1] Yong-Run GUO[2] ZHANG Jingjiang[1]
1. Institute of Urban Meteorology, CMA, Beijing 100089
2. National Center for Atmospheric Research. P. O. Box 3000, Boulder, CO 80307
jqzhong@ium.cn

Abstract

Based on a data serial of North China Ground-based GPS Zenith Total Delay that spanning two years from 2013 to 2014, a quality control scheme for ZTD observation is developed. The quality control scheme can check and mark out those data that make statistic character of the data serial away from Gaussion distribution by taking account of observation site stability, accuracy, outliers, systematic bias and standard deviation. The statistic character of data serial that have been processed by quality control module better meets the hypothesis of variational assimilation system, which verifies the validity of the quality control scheme. Analysis of verification scores of continuous simulation experiments show that the performance of experiments assimilating quality controlled ZTD is better than that of experiments assimilating uncontrolled ZTD and assimilating no GPS observation. Conclusion reached by according analysis is that assimilating ZTD can efficiently improve the precipitation forecast skill, which show that the quality control scheme is effective .

Keywords: GPS Zenith Delay, quality control, variational assimilation, numerical prediction

1、Introduction

Studies have investigated the impact of ground-based GPS data assimilation on improving the analysis quality and forecast skill for different weather conditions. At first, methods were developed for assimilating Integrated Water Vapor (IWV) derived from GPS ZTD data and surface pressure and temperature data (Kuo et al. 1993, 1996; Smith et al. 2000; Guo et al. 2005). Then, direct assimilation of ZTD observations enables to remove the errors due to the conversion of GPS ZTD into IWV. Studies show ZTD assimilation improve the skill of the short-range rainfall forecast (Vedel and Huang 2004; Poli et al. 2007; Yan et al. 2009; Bennitt and Jupp 2012).

Observation is rarely perfect. Errors in observation data include random errors and some gross errors. Besides removing o those that contain gross errors, another task of QC for the assimilation is to make sure that the assumptions of a data assimilation algorithm are not strongly violated. The most frequently used variational data assimilation algorithms assume that all errors are of Gaussian type. Therefore, prior to the assimilation of surface temperature data, it is important not only to systematically remove erroneous data and retain good quality data but also to verify that the Gaussian error assumption is approximately satisfied for both the data that passes QC and the background field that is used for assimilation.

A Ground-based GPS network in northern China consists of more than 146 stations. The 30-minute GPS ZTD solutions are computed in real-processing mode. Figure 1 shows the locations of the stations around northern China.

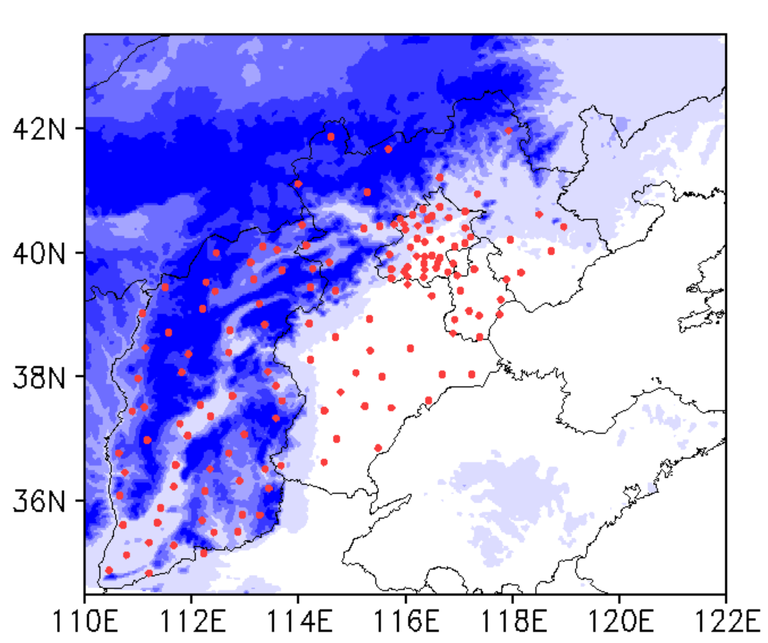

Fig 1. Ground-based GPS receiver location in Beijing, Tianjin, Hebei and Shanxi.

2、Observation

ZTD observation indicate the humidity information in the atmosphere. Typical range of ZTD in Beijing is between 1.9m and 2.8m with maximum in summer and minimum in winter. it varies within a much larger range in summer than in winter. ZTD observation on adjacent station can be much different when their station elevation differs obviously.

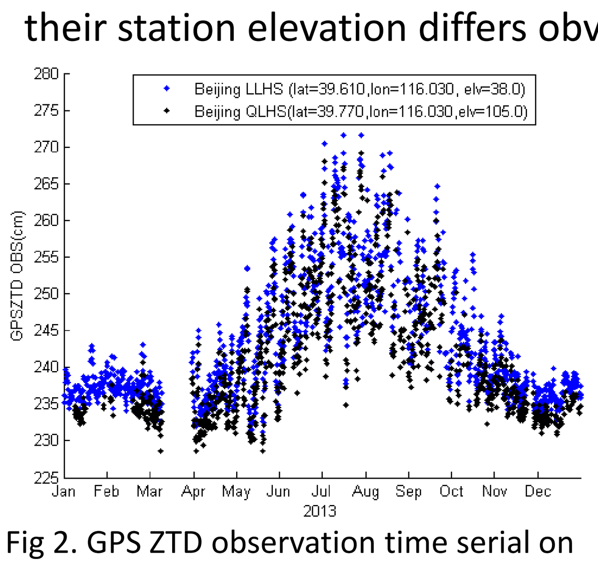

Fig 2. GPS ZTD observation time serial on station LLHS and station QLHS.

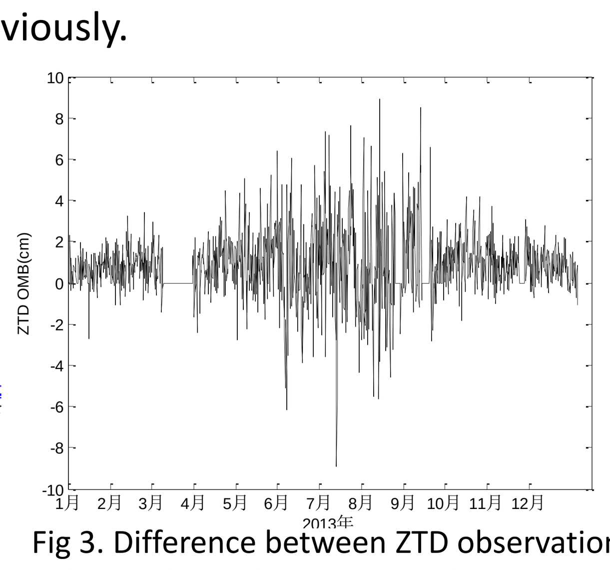

Fig 3. Difference between ZTD observation and according value in GFS analysis on LLHS.

Difference between ZTD observation and according GFS analysis up to 9 cm can be seen, and deviations are seen both as short sharp spikes and lower-frequency fluctuations. The short sharp spikes may be more indicative of higher resolution meteorological fluctuations ,which cannot be represented by NWP models because of the constraints on temporal and spatial resolution, and also may be result of bad observing quality.

3、Quality control

Prior to the assimilation, it is important not only to systematically remove erroneous data and retain good quality data but also to verify that the Gaussian error assumption is approximately satisfied for both the data that passes QC and the background field that is used for assimilation. Since the truth is not available, a feasible approach is to verify that the frequency distribution of the differences between the background fields and observations (i.e., observation increments) is Gaussian. It is a necessary condition for both the background errors and observation errors to be Gaussian since the sum of two random variables with Gaussian distributions is Gaussian.

The QC scheme is based on the hypothesis of ZTD observation in one month meet the "independent and identically distributed". The latter implies ZTD samples in one month are homogeneity, which in the time series perspective is statistical stationarity.

Several serials are set up as followings:

SSobs serial is consist of ZTD observation samples of Single station in Single month

SSomb seirial is consist of omb samples of Single station in Single month

ASobs serial is consist of ZTD observation samples of All stations in Single month

ASomb seirial is consist of omb samples of All stations in Single month

Quality Control Scheme:

- Deriving error and statbility check（QC1）
- Biweight check (QC2）
- Bias correction (QC3)
- Standard deviation check (QC4)

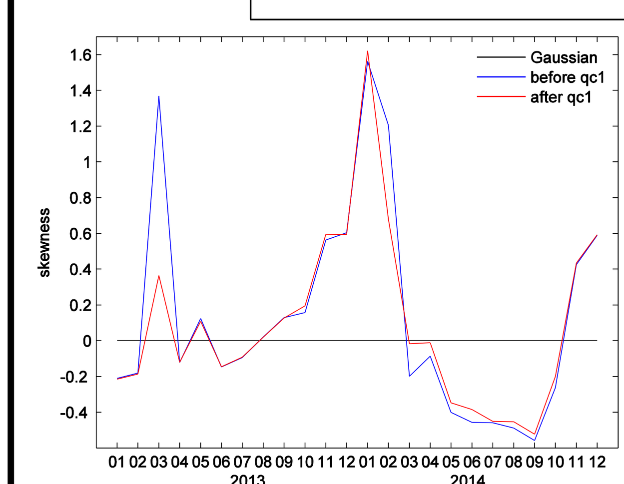

Fig. 4. Skewness of ASobs serial before and after QC1 during 2013-2014

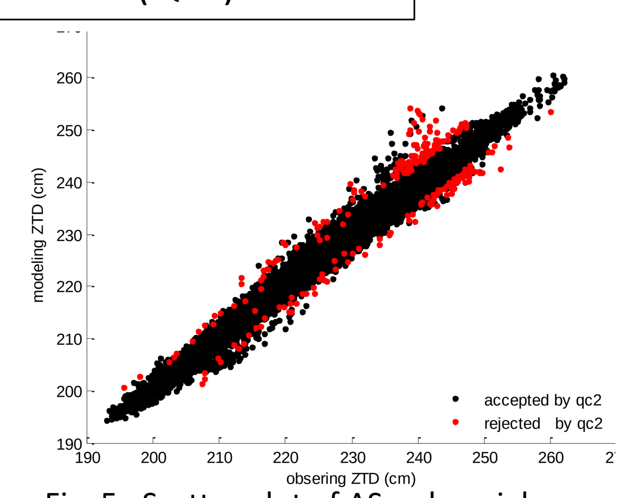

Fig. 5. Scatter plot of ASomb serial before and after QC2 on May 2014

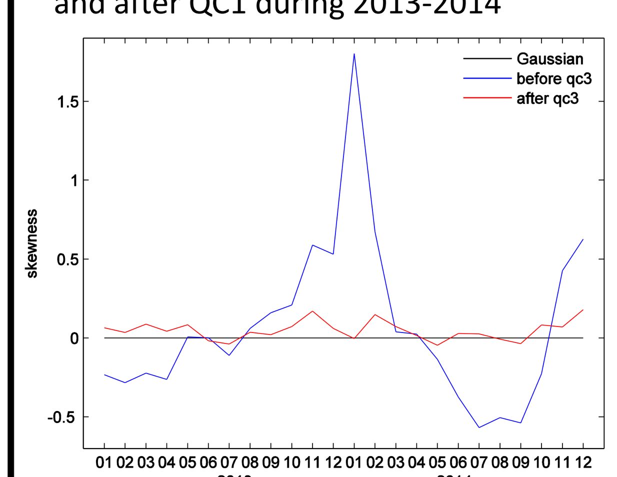

Fig. 6. Skewness of ASomb serial before and after QC3 during 2013-2014

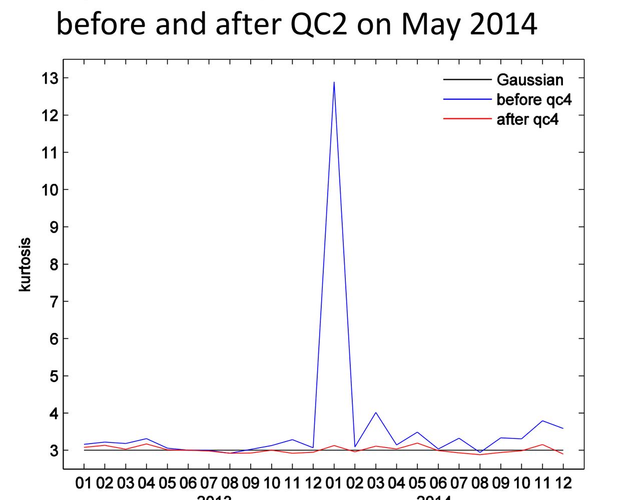

Fig. 7. Kurtosis of ASomb serial before and after QC4 during 2013-2014

QC1 is carried out on SSobs serial. Station whose sample valid ratio is less than 2/3 will be marked out. ZTD samples with a deriving error more than 10mm will be marked out.

QC2 is carried out on SSomb serial. The Biweight Zscore threshold is set to 3. samples in SSomb serial with a z score greater than 3 will be marked out as outliers of SSomb serial.

QC3 is carried out on SSomb serial. The bias is calculated from a average of observation minus first-guess differences on a time period of one month. Every sample in SSomb serial will be corrected with bias calculated.

QC4 is carried out on ASomb serial. A station will be marked out while its SSomb serial standard deviation is greater than the according ASomb serial standard deviation by 25%.

Pick out all observations and stations marked out by every step from QC1-QC4, serial PDF fits Gaussian better.

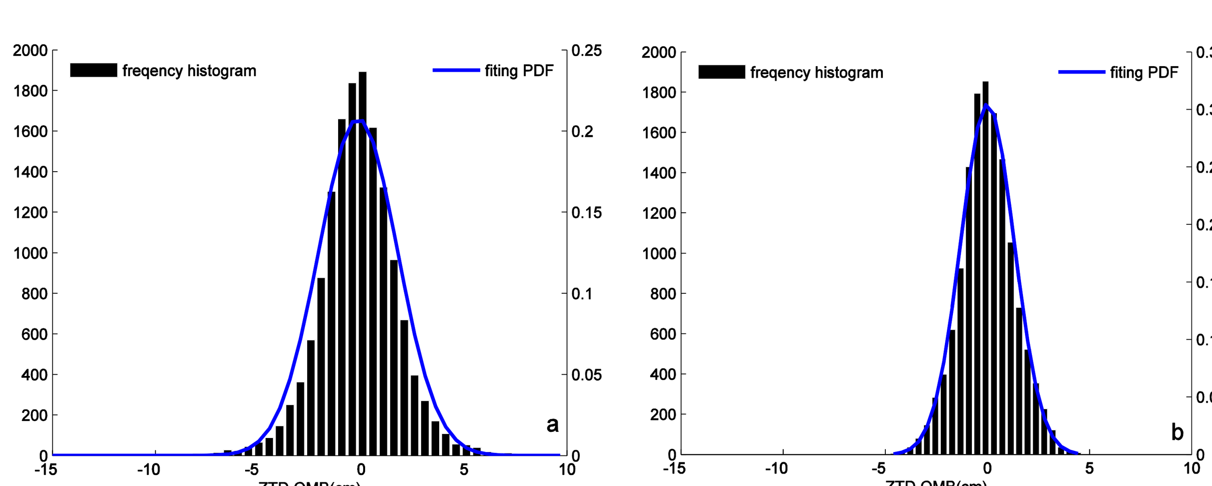

Fig. 8. Histogram of distribution of the ASomb serial (a)before QC1 and (b) after QC4 on May 2015. The blue curve is the Gaussian fitting.

4、Assimilation & forecast

Table1. Experiments design

Exp ID	Operating mode & IC BC	Observation assimilated
CNTL	WRFDAv3.1+WRFv3.1 Rapid update and cycling with 3hr update frequency. Cold start on 00UTC with NCEP data as IC and BC Forecast length of 24 hours	synop, sound, amdar, aws.
ZTD_NOQC		synop, sound, amdar, aws, QCed GPSZTD
ZTD_QCED		synop, sound, amdar, aws, raw GPSZTD

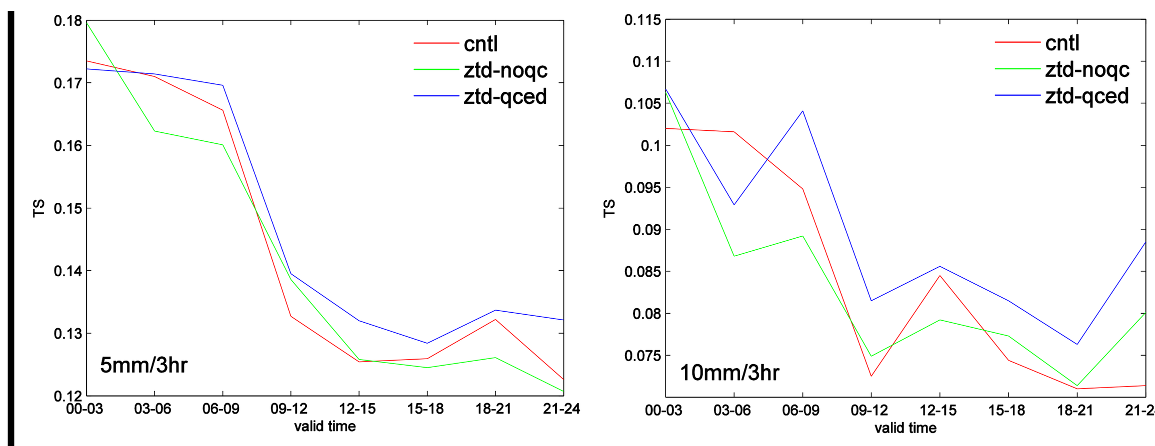

Fig. 9. The averaged 3-hour TS scores for the 3-hour cycled forecasts of different experiments

Assimilating Qced ZTD bring more positive impact on 5mm/3hr and 10mm/3hr precipitation forecast performance described as TS, comparing to experiment assimilating no GPS observation and raw ZTD.

Look into the verification detail, it is found that the increasing of TS benefits more from the decreasing of false alarm and missing than increasing of hit.

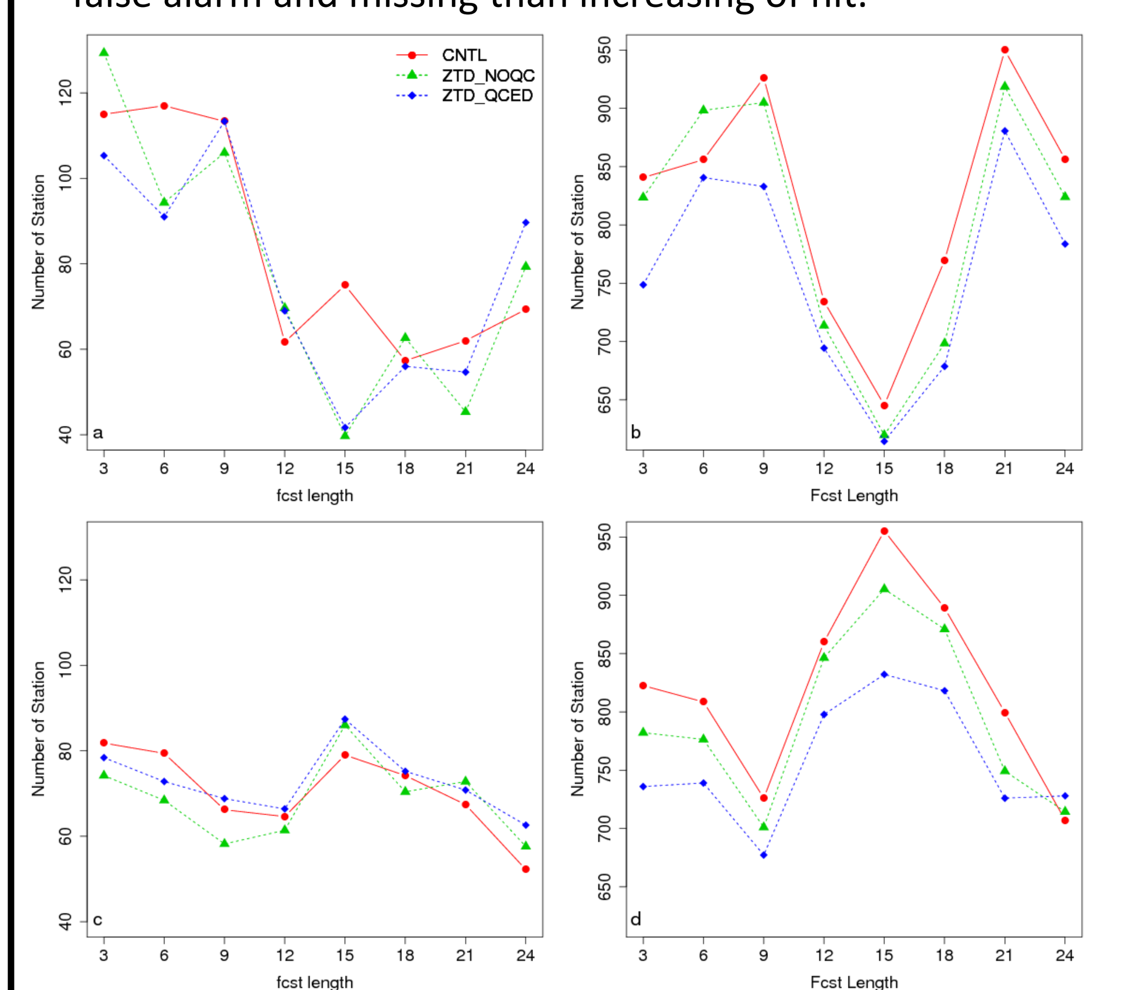

Fig. 10. the average hit station number from experiments assimilating (a) sounding data (c) no sounding data， and the average false alarm and missing station numbers from experiments assimilating (b) sounding data (d) no sounding data for 3-hour accumulated precipitation on different forecasting valid time.

5、Conclusion

A quality control scheme of Ground-based GPS ZTD observation is developed on base of a dataset of north China ZTD observation during 2013-2014. Statistical analysis is conducted against both raw dataset and quality controlled dataset to verify the reasonableness of the QC scheme. Data assimilation and forecast experiments results are carried out to verify the effectiveness of the QC scheme.

the QC scheme pick off the station with low stability and the observing data with high deriving error. It also identifies both the outliers in the observing data serial and all data observed by a station which appears high dispersion. Statistical analysis shows dataset after quality control present a more Gaussian histogram. Quality control procedure makes observation better meet the hypothesis of variational system.

Rapid fresh assimilation and forecast experiments results shows that assimilating QCed ZTD data improve the precipitation skill at most valid times, while comparing experiments assimilating QCed ZTD with experiments both assimilating no GPS data and assimilating raw ZTD data, especially in those experiments started at the time with no SOUND data.

Reference

Bennitt Gemma V. and Adrian Jupp, 2012: Operational assimilation of GPS Zenith Total Delay observations into the Met Office numerical weather prediction models. *Mon. Wea. Rev.*, **140**, 2706-2719.

Guo, Y.-R., H. Kusaka, et, al. 2005: Impact of ground-based GPS PW and MM5-3DVar background error statistics on forecast of a convective case. *SOLA*, **1**, 73-76.

Kuo, Y.-H, Y.-R. Guo, and E. R. Westwater, 1993:Assimilation of precipitable water into Mesoscale numerical model. *Mon. Wea. Rev*. **121**, 1215-1238.

Kuo,Y.-H, X. Zou, and Y.-R. Guo, 1996: Variational assimilation of precipitable water using nonhydrostatic mesoscale adjoint model. *Mon. Wea. Rev.* **124**, 122-147.-

Poli, P., P. Moll, et, al. 2007: Forecast impact studies of zenith total delay data from European near real-time GPS stations in Meteo France 4DVAR. *J. Geophys. Res.*, **112**, D06114, doi:10.1029/2006JD007430.

Vedel, H., and X.-Y. Huang, 2004: Impact of Ground based GPS data on numerical weather prediction. *J. Metero. Sco. Japan*, **82**, 459-472.

Vedel, H., and X.-Y. Huang, 2004: Impact of Ground based GPS data on numerical weather prediction. *J. Metero. Sco. Japan*, **82**, 459-472.

Yan, X., V. Ducrocq, et, al. 2009: Impact of GPS zenith delay assimilation on convective-scale prediction of Mediterranean heavy rainfall. *J. Geophys. Res.*, **114**, D03104, doi:10.1029/2008JD011036.