A Framework for the Analysis of Uncertainty in the Measurement of Precipitation Data: a Case Study for Nepal

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ABSTRACT

Uncertainty is prevalent in the result of any hydrological modeling studies. The uncertainty in a hydrological model is a function of uncertainty in input data, model parameters and the structure of the model. As precipitation is the driving variable of hydrological models, the uncertainty in precipitation input data is considered as the most dominant cause of hydrological model uncertainty. Precipitation uncertainty occurs due to two reasons: measurement error and error in representing spatial and temporal variability due to limited sampling. The aim of this study is to develop a general framework for analyzing the uncertainty in precipitation measurement and to apply it as a case study to the Bagmati River basin in Nepal. To analyze the accuracy in precipitation measurement, a qualitative approach is proposed at first. This approach includes preparation of enquiry lists, field survey of the precipitation gauging stations and the assessment of dominant errors in precipitation measurement based on the field study. Finally, the dominant sources of errors are evaluated in a quantitative way using error correction approach. From the analysis of qualitative study, wind error is identified as a major source of error, followed by wetting error and evaporation error. The result of the quantitative analysis shows that the total error in precipitation for the basin is less than 15%. However, the contribution of error due to human (both observation and data handling error) can not be given any specific value and this error should not be neglected. The only way to reduce this error is to implement strict quality control measures.

Keywords: Uncertainty, precipitation, enquiry list, Bagmati River, wind error

1. INTRODUCTION

Hydrological models are important tools for understanding the process and estimating the hydrological variables of interest required for water resources management. However, any model is imperfect since the results obtained from the model do not necessarily correspond to the values observed in reality. This discrepancy or model error is a result of the uncertainties in the modeling process. The stochastic variability and the lack of knowledge about the hydrological process are the causes of uncertainty in any hydrological modeling system. Stochastic variability is a result of inherent randomness of the natural system, which occurs in both temporal and spatial realm. It is usually not reducible, but can be quantified. Knowledge error can be reduced through further measurement or improved models.

There are three sources of uncertainty in hydrological modeling: input data, parameters and structure of model. A detailed review of these sources and uncertainty analysis methodologies can be found in Melching (1995). Any hydrological model requires input data, e.g. precipitation, evapotranspiration (which is usually computed from climatological data like temperature, humidity, wind speed, radiation), topographic, soil, land use and vegetation data, etc. There is uncertainty in input data due to the measurement errors and spatial and temporal sampling errors. Parameters are constants which represent the behavior of the system. Two types of parameters are used in hydrological model: physical parameters which are measurable and conceptual parameters which are not measurable. The only way to determine the conceptual parameters is by calibration, which is an adjustment procedure to match historical observations. In principle, physical parameters can be measured or estimated from catchment characteristics. However, in practice, the physical parameters in many cases have to be calibrated due to unknown spatial heterogeneity of parameter values and the cost involved in measurements. The parameters are uncertain as they can not actually represent the heterogeneous nature of the hydrological system. Both input and observed output data, e.g. discharge are required during calibration. Therefore, any uncertainty in both input and output data affects the parameters and the model results. Hydrological phenomenon is extremely complex in nature. For the purpose of modeling, simplified theory is used to represent hydrological processes. Thus, the model-structure uncertainty arises due to the inability of the model to truly represent a natural process.

Precipitation is a key input variable in any hydrological modeling studies. Though satellite based precipitation data is becoming widely available in recent days, ground based precipitation data is still used widely in modeling hydrological processes because ground based precipitation is available in all parts of the world and it is considered more reliable than the satellite and radar based data. Therefore, the focus of this research is to study the uncertainty in ground based precipitation data. The causes of uncertainty in ground precipitation data are:

- Error in measurement: There is uncertainty in precipitation data due to the errors in measurement. Those errors could be random or systematic. Random error occurs due to the error in instrument and observations. Random error is undetectable, which follows some probability distribution. Systematic error causes bias.
- Spatial and temporal variability: Measurements of data are made at discrete interval in time and at a limited number of points since it is not feasible to measure all the spatial and temporal variations. As precipitation is highly variable in both space and time, there is uncertainty in spatial and temporal representation of precipitation.

A Lot of studies were done in the past on how to correct the various sources of error in precipitation measurement. Among them, WMO (World Meteorological Organization) published an operational manual (Sevruk, 1982), which describes methods of correcting different types of errors in precipitation measurement with diagrams and formulae. WMO also carried out solid precipitation intercomparison project (Goodison et al., 1998), in which 16 countries participated. There were three purposes of this intercomparison: (a) to determine systematic bias errors in national methods of measuring solid precipitation, (b) to derive standard methods for adjusting solid precipitation measurements, and (c) to introduce a reference method of solid precipitation measurement for general use to calibrate any type of precipitation gauge. Legates and Willmott (1990) and Adam and Lettenmaier (2003) estimated the error in precipitation measurement on the global scale. Legates and Willmott (1990) concluded that error in global precipitation is 11%, whereas Adam and Lettenmaier (2003) found that the error in mean annual global terrestrial precipitation is 11.7%. Allerup et al. (1997) presented a sophisticated statistical model for correcting solid, mixed and liquid precipitation. Ye et al. (2004) corrected the precipitation for Chinese gauge. Daliakopoulos et al. (2006) assessed the measurement uncertainty in precipitation time series. Refsgaard et al. (2006) analyzed the uncertainty in river basin data in transforming from one scale to another scale, including the precipitation data.

Most of the uncertainty analysis studies in hydrology focus on parameter uncertainty. In hydrological modeling, a few papers have considered the impact of input data uncertainty, especially precipitation (e.g., Lebel et al., 1987; Storm et al., 1988; Andreassian et al., 2001; Maskey et al., 2004). As Precipitation is the driving variable of the hydrological models, precipitation uncertainty is one of the major factors influencing the uncertainty in model prediction results. The uncertainty in precipitation propagates through the model, thus affecting the model prediction results. On the other hand, if the parameters of a model are determined by calibration, then the erroneous precipitation will make the parameters uncertain. Thus, the quality of precipitation data is one of the most important factors to reduce its uncertainty in hydrological model.

The objectives of this study are:

- to establish a framework for identifying the errors in measurement based on field survey in a qualitative way
- to evaluate the magnitude of dominant sources of errors in a quantitative way.

2. STUDY AREA

The study area for the research is the Bagmati River basin, which is located in the central part of Nepal (Fig. 1). The catchment area of the basin is 2700 square kilometers. It originates in the north of Kathmandu Valley (the capital of Nepal). After flowing through the Kathmandu valley, it passes through the Mahabharat Range (middle mountains) and Siwalik hills and reaches to the Terai (plain area) and finally flows to India to join the Ganges River. The river is fed by springs and monsoon rainfall. The annual average precipitation of the basin is about 1800 mm and it produces 1400 mm of runoff per year on average which accounts for about 75% of annual average rainfall.

The climate of the Bagmati basin can be subdivided into three altitude/climate zones. These are:
(I) Subtropical sub humid zone below 1000 m: The southern most parts of the Bagmati basin including the Siwaliks region lie in this zone.
(II) Warm temperate humid zone between 1000-2000 m: A large part (more than 60 %) of the Bagmati basin lies in warm temperate humid zone between 1000-2000m altitudes
(III) Cool temperate humid zone between 2000-3000 m: Only a small portion (about 5%) of the Bagmati basin falls above 2000m.

Cultivated land is major land use pattern in the upper part of the basin while in middle and lower part of the basin, forest area is seen to be dominant land use type. Majority of built-up area falls on the upper part of basin which represents Kathmandu valley. More than half of the basin area

(58%) is covered by forest. Cultivated land accounts for 38% of the area of the basin while nearly 4% of the land in the basin is barren. Loamy soil texture is dominant in the basin.

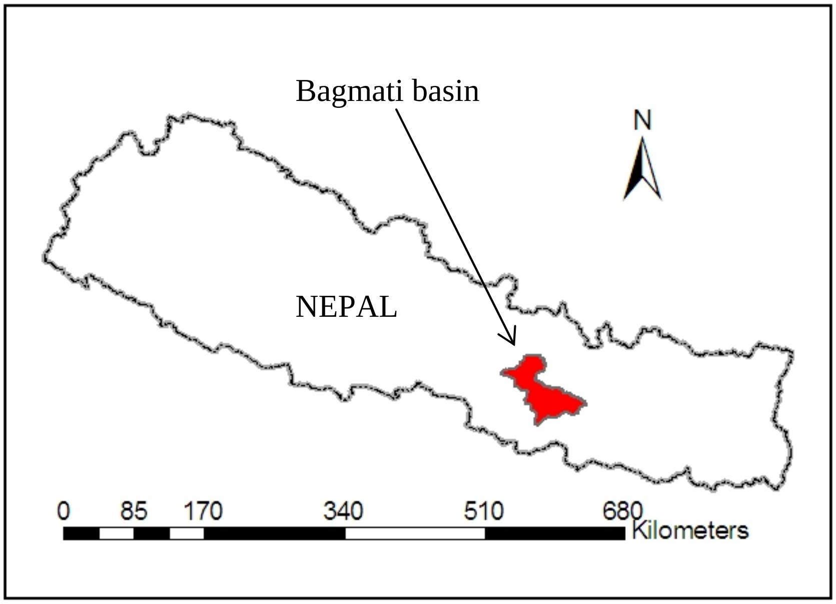

Figure1. Location map of the Bagmati basin in Nepal

3. QUALITATIVE ANALYSIS OF PRECIPITATION UNCERTAINTY MEASUREMENT

3.1 Framework for Qualitative Approach

The first cause of uncertainty in precipitation is the uncertainty in measurement of data. In order to understand the various sources of errors, it is necessary to understand the basics of the measurement in the field. This includes various aspects of measurement e.g., how the precipitation is measured, how about the observer's responsibility to provide quality data, what is the effect of site, climate on the measurement accuracy, what sorts of measures are adopted to control quality etc. In addition, improvement in data quality can be achieved by performing re-checking of data or statistical analysis after observing the data.

The purpose of the qualitative analysis in this study is to explore all possible sources of error in precipitation measurement and to understand what sorts of errors are dominant. In this study, errors in precipitation are classified into two categories: measurement error and error due to interpretation aspects.

Lists of enquiries are proposed to assess the errors in precipitation in a qualitative way. The lists include the following:

(a) General information: General information (see Table A in appendix) provides the basic information about the gauging station.

(b) Enquiry list for measurement error: There are several causes of errors in precipitation measurement. Some of the major causes are:

- Instrumental error: Instrumental error occurs due to instrument breakdown, improper setting of instrument and lack of prompt checking and maintenances.
- Site error: Due to site location and site conditions for setting instrument, there will be underestimation/overestimation of actual precipitation.
- Human error: Human error occurs due to error in observation of data. Furthermore, there is error in data due to the management factors like data transmission, data handling, and lack of quality control.
- Wind error: Wind-induced errors are caused by the wind field deformation over gauge orifice, resulting in a deficient catch.
- Wetting error: Wetting error occurs due to the loss from the surface of the inner walls of the gauge after precipitation event and from the gauge container after emptying.
- Evaporation error: Evaporation error occurs due to the water loss by evaporation before observation.
- Others: such as trace precipitation treated as zero

To understand the various errors in measurement, an enquiry list for measurement error (see Table B in appendix) is proposed, in which the causes of measurement error are classified into five factors: instrumental, site, human, weather and management.

(c) Enquiry list for interpretation aspects: The error in interpretation depends on how the precipitation data is used for modeling purposes. Various aspects of interpretation (see Table C in appendix) include the error coming from spatial interpolation, time averaging, treatment of missing data and precipitation correction. Various aspects of interpretation are important to reduce the error in the particular application. Such aspects are:

- Improvement of gauging network based on statistical analysis to reduce mean areal precipitation error
- Transformation of point to areal data: Mean, variance, correlation, bias distribution etc. to be checked for various methods of interpolation e.g., Thiessen polygon method, Isohyetal method, Inverse distance weighting method, Elevation based method, Spline, Kriging.
- Estimating of missing data: Stations with a significant proportion of the dataset missing should be excluded entirely. This decision is subjective, and will most likely depend upon the availability of other precipitation datasets. Short term missing data can be estimated using the data from nearby gauges or by analyzing previous years' record.
- Correction methodology: Empirical equations/Experimental values/Referred values for various factors and the correction equation to combine different sources.

Table A and Table B are filled for a particular station. Table C is used to understand some of the aspects of interpretation error for a particular area. As the approach proposed here is a qualitative analysis, it is not possible to give any numerical value to a particular error source. However, it is possible to assess the errors giving some ranking based on the enquiry done in the field. In this study, four levels of ranking are used:

0: unacceptable
1: poor
2: good

3: excellent

With the proposed enquiry lists, field visit is done to precipitation gauging sites, interview is conducted with the concerned authorities and an assessment of errors is done.

3.2 Application to the Bagmati River Basin in Nepal

3.2.1 Visited Rain Gauge Sites

Figure 2 shows the map of the Bagmati basin with hydrological and meteorological stations. The basin consists of 17 rain gauge stations and 1 discharge gauging station. The upper part of the basin has higher density of gauge network than the lower part.

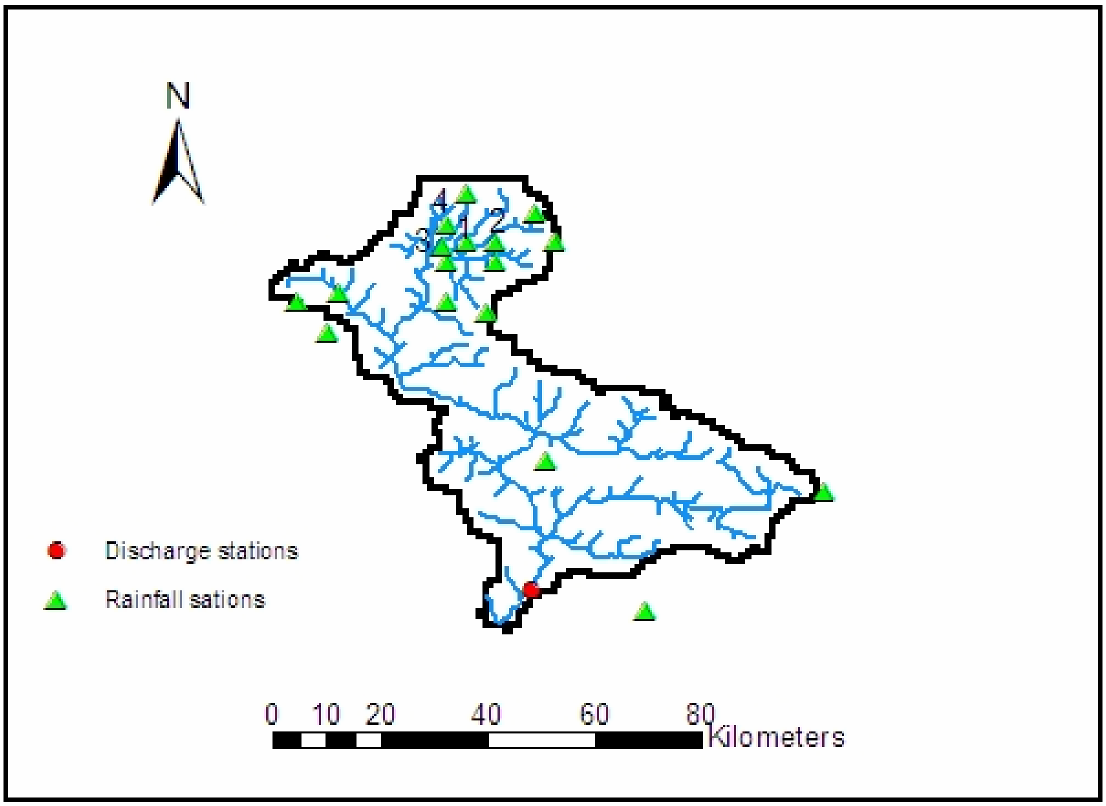

Figure 2. Map of the Bagmati basin and location of rainfall stations

Four of the gauging stations within the basin are considered for field study. They are shown by 1, 2, 3, and 4 in the Figure 2. The description of rainfall stations is shown in Table 1.

The type of installed rain gauges are: both manual and automatic gauge (tipping bucket type) at Kathmandu airport, manual gauge at Changu and Panipokhari, automatic gauge (float type) at Babarmahal. Changu station is located in rural area on the top of mountain, while others are located in the plain urban areas. Based on type of rain gauge and location of the site, four stations selected in this study are considered as representative stations even though they are located in the upstream part of the basin.

Table 1. Description of visited rainfall stations

S.No.	Station name	Latitude (degree)	Longitude (degree)	Elevation (m)	Type of station
1.	Kathmandu airport	27.7	85.367	1336	Aero-synoptic
2.	Changu	27.7	85.417	1543	Precipitation
3.	Panipokhari	27.733	85.333	1335	Climatological
4.	Babarmahal	27.325	85.698	1315	Precipitation

3.2.2 Assessment of Error

The following is the summary of field survey and interview report of four stations regarding measurement error.

Instrumental error: There is prompt checking and maintenance of the instrument time to time. Frequency of checking the instrument is at least once in every month at three stations and once in 2-3 months at Changu. The gauge is cleaned time to time by the observer; fixture and working condition of instruments are regularly checked. In addition, double mass curve analysis is performed to check instrumental error in long term data. Thus, the systematic instrumental error seems to be insignificant.

Site error: Kathmandu airport station is close to the Tribhuvan international airport Kathmandu. Babarmahal and Panipokhari stations are in urban areas. Changu station is on a hill in rural area. All stations are very close to residential area. There is no any influence of building/trees near by the stations. Three stations are on the ground, and one station, Babarmahal, is on the roof. The ground is level for three ground stations. The base of Kathmandu airport station and Babarmahal is concrete block, while the rest two are on wooden support. The gauge setting at all station is vertical. Evaluation of various factors (site location, site conditions, surrounding environment, gauge setting conditions) confirms that there is no significant error in precipitation measurement due to the location and condition of site.

Human error: Observer is layman at Changu and Panipokhari and office staff at Kathmandu airport and Babarmahal. Data handling person for automatic gauge is expert staff (Kathmandu airport and Babarmahal). Maintenance person is office staff having good engineering knowledge on maintenance. Basic training is available for observer at Kathmandu airport and Babarmahal. For other stations, there is no any training, just basic guide is provided by the office staff on how to take measurement. Although the error due to observer's ignorance, fraud can not be analyzed, the concerned office has strictly asked the observers to take the measurement honestly and accurately.

Human error in management of data (data transmission, entry, editing etc.) is reduced by taking several measures. The office has maintained some rules and regulations, e.g. time for recording data, data receiving and dissemination systems. Besides, there are no any fixed operating rules.
To detect any error in recording data, following analyses are done:

- Comparing with nearby stations
- Comparing with previous years record
- Comparing with manual and automatic rain gauge data if any

To detect error in data entry, entered data is rechecked with the paper data. Double mass curve analysis is performed for cross checking for consistency.

Wind error: The form of precipitation in the area is only rain. Average wind speed of the area is 1.3 m/s. Gauge type is manual in most cases and height of gauge orifice above ground is 1.6 m. As wind shield is not provided in any rainfall stations and the stations are located in open place without natural wind protection, the wind error seems to be the most significant in the area.

Table 2. Assessment summary for measurement error

Factors	Assessment index			
	Kathmandu airport	Changu	Panipokhari	Babarmahal
1. Instrumental				
(a) Frequency of checking	3	2	3	3
(b) Wind shield	1	1	1	1
2. Site				
(a) Location	3	3	3	3
(b) Accessibility	3	3	3	3
(c) Influence of nearby objects	3	3	3	3
(d) Gauge support	3	3	3	3
(e) Ground condition	3	3	3	NA
(f) Gauge setting	3	2	2	3
3. Human				
(a) Observer	3	3	3	3
(b) Data handling personnel (automatic gauge)	3	NA	NA	3
(c) Maintenance personnel	3	3	3	3
(d) Training to observer	3	2	2	3
4. Weather				
(a) Wind	2	1	1	1
(b) Freezing condition	NA	NA	NA	NA
(c) Snow in windy condition	NA	NA	NA	NA
(d) Intense rain	3	3	3	3
(e) Evaporation error	2	2	2	2
5. Management factor				
(a) Data transmission, entry/processing	3	3	3	3
(b) Operating rules	2	2	2	2
(c) Checking systems	2	2	2	2

Evaporation error: The climate of the area is temperate with cold winter and hot summer. For automatic gauge, evaporation error is not significant due to continuous measurement. For manual gauge, there is some evaporation error as the frequency of measurement is daily.

Wetting error: Wetting error occurs due to the adhesion of some water on the walls of the container of both the manual and automatic gauges. The wetting error is less for rain than snow. As the manual gauge is emptied daily, there is some wetting error.

Assessment index for various aspects of measurement error is shown in Table 2. The assessment index 1 is on wind shield and wind factors. The assessment index 2 is on gauge setting, training to observer, evaporation error, operating rules and checking systems. For all other factors, assessment index 3 is specified. It can be concluded from the assessment that the wind error is the most dominant. For daily measurement, there is some error due to evaporation. In addition, there is wetting error as some precipitation remains on the gauge due to adhesion. Operating rules and checking systems reduce overall error in measurement. Therefore, some more attention needs to be given for quality control aspects.

The following is the summary of information obtained for interpretation aspects from the Department of Hydrology and Meteorology, Kathmandu, Nepal:
The country average is one gauge for about 500 square kilometers, especially very sparse in mountainous areas. However, the Kathmandu area has high densities of gauge network with one gauge for about 30 square kilometers. Point to area transformation is not done in the office. The method depends on the input data requirement of hydrological model. Data from manual gauge is available for public, which is observed at 8:45 a.m. everyday. Missing data is not estimated. There is no any value adopted for wetting error, no any specific values/ experimental values for evaporation error and no wind error correction. Trace precipitation is recorded, but not given any specific value.

4. QUANTITATIVE ANALYSIS OF PRECIPITATION UNCERTAINTY MEASUREMENT

In the quantitative approach, error correction model is formulated and various sources of error included in the correction model are specified.

4.1 Correction Model

Based on the conclusion of interview, wind error is taken as the dominant source of error. As wetting error and evaporation error has also some influence, the following precipitation correction model is considered, which is based on the correction model of Allerup et al. (1997).

$$P_c = c\left(P_m + ew + et\right) \qquad (1)$$

where

P_c = Corrected precipitation
P_m = Measured precipitation
c = Correction factor for wind
ew = Wetting error
et = Evaporation error

In equation (1), both the wetting error and evaporation error are multiplied by the factor c. Since the wind field deformation affects the total catch, including the wetting error and evaporation error, the amount of wetting error and evaporation error is partly dependent on wind error besides other factors.

4.2 Specification of Errors

4.2.1 Wind Error

Wind error varies with precipitation type, gauge type, height of gauge above ground surface, wind speed and physical surrounding of the gauge. Usually, wind correction factor is expressed as a function of wind speed.

The ordinary rain gauge in Nepal is almost similar to the standard Chinese gauge. Therefore, *c* factor for rain is obtained from regression equation for Chinese gauge (Ye et al., 2004). The regression equation for catch ratio is

$$CR = \exp(-0.041V_g) \qquad (2)$$

where CR = Catch ratio, V_g = Wind speed (m/s) at gauge height

Logarithmic wind reduction equation is used to convert the measured wind speed at certain height to the wind speed at gauge height.

$$V_g = \frac{\log(h / Z_0)}{\log(H / Z_0)} V_H \qquad (3)$$

where

V_g = Wind speed (m/s) at gauge height

h = Height of the gauge orifice (m)

H = Height of the wind speed measurement (m)

Z_0 = Roughness length (m) (usually taken as 0.02m)

V_H = Wind speed measured at height H

c is computed as

$$c = 1 / CR \qquad (4)$$

According to equations (2), (3) and (4), when wind speed increases, *c* increases. However, if the wind speed is very low, the error in measurement is not significant. So, the observed catch can be considered as actual catch in such case. In case of high wind speed, the increase of wind speed decreases the gauge catch and the observed precipitation should be increased.

As there is no any wind speed measurement data available in the study area, monthly average wind speed values (New et al., 2002), which was downloaded from Climatic Research unit's (CRU) web site, were used to derive the wind correction factor for each month.

4.2.2 Wetting Error

Wetting losses depend on gauge type, precipitation type and the number of times the gauge is emptied. In this study, wetting error is taken as 0.25 mm per measurement (Patra, 2001).

4.2.3 Evaporation Error

Evaporation losses vary by gauge type, climate and frequency of precipitation measurement. As there is no any experimental value or computational procedure available for evaporation error, only the range of error can be specified from references.

4.3 Results of Quantitative Analysis

4.3.1 Wind Error

According to equations 2, 3 and 4, wind error is computed for all the stations of the Bagmati River basin. As a sample, Figure 3 shows the variation of wind error for each month of Kathmandu airport station. The result shows that the wind correction factor for Kathmandu airport station varies from 1.02 to 1.08. The factor is the lowest for December and highest for March.

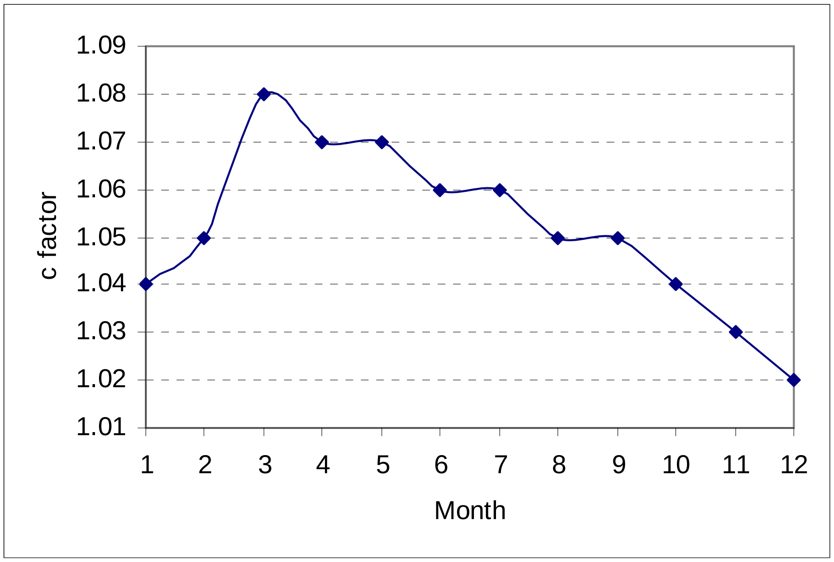

Figure 3. Wind correction factor (*c* factor) for Kathmandu airport station

From the computation of wind correction factors for all the stations, it is found that the wind error for the area varies from 2% to 8%. According to the recommendation by Sevruk (1982), wind error for rain is between 2% to 10%. The result obtained here is also in conformation with the recommendation.

4.3.2 Wetting Error

Taking 0.25 mm wetting error for daily rainfall, it is found that wetting error in annual precipitation for all stations varies from 1%-2.2%. According to the recommendation by Sevruk (1982), wetting error varies from 2% to 10%. As the manual gauge is emptied once a day, the wetting error is not so high in the Bagmati River basin.

4.3.3 Evaporation Error

According to Sevruk (1982), the range of evaporation error is 0%-4%. This is the common range of error for any gauge, which is also adopted in this study.

4.3.4 Total Error

Besides wind error, evaporation error and wetting error, there may be some other errors present in the measured data. Not all the errors are significant for different methods used to collect the rainfall data. The individual contributions of some of the factors are very small and can be neglected. From the result, it is found that the range of total error in the Bagmati basin (wind error, evaporation error and wetting error) is less than 15%. According to Sevruk (1982), the sum of wind error, evaporation error, wetting error and splashing error in case of rain is 5% to 26%. So, the range obtained in this study is also not outside the range recommended by Sevruk (1982).

5. CONCLUSIONS

Although various sources of uncertainty influence the hydrological modeling results, the impact of all sources is not significant. As the hydrological system starts from precipitation, it is very important to understand how the precipitation becomes uncertain in measurement phase. In this study, enquiry lists are proposed to evaluate the errors in precipitation measurement. Although this does not give any numerical value of error, it can provide qualitative assessment to understand the error causing factors and we can recommend the concerned authorities to give attention on quality control. This is a one step to get reliable results and to reduce predictive uncertainty. As an application of this framework, field survey is done for some precipitation sites in Nepal, which concludes that wind is the significant error and some more focus needs to be given for controlling quality. Then, a quantitative approach for evaluating the major factors of measurement errors in precipitation is formulated and implemented. The result of the analysis shows that the range of total error (wind error, evaporation error and wetting error) is less than 15%. However, the contribution of error due to human (both observation and data handling error) can not be given any specific value though this error should not be neglected. The only way to reduce this error is to implement strict quality control measures.

It is recommended to carry out further research to understand how the range of error in precipitation affects the performance of hydrological model.

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APPENDIX

Table A. General information

Date and time of interview	
Interviewer	
Interviewee (Name, position, experiences)	
Name of station	
Country code	
Location (Latitude, longitude)	
Elevation	
Responsible authority & office	
Surrounding landscape	
Type of station	
Area covered by the observation site	
Ground cover of the site	
Name of instrument	
Height of the instrument	
Instrument type	
Date of installation of the instrument	
Date of replacement of the instrument	

Table B. Enquiry list for measurement error

Factors	Description	Assessment
1. Instrumental factor		
(a) Frequency of checking the instrument check list of maintenances if any		
(b) Provision of wind shield if provided, what type		
2. Site factor		
(a) Location of precipitation site (urban/rural/forest/hills/open field) (vulnerable to flood/landslide)		
(b) Distance of the site from nearest residential area		
(c) Influence of objects e.g. trees, buildings very close to the gauge		
(d) Support of the gauge (ground/tower/roof)		
(e) Ground condition (level/not level)		

(f) Setting of gauge (firm/loose fixtures, how splashing in/out is prevented)		
3. Human factor		
(a) Type of the observer (manual gauge)		
(b) Type of data handling personnel (automatic gauge)		
(c) Type of maintenance personnel (professional/office staff/engineering background/experiences)		
(d) Availability of training		
4. Weather factor		
(a) Influence of gauge catch by strong winds		
(b) Procedure of measurement of precipitation under the freezing condition		
(c) Procedure of measurement of the snow precipitation in general condition, how snow measurement is done under very windy condition (if snowfall occurs)		
(d) Any overflow problem during heavy rainfall		
(e) Any measures taken to reduce evaporation error		
5. Management factor		
(a) Method of transmission of data (Hand written, chart processing, cable and data logger), any checking of error in data entry /processing/formatting etc.		
(b) Any operating rules/guidelines to control quality		
(c) Availability of any checking systems		

Table C. Enquiry list for interpretation aspects

Factors	Description
1. Point to area transformation	
(a) Criteria for design of precipitation gauge network, addition of gauges by doing statistical analysis to improve spatial representation	
(b) Method used to transform point data into areal data (if done)	
2. Time averaging	
(a) Frequency of measurement	
(b) Time of measurement	
3. Missing data	
(a) Method of recording missing data	
(b) Method of estimating missing value (if done)	
4. Precipitation correction	
(a) Any correction for wind error, evaporation error, wetting error, trace precipitation etc.	
(b) Correction method	