Bias Correction of Daily Precipitation Measurements for Mongolia

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Introduction

Fluctuations in precipitation profoundly impact water cycles and water resources at both regional and global scales. Accurate ground truth of precipitation is absolutely critical for regional and global climatic and hydrologic simulations. However, measured precipitation from standard national gauge networks has long been known to underestimate true precipitation amounts. In addition, measured amounts can be incompatible across national boundaries (UNESCO, 1978; Sevruk, 1989; Karl et al., 1993; Legates, 1995). Systematic errors (i.e., biases) in precipitation measurement are caused by wind-induced under-catch, wetting, evaporation-loss, and uncounted trace events and affect all types of precipitation gauges (Goodison et al., 1981; Sevruk, 1982; Tabler et al., 1990). With knowledge of the magnitude of the errors and their variation among gauges, the need to correct the biases has been more widely acknowledged. Such bias correction will ameliorate the potential effects on regional, national, and global climatic and hydrologic studies (Groisman et al., 1991; Groisman and Easterling, 1994; Goodison and Yang, 1995; Desbois and Desalmand, 1995).

The World Meteorological Organization (WMO) began the solid precipitation measurement intercomparison project in 1985 (Goodison et al., 1989) to assess various national methods of observing solid precipitation. The octagonal vertical Double Fence surrounding a shielded Tretyakov gauge is the Intercomparison Reference (DFIR) recommended by WMO. Bias correction techniques were developed for other precipitation gauges commonly used worldwide. These correction procedures are recommended in those countries where national meteorological or hydrological station networks use the biased gauges to measure precipitation (Goodison et al., 1998). The bias correction has recently yielded significantly higher estimates of precipitation in some countries (Yang et al., 1998).

Mongolia has a continental climate influenced predominantly by a Siberian high-pressure cell called the Mongolian or Asiatic high. This high is often centered over northern Mongolia from winter through late spring .In addition, the midlatitude westerly jet converges with monsoonal airflow from the southwest over Mongolia (Yatagai and Yasunari, 1995). Forests and rangeland cover 8.1% and more than 80% of the total area of the country, respectively, . Permafrost is present over about 63% of Mongolia, which is on the southern fringe of Siberian permafrost. Meteorological instrumentation began in the 1940s, and a network of 31 meteorological stations. However, few studies on precipitation climatology have been reported.

To improve the accuracy of gauge-measured precipitation in Mongolia, the bias-correction methodology developed by the WMO Solid

Precipitation Measurement Intercomparison Project was applied for 31 meteorological stations in Mongolia for 20 years (1980-1999). The magnitudes of the biases and their seasonal and spatial variability were computed. Interannual changes in the bias-correction were investigated by coupling changes to measured annual precipitation. Bias correction performed in this study should significantly improve the accuracy of observed precipitation data and will meaningfully impact climate monitoring and hydrological modeling in arid- and mid-latitude regions, such as Mongolia.

Using data and methodology

Data

Daily observations of temperature, wind speed, precipitation, and snow depth for the period 1980 to 1999 were used in this study. These data are from 31 meteorological stations, including the mean annual values of air temperature, gauge-measured precipitation and wind speed, were used for this work.

Methodology for bias correction

A bias-correction method for precipitation measured by the Tretyakov gauge has been developed and applied to Siberian data (Yang et al., 1998, Yang and Ohata, 2001). This work follows those studies and uses daily climatic data, including maximum, minimum, and mean air temperature, measured precipitation, and wind speed. The general precipitation correction formula is (Sevruk and Hamon 1984):

$$Pc = K(Pg + \Delta Pw + \Delta Pe) + \Delta Pt, \qquad (1)$$

where Pc is the corrected precipitation, K is the wind-loss correction coefficient (usually K>1) for wind-induced errors, Pg is the gauge-measured precipitation, ΔPw is wetting-loss refers to the rain or snow water subject to evaporation from the surface of the inner walls of the gauge after a precipitation event and from the gauge container after its emptying (WMO/CIMO, 1993). ΔPe is evaporation-loss, which is defined as the under-measurement caused by water loss by evaporation before observation. ΔPt is the trace precipitation, which denotes a precipitation event of less than 0.10 mm is beyond the resolution of the Tretyakov gauge measurement. Officially, all of the trace precipitation is treated quantitatively as a zero event, which contributes nothing to the monthly totals.

The correction coefficient (K), a function of the catch ratio (CR), is expressed as $K = 100/CR$. For the WMO Inter-Comparison Project, catch ratio was defined as the ratio of the amount of precipitation caught by a gauge (including the recorded amount and wetting-loss) to the true precipitation (Goodison et al. 1998). WMO has recommended DFIR measured precipitation instead of "true precipitation" to calculate CR (CR = measured/DFIR). A catch ratio that is a function of wind speed and air temperature was developed for the Tretyakov gauge using WMO intercomparison data (Yang et al. 1995; Goodison et al. 1998). The WMO experiments found that wind speed was the most important factor determining gauge catch; air temperature had a secondary effect when precipitation was classified into snow, mixed, or rain. The equations for gauge catch ratio versus wind speed (Ws) at gauge height and daily maximum and minimum temperature (Tmax, Tmin) on a daily time step for various precipitation types are given below. CR has units of %; Ws is in m/s; and air temperatures are in °C.

$$CR\,(snow) = 103.10 - 8.67\,Ws + 0.30Tmax, \qquad (2)$$

$$CR(mixed) = 97 - 4.5Ws + 0.88Tmax + 0.22Tmin, \qquad (3)$$

$$CR\,(rain) = 100.00 - 4.77\,Ws^{0.56}, \qquad (4)$$

Once the daily wind speed at gauge height was determined and air temperature was valid that measured at gauge height in Mongolia, the daily catch ratio (CR) for the Tretyakov gauge was calculated using regression equations (2) - (4) for snow, mixed precipitation and rain, respectively. The correction equations developed for the WMO intercomparison dataset are used over a great range of environment conditions. Therefore, it is important that the combined dataset contains a wide range of wind speeds and catch ratios. The performance of the correction equations was checked independently using intercomparison data for 11 WMO experimental stations. At most of the stations, the differences between the overall totals of corrected precipitation and the true precipitation were within 10% for snow, and were less than 5% for both rain and mixed precipitation (Yang et al. 1995, Yang and Ohata, 2001).

Result of correction implementation

For the period 1980 to 1999, Average total yearly corrections range from 15.2 (Station no. 24) to 80.6 (Station no. 21) mm, which is 17 to 42% of their gauge-measured annual precipitation respectively. Average yearly corrections for the wind-induced under-catch range from 4.4 to 48.4 mm per year, which is 5 to 30% of their gauge-measured annual precipitation respectively. The average yearly corrections for wetting-loss vary from 3.7 to 18.5 mm, which is 3 to 9% of their gauge-measured annual precipitation respectively.

The annual mean corrections for evaporation range from 5.1 to 24.6 mm, which is 4 to 11% of the gauge-measured annual precipitation. The evaporation-loss bias is slightly higher than for previous work for Siberia, where estimates of 2 to 8% of the gauge-measured total precipitation were obtained (Groisman et al., 1991). This difference should be anticipated, however, considering the climate features of Mongolia. The climatic condition in Siberia is characterized by cold-moist atmosphere. The minimum of mean annual air temperature among 62 meteorological stations has been reported to be –16.0 °C (Yang and Ohata, 2001), which much lower that recorded in Mongolia. The annual evaporation loss in Siberia region, therefore, is expected to be small. Yang and Ohata (2001) neglected this component when they performed bias correction in Siberia region. For arid region like Mongolia, the evaporation loss should a significant component in bias of measured precipitation due to evaporation rate has been evidenced to be very large. It has been reported that more than 90% of annual precipitation is evaporated in Mongolia (Myagmarjav and Davaa, 1999).

Concluding mark

The bias correction procedures derived from the WMO Solid Precipitation Measurement Intercomparison dataset for the Tretyakov gauge were applied at 31 climate stations in Mongolia regions with a 20-year record. Biases from wind-induced under-catch, wetting-loss, and evaporation-loss were corrected daily. The results show that the gauge-measured annual precipitation increased significantly by 15.2 to 80.6 mm (about 17 to 42% of the gauge-measured yearly total). Of the three biases in precipitation measurement, wind-loss was the greatest at stations located in prairie and forest areas. Evaporation from water deposited in the gauge before precipitation is observed and wetting-loss of precipitation were also a significant source of bias in regions with low precipitation.

The correction factor (*CF*) is greater in winter than in summer because of the increased effect of wind on under-catch of snowfall. Clear seasonal variation was found in the absolute value of the bias-correction, as well as in each individual component of the correction.

Monthly correction factors differ from station to station in Mongolia. The spatial variation in the bias-correction is related to the spatial distribution in gauge-measured precipitation. The bias correction for gauge-measured annual precipitation over Mongolia was 60-80 mm/year for forests, 20-80 mm/year for steppes, 25-45 mm/year for steppe-deserts, and 15-45 mm/year for the Gobi desert.

There was a negative correlation between the interannual change of the correction factor and the fluctuation in annual precipitation. The bias-correction decreases as gauge-measured precipitation increases, which is caused by a decrease in the proportion of snow to the total precipitation.

REFERENCE

Desbois, M., and F. Desalmand, 1995: Past and present precipitations related to climate changes - methodologies and perspectives, *Bulletin of American Meteorological Society*, 76(7), 1173-1178.

Goodison, B.E., H.L., Ferguson and G.A., McKay, 1981: Comparison of point snowfall measurement techniques, In: *Handbook of Snow*, D.M. Gray and M.D. Male, Eds, Pergamon Press; 200-210.

Goodison B.E., and D. Yang, 1995: In-situ measurement of solid precipitation in high latitudes: the need for correction, *Proc. ACSYS Solid Precipitation Climatology Project Workshop*, Reston, VA, WMO/TD-No.739, WMO, 1-12.

Goodison, B.E., P.Y.T. Louie, and D. Yang, 1998: WMO solid precipitation measurement intercomparison, final report, *WMO/TD-No. 872*, WMO, Geneva, 212pp.

Groisman, P.Ya., and D.R. Easterling, 1994: Variability and trends of total precipitation and snowfall over the United States and Canada, *J. Climate*, 7(1), 184-205.

Karl, T.R., R.G. Quayle, and P. Ya. Groisman, 1993: Detecting climate variations and change: new challenges for observing and data management system, *J. Climate*, **6**(8), 1481-1494.

Legates, D.R., 1995: Global and terrestrial precipitation: a comparative assessment of existing climatologies, Inter. *J. Climate*, **15**, 237-258.

Sevruk, B., 1982: Method of correction for systematic error in point precipitation measurement for operational use, *WMO-No. 589*, 91pp.

Sevruk, B., 1989: Reliability of precipitation measurement, *Proc. International Workshop on Precipitation Measurement* (edited by B. Sevruk), St.Moritz, Switzerland, WMO/IAHS/ETH; 13-19.

Sevruk, B., and W.R. Hamon, 1984: International comparison of national precipitation gauges with a reference pit gauge, *WMO Instrument and Observing Methods Report No.17*, WMO; 111pp.

UNESCO, 1978: World water balance and water resources of the earth, *Studies and reports in hydrology, No. 25*, UNESCO, Paris; 663pp.

WMO/CIMO, 1993: International Organizing Committee for the WMO solid precipitation measurement intercomparison, final report of 6th session, 140 pp.

Yang, D., B.E. Goodison, J.R. Metcalfe, V.S. Golubev, R. Bates, T. Pangburn, and C.L. Hanson, 1998: Accuracy of NWS 8-inch standard non-recording precipitation gauge: result of WMO Intercomparison, *Journal of Atmospheric and Oceanic Technology*, **15**(2), 54-68.1999.

Yang, D., B.E. Goodison, J.R. Metcalfe, V.S. Golubev, E. Elomaa, Th. Gunther, R. Bates, T. Pangburn, C.L. Hanson, D. Emerson, V. Copaciu, and J. Milkovic, 1995: Accuracy of Tretyakov precipitation gauge: results of WMO Intercomparison, *Hydrological Processes*, **9**(8), 877-895.

Yang, Daqing and T. Ohata. 2001: A Bias-Corrected Siberian Regional Precipitation Climatology. *Journal of Hydrometeorology*, **2**(2), pp. 122–139.

Yatagai, A., and Yasunari, T., 1995: Interannual variations of summer precipitation in the arid/semi-arid region in China and Mongolia: The regionality and relation to Asian summer monsoon, *J. Meteor. Soc. Japan*, **73**, 909-923.