Intercomparision of snowfall measured by weighing and tipping bucket precipitation gauges at Jumla Airport, Nepal

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Abstract

A comparison of data from an unheated Ott Pluvio^2 weighing precipitation gauge with Tretyakov wind shield and an unheated Lambrecht tipping bucket precipitation gauge without wind shield for snowfall (snow water equivalent) was carried out in Jumla airport meteorological station, Nepal Himalaya (2375m) for snowfall events in Jan, Feb and March of 2012.

Overall the weighing gauge recorded 15% more total precipitation than in the tipping bucket gauge. The difference in individual precipitation events varies with the large differences occurring during freezing temperatures. Compared to the real time recording of precipitation from weighing gauge, the delayed precipitation record has been observed in tipping bucket gauge. In the absence of a heating system, the tipping bucket gauge records precipitation only after melting due to solar heating. The wind related errors are complicated to study due to the difference in measurement systems.

1. Introduction

Precipitation is one of the most important atmospheric variables for ecosystem, hydrological system, agricultural operations, climate and weather forecasting. Ground based precipitation measurement appears simple but accuracy is difficult to achieve because precipitation measurements on the ground are influenced by exposure, wind, topography and temperature. The magnitude of errors varies due to the type of precipitation and type of instruments used. An underestimate of 30% or more compared to actual precipitation falling on ground is common for most precipitation gauges (WMO-8, 2008 CIMO Guide).

The most widely used type of automatic gauges for point measurement of precipitation on the ground are tipping bucket and weighing precipitation gauges. For both solid and liquid precipitation, the largest source of error is wind induced undercatch. Snowfall events tend to be lighter intensity precipitation events, therefore measured snowfall is particularly affected by wind effects, especially for unshielded gauge (e.g., Yang et al.,1999, 2000; Sevruk, 2004, 2005). Furthermore, measurement of snowfall is also affected by snow capping in the rim, deposition in the upper funnel and overflow in heavy precipitations. Besides, that wetting loss, evaporation loss and drifting and blowing snow are the other errors in snowfall measurement. Therefore, to reduce the errors different windshields, antifreeze liquids and heating of the gauges are used.

In Nepal, US Standard (8” diameter) manual precipitation gauges are in use for both solid and liquid precipitation measurement. Tipping bucket gauges without heating and wind shields are mostly in use at automatic stations.

Recently, unheated weighing precipitation gauges have been installed in various stations of Nepal. In some stations, both a weighing precipitation gauge with wind shield and a tipping bucket precipitation gauge without wind shield are co-located in the same observatory.

In this study, an inter-comparison of total accumulated precipitation (snow water equivalent) between two measurement systems in one of the high altitude stations (Jumla Airport, 2375m) for precipitation events of Jan, Feb and March of 2012 has been made.

At this time of year, precipitation is predominantly snowfall although, rainfall is also possible. The wind induced errors in the measurement are also incorporated as best as possible.

2. Instruments, study site, data and methodology

2.1. Meteorological Instruments

The precipitation inter-comparison measurement gauges are Lambrecht tipping bucket (LTB) precipitation gauge model 15189 (Lambrecht Meteorological Instruments, www.lambrecht.net, Germany) and Ott Pluvio2 weighing (OP2W) precipitation gauge (Ott Hydromet, www.ott.com, Germany). The measurement precision for both gauges is 0.1mm. Both gauges are installed 1.3m above surface, have the same orifice area of 200cm^2, and are without heating systems. The tipping gauge has no wind shield but the weighing gauge is equipped with Tretyakov wind shield. For measurement, precipitation has to flow from funnel to the tipping mechanism in LTB but the OP2W has the open collector where precipitation directly falls on the weighing container (Fig. 1). Therefore, the weighing gauges are considered superior to the unheated tipping bucket for snowfall measurements, as the time delay between snowfall, melting and ultimate measurement of the event in the tipping bucket gauge increases the chance of evaporative, wetting and windblown snowfall losses.

In addition as the weighing guage is equipped with a wind shield while the tipping bucket gauge is not, it is expected to be less influenced by wind induced loss of snow. Problems due to snow capping in the rim can affect both instruments during heavy snowfall but less over flow in weighing is assumed due to its high capacity and comparatively larger depth of container.

Air temperature was measured using a Lambrecht combined temperature-humidity sensor model no 8091 at 2m above ground and wind from Climatronics ultrasonic wind sensor model no WE-1100 at 10m above surface.

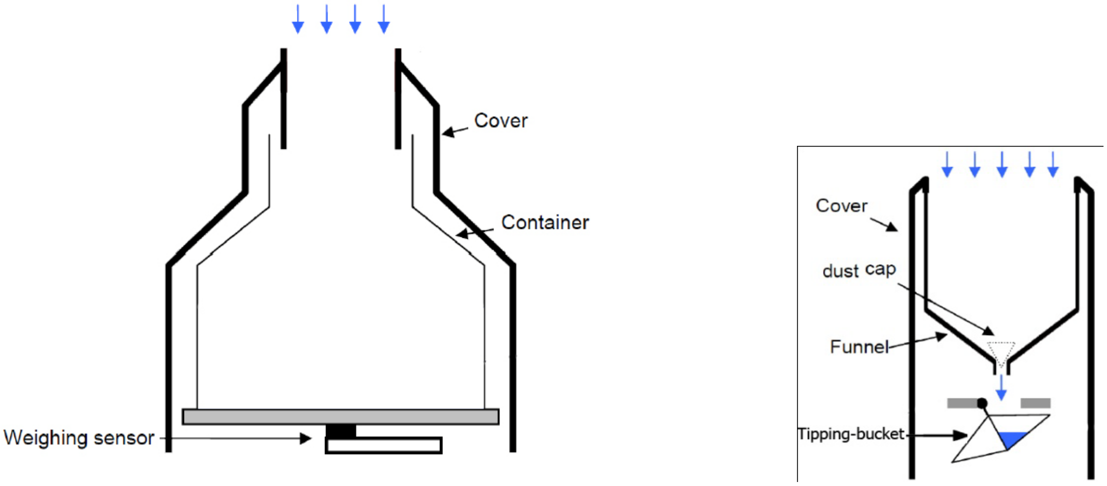

Fig.1. a. Ott Pluvio^2 (200cm^2, 1500mm capacity) weighing gauge. b. Lambrecht Tipping (200cm^2) bucket gauge.
(Modified from Christian Félix, 2010 original design)

2.2. Site

The inter-comparison site is the Nepal Department of Hydrology and Meteorology, meteorological station in the western Nepal at Jumla airport (2375m), Khalanga.

The weather station is located in an open site inside the airport perimeter in the valley floor of Jumla (Fig. 2). The average climatological data of the place is presented in Table 1.

Table 1. Climatological normal of the Jumla synoptic meteorological station (1971-2000).

Month	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Maximum air Temp (^{o}C)	13.2	14.3	17.7	21.3	24.1	25.5	24.7	24.2	23.8	21.4	18.3	15.5	20.3
Minimum air Temp (^{o}C)	-5.1	-3.3	0.0	3.4	7.5	12.9	15.4	15.2	12.0	4.2	-1.6	-4.6	4.7
Precipitation (mm)	31.7	40.5	60.9	43.3	58.0	79.2	181.5	180.8	102.9	38.5	10.6	15.9	835.6

Fig.2. Department of Hydrology and Meteorology, Nepal, meteorological station at Jumla airport. The LTB (Right), OP2W (left) and manual raingauge and stevenson screen (behind)

2.3. Data and methods

This study uses measurements of total precipitation, average air temperature and wind speed data available in 1, 30 and 10 minute intervals respectively during Jan 1 to March 31 of 2012. As the focus of this study is on snowfall events, SYNOP data including manual snow depth observations from the nearby (~2km) Jumla Synoptic meteorological station was used to verify the precipitation events in this study as snowfall events. These observations are only available in 3 hourly intervals during the day time so there is a possibility that snowfall events analyzed here include some mixed precipitation event.

The precipitation data from the weighing gauge is taken as reference for the start and end of precipitation event due to its reliable working mechanism.

All the meteorological data are aggregated into hourly intervals. To analyze the data, the differences in precipitation between two gauges are calculated. The delay in precipitation record in tipping is analyzed from the visual inspection of data and graphs.

The temperature and wind data are compared with the precipitation data to study the effect of these variables on undercatch and delay in record. The value in the graphs indicates average or total values within the hours depending on parameters. Such as the precipitation record at 11:00 is the precipitation total within 10:00 to 11:00 hour.

As the precipitation in the tipping bucket gauge is expected to be recorded with a considerable delay, a measurement from the day following a single precipitation event is included in total precipitation. Five major snowfall events occurred over the study period, and these are presented as detailed case studies.

3. RESULTS

3.1. Total Precipitation (snow water equivalent)

In total, the OP2W gauge recorded 133.1mm, the LTB gauge 113.0mm with a difference of 20mm (15%) over the entire 3 months study period. Ten very light precipitation events (total precipitation in each event ≤ 0.3mm) with total amount of 2.2mm over the entire period were recorded only by weighing gauge. In these cases the snowfall might have been lost to evaporation and wetting loss in tipping.

3.2. Case studies of snowfall events

Case 1 (1 - 2 Jan, 2012)

Very light precipitation (0.1mm) was recorded within hour at 11:00 on Jan 1. Continuous precipitation was recorded from 13:00 to 21:00 of the same day in OP2W (*Fig. 3*). The total amount of precipitation recorded during all precipitation hours from OP2W is 14.1mm and no precipitation was recorded after that on subsequent hours on Jan 1 and Jan 2. In comparison, LTB started to record the precipitation at almost the same time and recorded the same amount of precipitation for the first 2 hours of continuous precipitation but no precipitation from 16:00 to 18:00, during which most of the precipitation was recorded in OP2W.

The total precipitation recorded in LTB during the actual precipitation hours was only 3mm. The LTB recorded a small amount of precipitation after the precipitation event following a period of positive air temperatures, but most of the precipitation (8.2mm) was recorded between 10:00 and 12:00 on Jan 2 after sunshine and rising temperatures allowed snow in the funnel to melt. The total amount of precipitation recorded from tipping bucket gauge on Jan 1 and Jan 2 is 11.9mm which is 16% less than in OP2W.

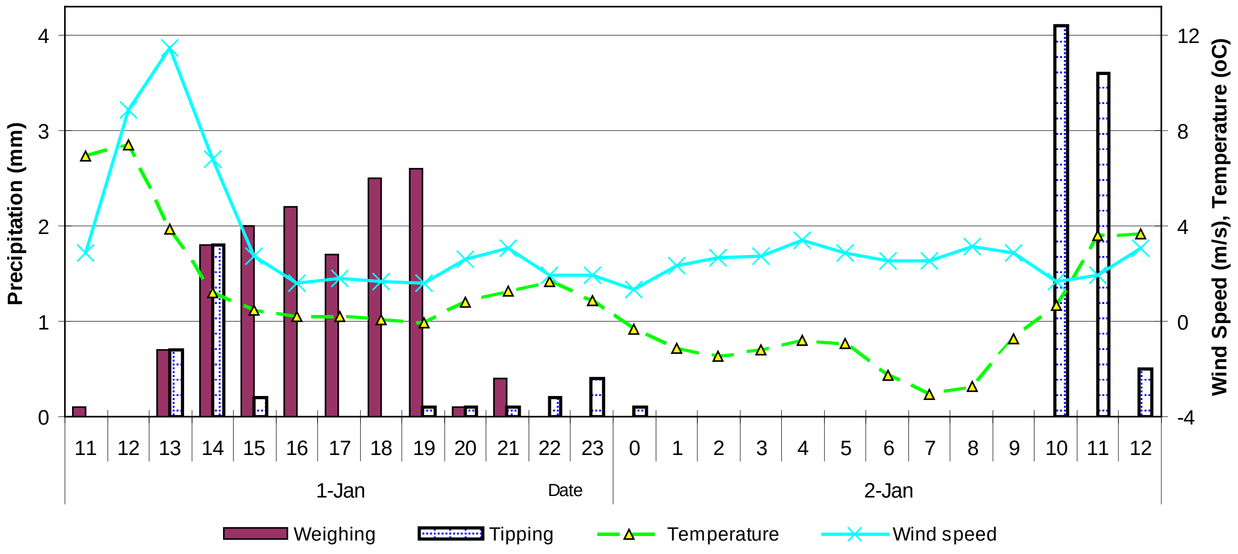

Fig. 3. Comparison of Precipitation event of Jan 1 - 2.

The temperature at the start of precipitation fell from 7 to 4°C and was near 0°C during most of the precipitation hours. The wind speed was 11 to 7m/s during the first 2 hours of the precipitation events (12:00 to 14:00 hour) but there is no difference in amount of precipitation at those hours between two measurement systems.

Case 2 (9 - 11 Jan, 2012)

The three day total precipitation (Jan 9 - 11) recorded in OP2W was 11.9mm while the LTB recorded 8.8mm with a difference of 3.1mm (26%).

The precipitation was recorded in OP2W from 8:00 to 19:00 of Jan 9 with a short break at 9:00. The total accumulation during the event was 8.6mm.

In Jan 9, precipitation (5.1mm) was also recorded in LTB from hour 10:00 to 18:00 with a break in 16:00. The LTB recorded precipitation (1.2mm) between 10:00 and 11:00 the following day (Jan 10) during which no precipitation was observed in OP2W (*Fig. 4*).

As in the previous case this is interpreted as being the eventual melt of the previous day's snowfall accumulation. Thus over this event 6.3 mm of precipitation were measured by the LTB as compared to 8.6mm by the OP2W. The LTB recorded the delayed precipitation at air temperatures that were still negative, implying that solar heating of the instrument can trigger melt even in sub zero temperatures. The next precipitation event spanned 23:00 of Jan 10 to 03:00 of Jan 11 as per the record in OP2W (*Fig. 4*) but no precipitation was recorded in LTB.

The total precipitation of that event was 3.3mm (OP2W) and 2.5mm of precipitation was recorded at 10:00 hour of the following day in LTB after rising temperature.

The temperature during that night was below -2ºC which favored for the deposition of precipitation in the upper funnel of tipping bucket leading to no record during the actual time of precipitation in LTB.

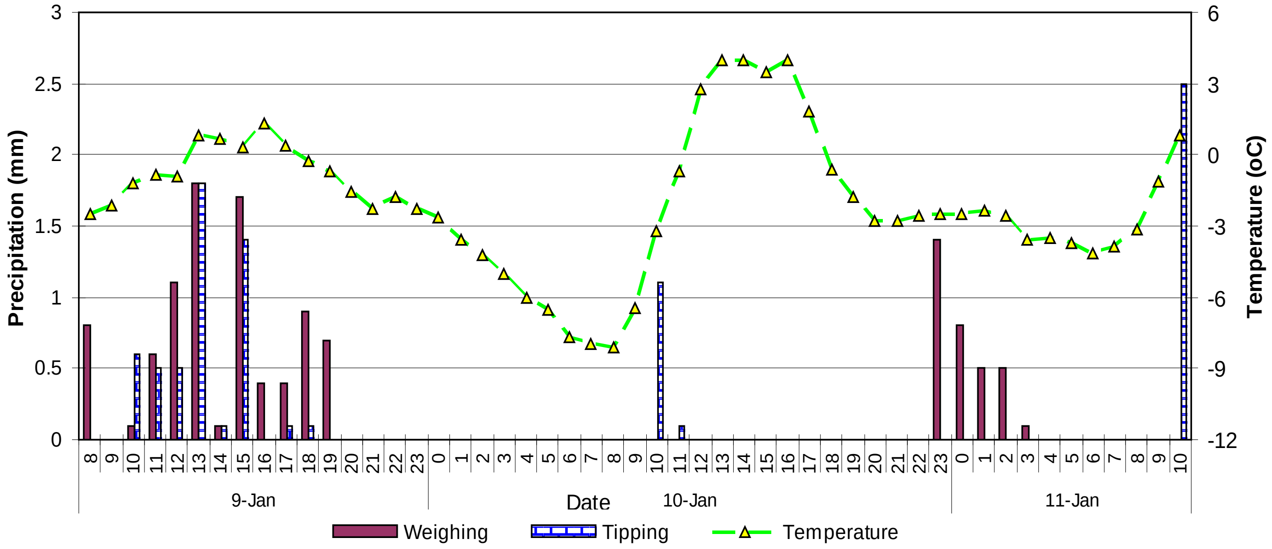

Fig. 4. Comparison of Precipitation event of Jan 9 - 11.

Case 3 (19 - 20 Jan, 2012)

In the OP2W record, precipitation occurred from 17:00 on Jan 19 and continued until 01:00 Jan 20. Some precipitation (2.1mm) was also recorded at 11:00 on Jan 20 *(Fig. 5).* The total amount of precipitation recorded in OP2W in 2 days was 15.9mm.

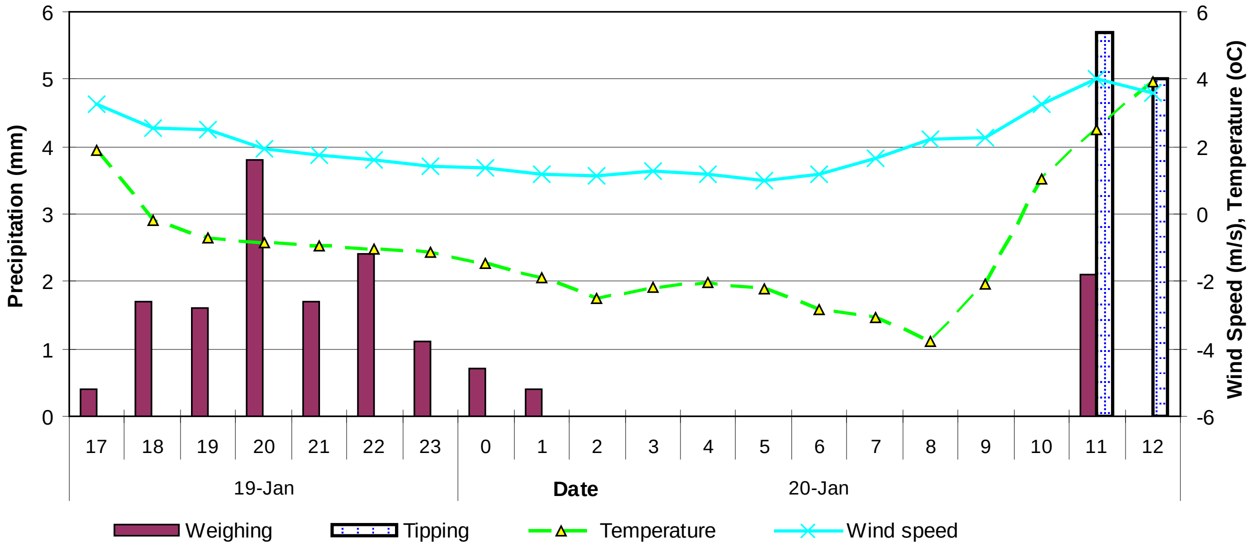

Fig. 5. Comparison of Precipitation event of Jan 19 – 20.

Precipitation was not recorded by the LTB in any of the major precipitation hours and instead all the precipitation (10.7mm) was recorded within 2 hours between 10:00 and 12:00 of Jan 20. The difference in precipitation between two systems was 5.2mm (32%). During most of the precipitation hours, the temperature is below freezing which might have favored for deposition of snow in the upper funnel part of the tipping gauge and no precipitation was recorded in the actual day of precipitation. The melting as in previous cases was as a result of melting after sunshine on the following day, in this case also coincident with positive air temperatures.

The wind speed during most of the precipitation hours was below 3m/s at 10m so it is assumed that there is no significant wind effect at gauge height.

Case 4 (7 - 9 Feb, 2012)

Precipitation was recorded from 19:00 of Feb 7 until 13:00 of Feb 8 in OP2W *(Fig. 6).* A little precipitation (1.1mm) occurred between 20:00 and 22:00 hour of Feb 8 as well. No precipitation was recorded after that in OP2W. The total precipitation recorded in OP2W in 2 days was 39.5mm with most of the precipitation (38.4mm) occurring between 19:00 of Feb 7 to 13:00 of Feb 8.

During those hours LTB recorded only 11.2mm of precipitation. The total precipitation (35.6mm) recorded in 3 days in LTB is 10% less than in OP2W. LTB recorded most of the precipitation (22.8mm) in the subsequent 3 hours (14:00 to 16:00 of Feb 8) after the end of actual precipitation hour with the highest amount (13.8mm) on hour 15:00.

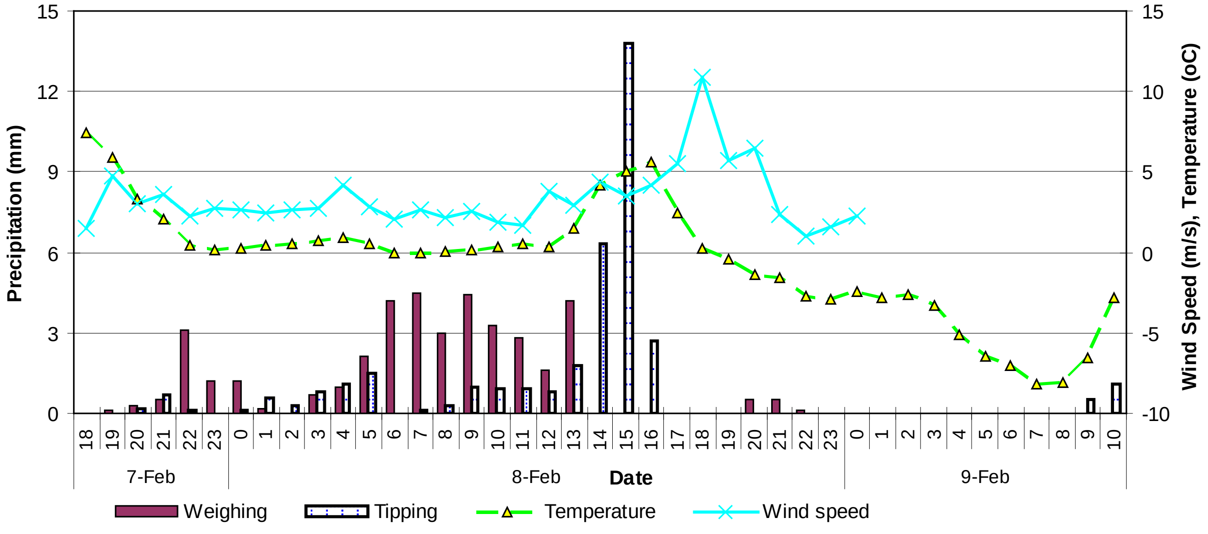

Fig. 6. Comparison of Precipitation event of Feb 7 - 9.

During the actual precipitation hours temperature was near to or above freezing. Between 14:00 and 16:00 of Feb 8 in which the LTB has recorded most of its precipitation, air temperature was between 4 - 6°C. The high temperature in the subsequent hours might have caused the rapid melting of precipitation collected in upper funnel of the tipping gauge. No significant wind was observed in the precipitation hours but there were some high wind speed values after the actual precipitation hours.

Case 5 (13 - 14 March, 2012)

Precipitation was recorded from 11:00 to 17:00 on March 13 with total precipitation of 20.2mm in the OP2W gauge (*Fig. 7).* Lesser precipitation was observed in LTB over the same period, and after the actual precipitation hours up until 19:00 of March 13. Seven millimeter of precipitation was recorded by the LTB the next day (March 14) from 9:00 to 11:00 hour during which no precipitation was observed in OP2W.

This suggests some storage of snow in the funnel occurs even when a degree of concurrent precipitation is measured during the hours of the snowfall event. There is no difference in total precipitation between two systems if we consider the amount of precipitation from LTB on March 14 as well.

The temperature during most of the precipitation hours was between 0.1 - 6.5°C and night time temperature was below 0°C.

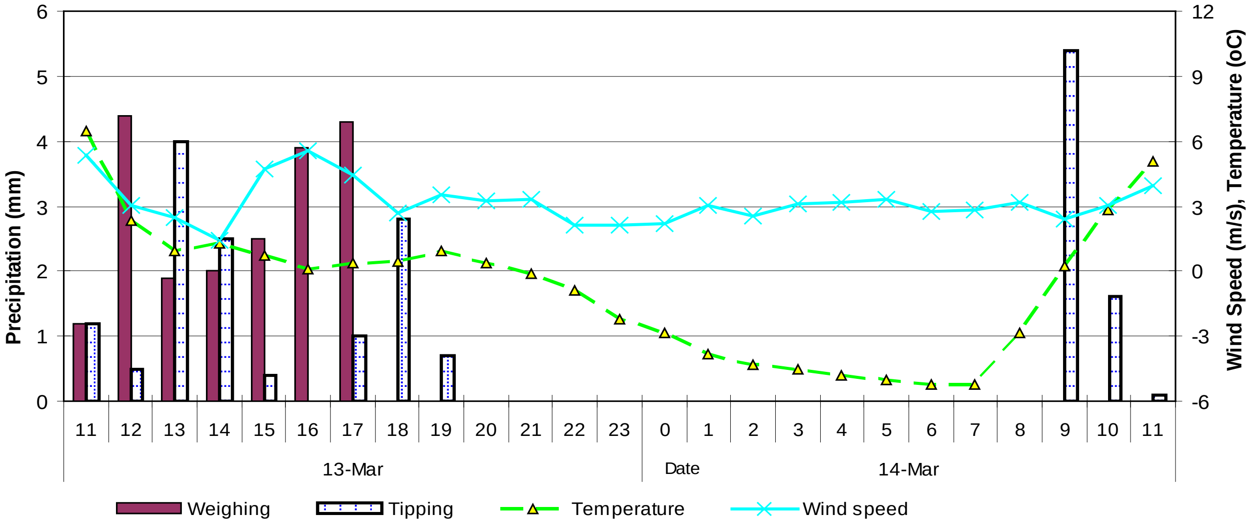

Fig. 7. Comparison of Precipitation event of March 13 -14.

4. Discussion and Conclusions

In this study, the performance of snowfall measurement by two different gauges (tipping bucket gauge and weighing gauge) was analyzed. The gauges were a Lambrecht tipping bucket gauge (LTB) without wind shield and an Ott Pluvio^2 weighing gauge (OP2W) with Tretyakov Wind shield. Both gauges are without heating system and weighing container in weighing gauge is without antifreeze solution.

Overall during Jan 1 to March 31, 2012 the LTB recorded 15% less precipitation than OP2W. The difference varies from individual events with maximum - 32% and minimum no differences between the LTB and OP2W. The higher undercatch of LTB (cases 2 and 3) with respect to OP2W is observed during snowfall events at air temperatures well below freezing which indicates the role of temperature in more deposition in upper funnel. This results in losses with overflow, evaporation, wetting loss and blowing of collected snow. Wind induced undercatch are different in two systems due to the OP2W having a wind shield therefore undercatch in LTB compared to OP2W is the cumulative errors of wind deformation, evaporation loss, wetting loss and overflow etc and difficult to distinguish wind errors only.

The OP2W records precipitation as soon as it enters the weighing container where as in non heating LTB the deposition in upper funnel leads to delay in precipitation record.

The delay in record is more if the temperature is well below freezing. Precipitation is recorded only after solar heating in most of the cases. The timing of delivery and measurements of this melted snow accumulation is not determined solely by temperature, sometimes, it can also occur at sub-zero temperatures (e.g. case 2).

The data here indicate that under some conditions a portion of snow is melted into the tipping bucket during the snowfall event while some remains in the funnel and is only melted into the measurement bucket later (cases 4 and 5).The delay does not give accurate timing of the precipitation events from tipping bucket gauge which are problematic for weather forecasting and warnings, diurnal variability studies and many research applications.

The study shows the difficulties of the unheated LTB in accurately and timely measuring snowfall but this is only a comparison so the accuracy of two gauges cannot be stated.

This is one of the lowest stations in high altitude area of Nepal and there are many stations above this altitude. Therefore, in the places where temperature is very low the undercatch of the unheated LTB compared to the OP2W can be expected to be greater than 30%. The data will be problematic for climate change studies, water resources assessment and many research applications if the measurement system is changed from time to time and detail studies are not done to make the data homogeneous.

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