Status of Automatic Weather Stations in Nepal and Comparison of Air Temperature and Precipitation Data Between Automatic Weather Station and Manual Observation.

Ramchandra Karki
Meteorologist
Department of Hydrology and Meteorology
Ministry of Environment
Government of Nepal
P.O. Box 406, Babarmahal, Kathmandu, Nepal
Email: rammetro@hotmail.com, ramchandra@dhm.gov.np

Abstract:
Department of Hydrology and Meteorology (DHM), Nepal is operating 22 Automatic Weather Stations in the country. Most of the AWSs are Environdata, Australia made and were installed only after 2000.
The measurement of air temperature is measured with sensors mounted inside thermoplastic radiation shield and 8 inch diameter tipping bucket Rainguage (0.2mm resolution) is used for precipitation measurement.
Due to lack of telemetry data transmission system, only conventional Manual observatories data are used for weather forecasting purpose in Nepal.
In conventional Manual observatories, air temperature is measured with liquid in glass thermometers housed in wooden Stevension screen and precipitation measurement is done with 8 inch diameter manual Raingauge.
As the observational system of manual and automatic are completely different, so, an attempt has been made to analyze the measurement difference between co-located manual and automatic observational data of air temperature and precipitation of 4 stations of Nepal from 2002-2009.
In addition to this, the possible causes behind the disparity of automatic and manual observational data are also discussed.
The preliminary result shows that rainfall amount measured by AWS is more compared to manual in most of the rainfall intensity events. Similarly, minimum air temperature measured by AWS, in most of the cases, is lower than the temperature readings from alcohol thermometer.
But, the difference between AWS and manual observed daily maximum air temperature data is quite random.

1. Introduction:

Department of Hydrology and Meteorology, (DHM) Nepal started to install automatic weather stations in Nepal since 2000. Till to date, altogether 22 automatic weather stations are in operation.But, the oldest AWS being operated by DHM is the station established by Glaciological expedition in Nepal (GEN) project in 1994 at Syangboche of Khumbu region.

Since the functioning of automatic weather station is different from manual observation, studies on difference between automatic and manual data are very crucial to validate data and to identify the systematic error.

A lot of research has been conducted on the difference between automatic and manual observation in the world.

In India, a study conducted by Vashistha et all (2005) found the AWS data within WMO accuracy limit but another study (Amudha et all 2008) identified the marked deviation in air temperature data at 03 UTC. Similarly, in few stations of China systematic error in maximum and minimum air temperature with AWS values a little higher than Manual observation were observed (Ying et all 2008).

If only the systematic error exist in the data, then the correction can be applied to make the data homogeneous, but in many cases, the random errors also exist.

So far, the inter-comparison of automatic and manual data has not been carried out in Nepal. Hence, in this paper an attempt has been made to study the difference between automatic and manual observed data of dominant meteorological elements air temperature and precipitation.In addition to this, the possible causes behind the discrepancies of automatic and manually observed data are also discussed.

1.1 Status of Automatic Weather Stations in Nepal:

The AWS were installed in different time period in Nepal by different project for a short period research work but after the completion of projects, stations were closed. The AWS (Aanderra made) established by GEN in 1994 at Syangboche of Khumbu region is the oldest station in operation by DHM. In Khumbu region of Nepal, one automatic weather station was also installed at that time by EVK2CNR, an Italian organization and now there exists altogether 8 automatic weather stations under the EVK2CNR network in Khumbu region in the altitudinal range from 2600m to 8000m (in South Col of Everest) for high altitude weather and climate research.

The installation of automatic station from regular budget of DHM started after 2000 and now 22 automatic weather stations are in operation with most of the AWSs (20) from Environdata, Australia Company. Besides these AWSs,several tipping bucket Raingauges are installed under the flood forecasting project of DHM and indigenous CDMA based data transmission system is successfully utilized for real time data transmission to internet. As real time data is the backbone for weather forecasting and warnings, DHM is planning to upgrade its AWSs with CDMA/GSM dual real time data transmission system in the coming fiscal year. List of automatic weather stations in Nepal is presented in table 1.

The common problems associated with operation of AWS are listed below:

1) Non synchronous time in logger due to design fault in few old loggers.
2) Data missing in remote stations due to low capacity of logger.
3) Rusting in the connecter between sensor cable and sensor logger interface.

4) Frequent on/off problem in logger for few seconds and this leads to wrong data out put as it counts time after it starts only. If the logger gets off in last minute of the recording interval then the data goes wrong and in the cases of rainfall and solar radiation total values are missed.
5) Hanging of logger if the network cable between logger and PC is long.
6) Instrument has to survive the harsh cold weather condition in high altitude (Himalayas)

S.N.	Station Name	Elevation (m)	Height of wind mast (m)	Established Date	Type of station	Company
1	Kathmandu A/P	1337	10	2001	Aero Synoptic	Environdata
2	Biratnagar A/P	72	10	2001	Aero Synoptic	Environdata
3	Nepalgunj	165	10	2004	Aero Synoptic	Environdata
4	Simara A/P	130	10	2004	Aero Synoptic	Environdata
5	Kathmandu A/P Tower	1340	2	2006	Aero Synoptic	Environdata
6	Pokhara A/P	817	10	2007	Aero Synoptic	Environdata
7	Babarmahal	1295	10	2006	Rooftop observatroy/weather display	Environdata
8	Dang	634	10	2004	Synoptic	Environdata
9	Dhangadi	187	10	2004	Synoptic	Environdata
10	Dadeldhura	1350	2	2009	Synoptic	Environdata
11	Thankot	1730	10	2001	Wind monitoring	Environdata
12	Sankhu	1805	10	2003	Wind monitoring	Environdata
13	Lele	1987	10	2003	Wind monitoring	Environdata
14	Budhanilkantha	1350	10	2003	Wind monitoring / Climatic	Environdata
15	Nagarkot	2100	2	2007	Wind	Environdata
16	NAST	1350	30,10	2006	Wind monitoring/ Pollution	Environdata
17	Dingboche	4400	2	2002	High altitude weather monitoring	Environdata
18	Syangboche	3800	3	1994	High altitude weather monitoring	Aanderra
19	Kyangjing	3900	2	2002	High altitude weather monitroing	Environdata
20	Gokyo	5000	2	2006	High altitude weather monitroing	Environdata
21	Thukla	4600		2008	High altitude weather monitroing	Thies Clima
22	Annapurna				High altitude weather monitroing	Environdata

Table1: The Network of AWS in Nepal (Established by DHM)

2. Data used and Methodology:

The AWS data is stored in hourly and daily interval. As a result of missing hourly data due to low capacity of data logger and lack of timely downloading, this analysis is limited to daily extreme temperature and rainfall total only.

On the other hand, due to various technical problems some data were not available for the entire period and some were erroneous. Therefore, only the quality controlled data of 4 AWSs available within the period of 2002-2009 have been utilized in this study. (Table 2)

S.N.	Station name	Type of station	Latitude	Longitude	Elevation
			deg.min.	deg.min.	meter
1	Nepalgunj Airport	Aero Synoptic	2806	8140	165
2	Simara Airport	Aero Synoptic	2710	8459	130
3	Kathmandu Airport	Aero Synoptic	2742	8522	1337
4	Dang (Ghorahi)	Synoptic	2803	8230	634

Table 2: Stations selected for the study.

Name of station	Parameter	Month												Annual
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Nepalgunj Airport	Max Temp (°C)	19.7	24.7	30.3	36.1	38.0	36.6	33.4	33.1	32.7	31.3	28.1	23.4	30.6
	Min Temp (°C)	7.8	9.2	12.7	18.4	23.1	25.3	25.8	25.5	24.4	20.0	14.1	9.6	18.0
	Rainfall (mm)	29.3	19.6	13.4	24.7	60.5	214.7	460.6	327.6	202.7	60.5	7.6	3.9	1502.5
Dang Ghorahi	Max Temp (°C)	20.1	22.2	27.7	32.8	33.8	32.2	29.8	29.6	29.2	28.4	25.2	21.5	27.7
	Min Temp (°C)	5.9	8.0	12.4	17.2	21.5	23.1	23.1	22.8	21.4	16.1	10.8	6.9	15.8
	Rainfall (mm)	22.3	20.8	28.7	23.7	74.8	270.0	388.2	435.7	248.0	56.5	17.6	14.6	1600.8
Simara Airport	Max Temp (°C)	22.4	25.4	30.7	35.0	35.0	34.2	32.3	32.6	32.2	31.4	28.8	24.6	30.4
	Min Temp (°C)	7.5	9.0	13.0	18.7	23.1	25.3	25.4	25.3	23.9	19.6	13.7	8.6	17.7
	Rainfall (mm)	14.0	14.2	17.4	51.6	124.4	262.9	547.3	401.9	276.7	77.3	5.3	13.2	1815.8
Kathmandu Airport	Max Temp (°C)	18.1	20.3	24.4	27.4	28.2	28.5	27.8	28.0	27.3	25.9	22.8	19.5	24.8
	Min Temp (°C)	2.1	3.8	7.4	11.3	15.6	19.0	20.0	19.7	18.2	13.1	7.4	3.1	11.7
	Rainfall (mm)	13.7	17.5	30.3	56.9	116.0	262.6	356.5	319.6	186.9	56.7	7.5	15.1	1439.7

Table 3: Climatological Normal of the stations selected for study.

3. Result and Discussion:

3.1 Inter-Comparison of Daily Air Minimum Temperature:

The measurement of air temperature in AWS is done with sensors mounted inside thermoplastic radiation shield made by Environdata Australia.

In conventional manual observatories, air minimum temperature is measured with alcohol thermometers housed in wooden Stevension screen. The values taken at 03UTC of each day have been used for this study.

The difference between Manual and AWS daily minimum air temperature value have been computed for each station and presented in fig 1 to 4.

Dang (Ghorahi):

Temperature measured by AWS, in most of the cases, is lower than the temperature readings from alcohol thermometer.

Although the maximum difference in individual values reaches up to -3.5 to 4 degree celcius in few cases, most of the deviations (70%) are ranged within 0.5 degree celcius.Systematic differences have been observed in the values of daily minimum temperature in this station.The few exceptional cases may be outliers due to data quality.

Simara Airport:

The difference between manual and AWS values, in most of the cases (90%), ranges from $+0.5^{o}$ to –0.5 degree celcius with about 55% data in the range of 0 to 0.5 ^{o}C, however the maximum deviation on few values reaches up to -6 to +4 degree celcius. No systematic differences between AWS and manual values have been observed in this station. The differences are very less in this station relative to other stations.

Kathmandu Airport:

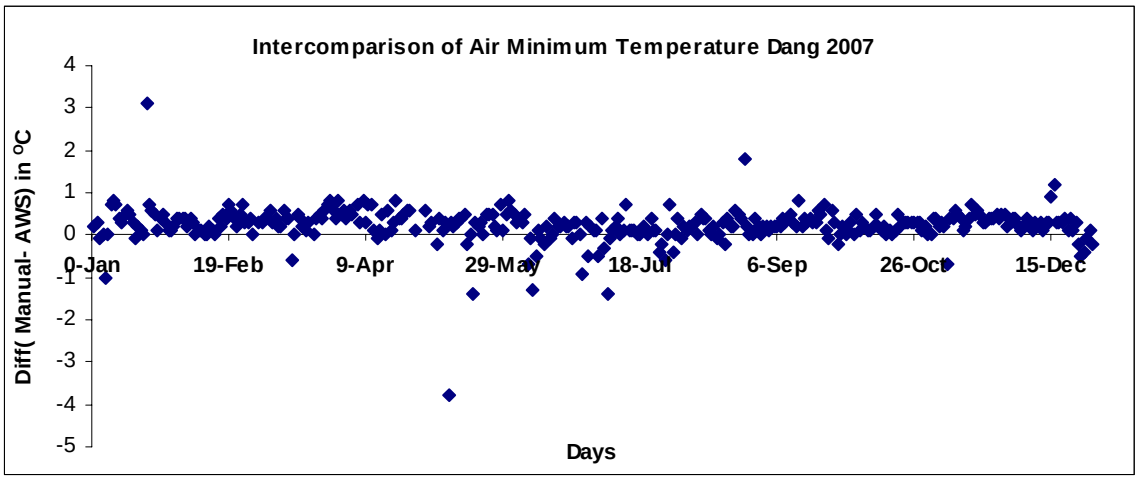
Systematic difference between manual and AWS values have been observed with AWS measured values lower than the manual values in most of the cases. Except for few exceptions on individual values, most of the difference (70%) are within +0.5 degree celcius.Some differences are very large as much as -3.5^{o}C which may be outliers.

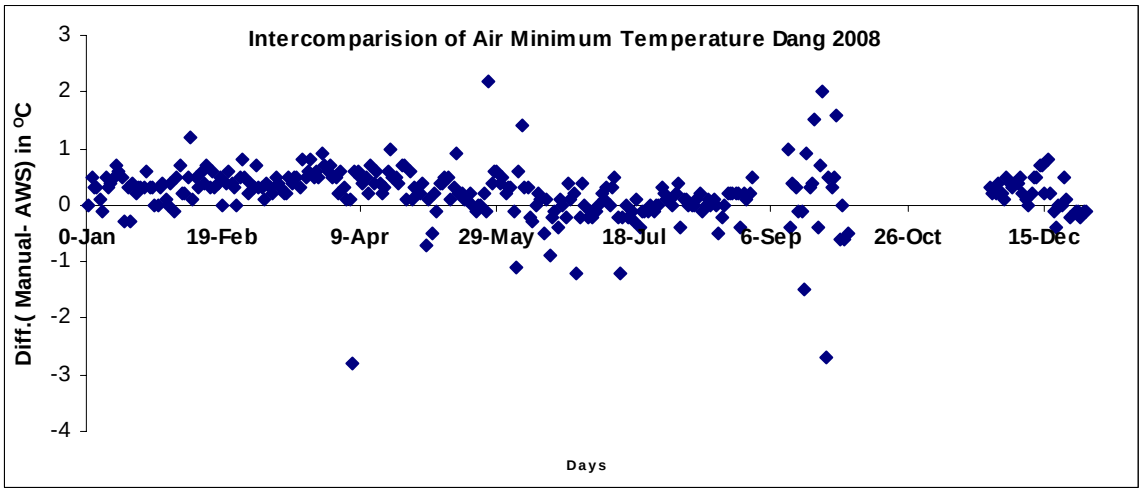
Nepalgunj Airport:

The difference between manual and AWS values, in most of the cases (85%), ranges from $+1^{o}$ to –1 degree celcius with 55% in the range of 0 to 0.5 ^{o}C. No systematic differences between AWS and manual values have been observed in this station.

In overal, systematic difference has been observed in the data set with very small discrepancies.The discrepanices may be as a result of differnce between sensitive of screens and their designs.Few exceptional cases with higher degree of fluctuation may be due to human errors or short term instrumental errors such as frequent break in minimum thermometers.

Dang (Ghorahi):





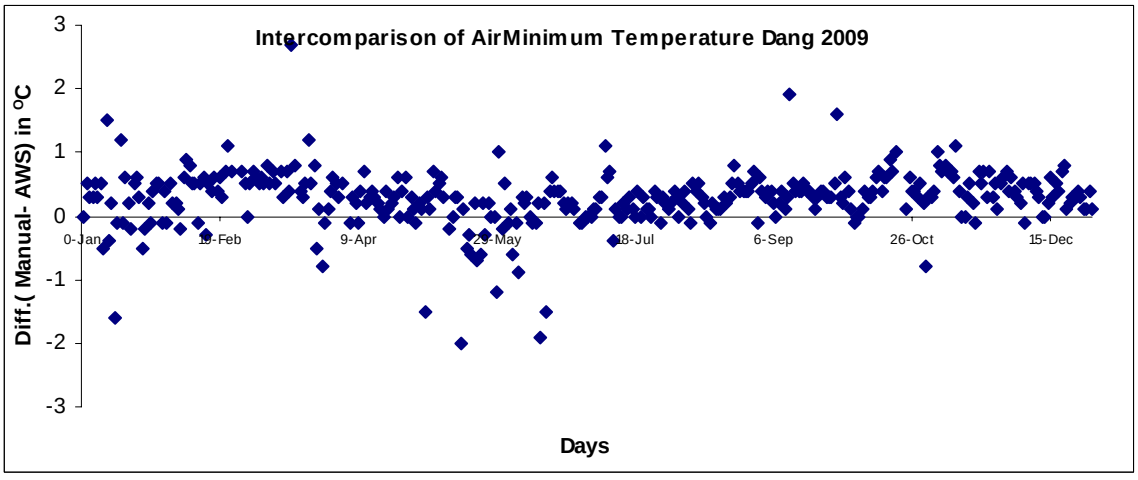
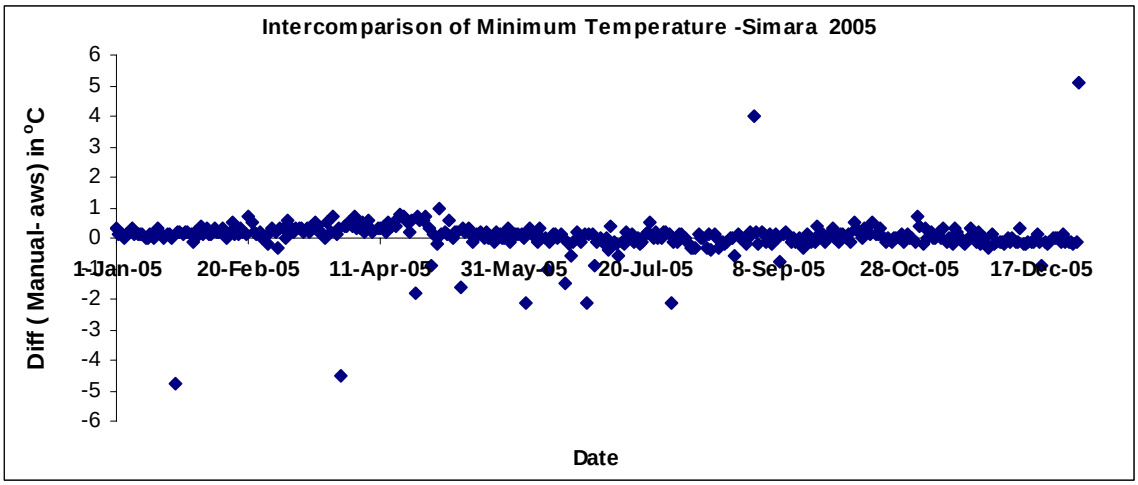
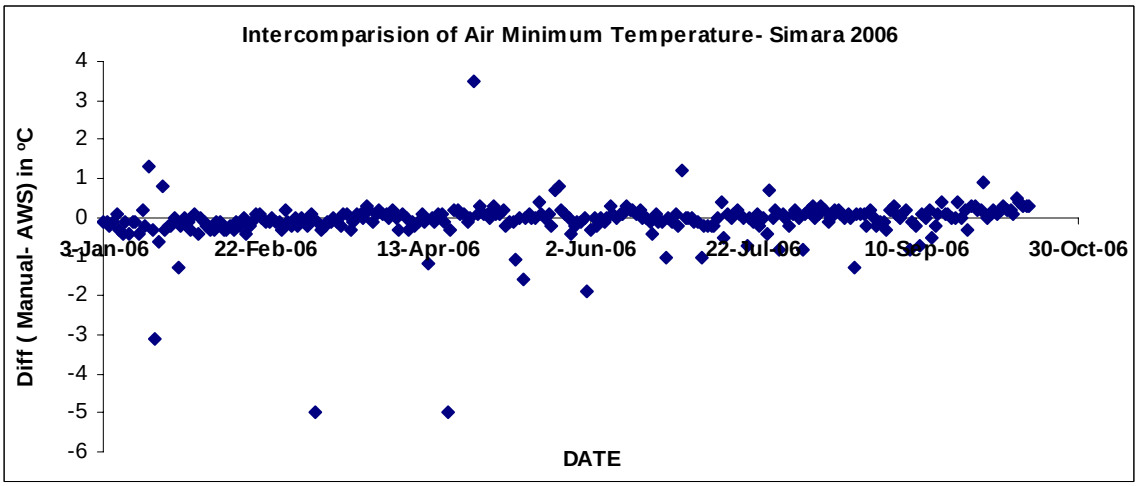


Fig1: Daily Air Minimum Temperature Inter-comparison at Dang

Simara Airport:





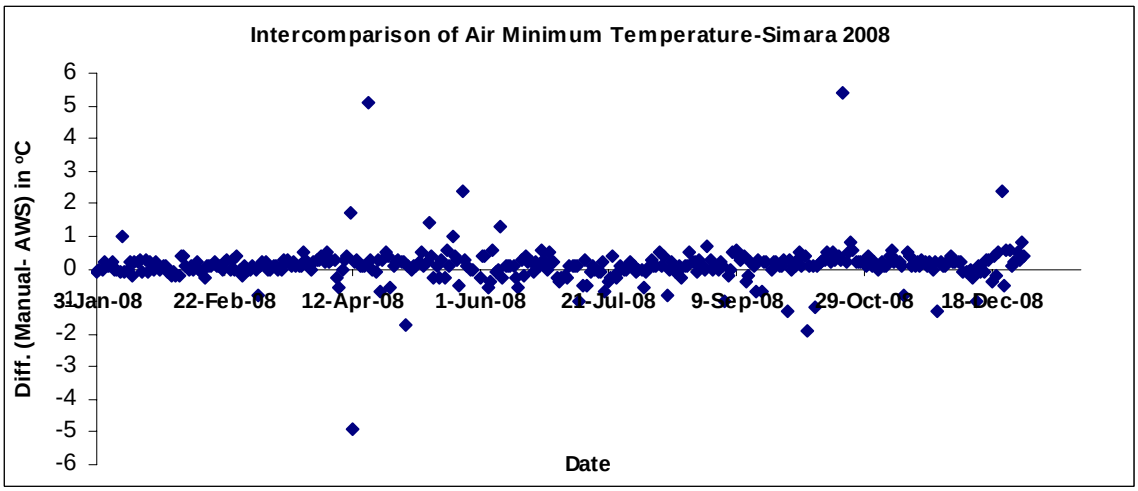


Fig 2: Daily Air Minimum Temperature Inter-comparison at Simara Airport

Kathmandu Airport:

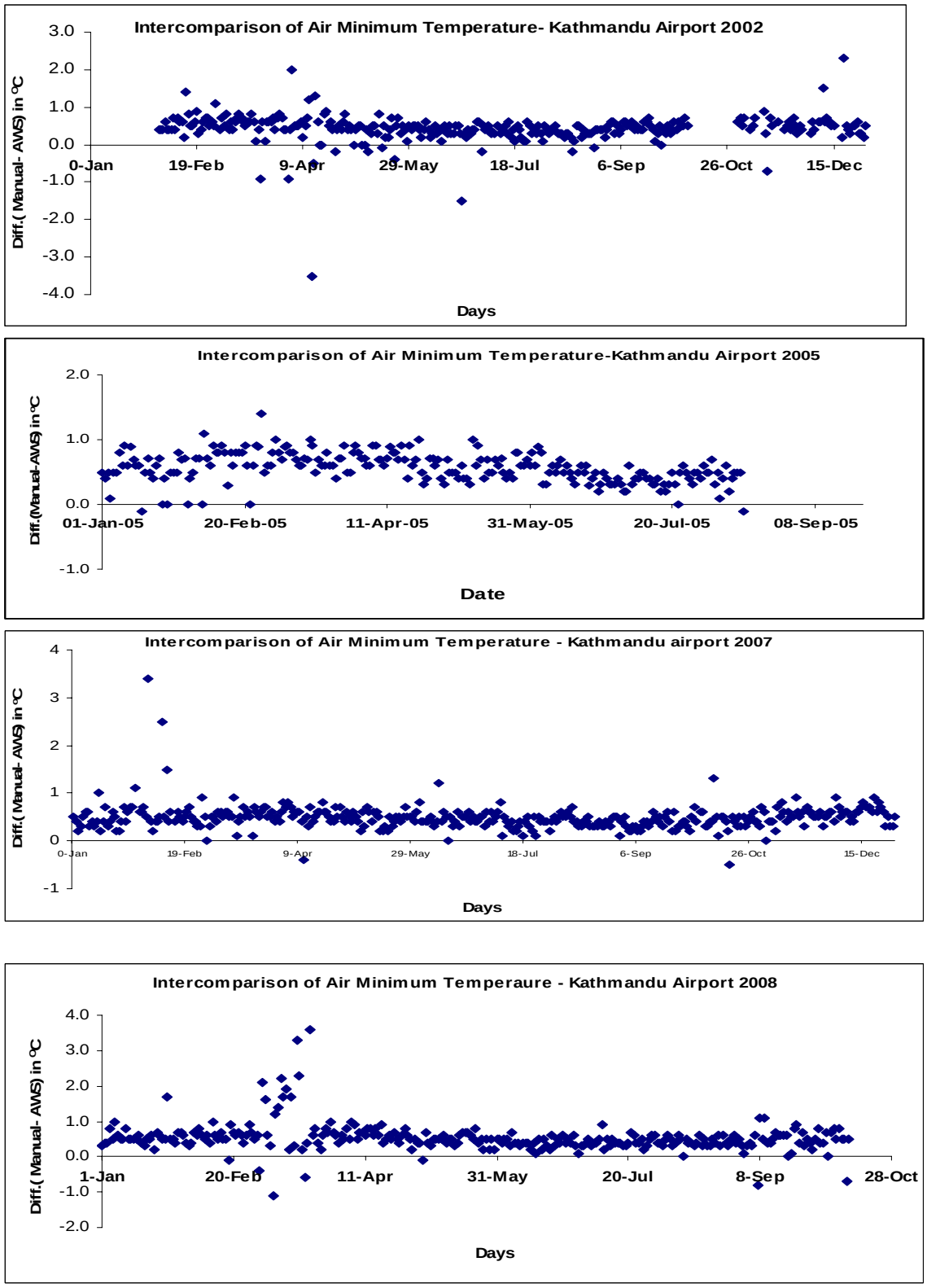


Fig 3: Daily Air Minimum Temperature Inter-comparison at Kathmandu Airport

Nepalgunj Airport:

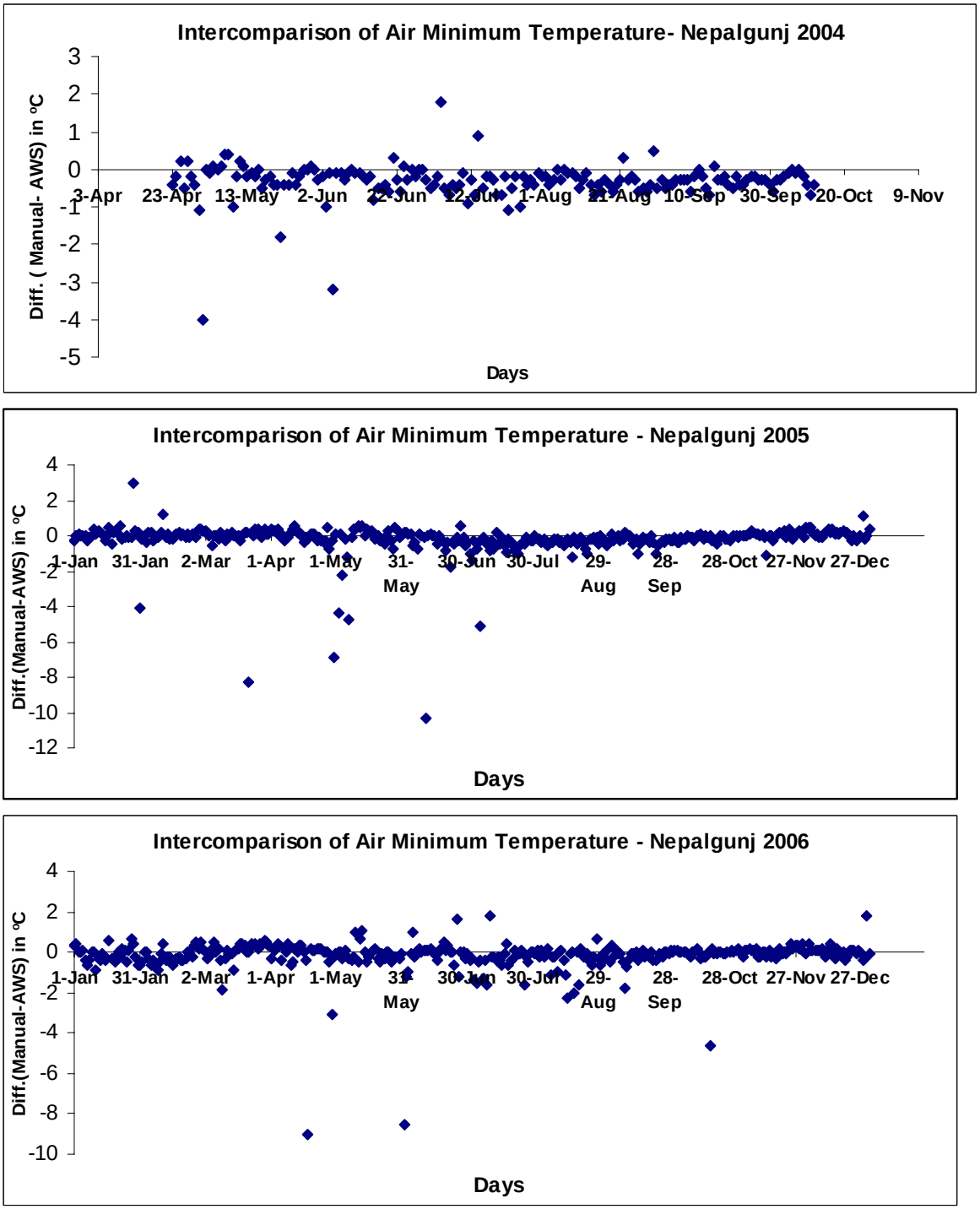


Fig 4: Daily Air Minimum Temperature Inter-comparison at Nepalgunj Airport

3.2 Inter-Comparison of Daily Air Maximum Temperature:

The measurement of air temperature is done with sensors mounted inside thermoplastic radiation shield made by Environdata Australia where as in conventional Manual observatories, Air Maximum temperature is measured with mercury maximum thermometer housed in wooden Stevension screen. The values taken at 12UTC of each day are utilized in this study.

The difference between Manual and AWS (Manual- AWS) measured daily maximum air temperature value have been computed for each station and presented in Fig 5 to 8.

Dang:

The daily maximum air temperature determined by AWS exceeds the air temperature value from manual mercury thermometer in most of the cases. Reverse pattern with manual reading higher than AWS are also noted specially in winter season. The higher value of manual reading might be as a result of prolonged fog and cloudiness during winter season. About 85% differences are ranged within -1^{o} to $1\ ^{o}C$ with majority of difference in negative range. As most of the difference (80%) are in the range of 0^{o} to $-2\ ^{o}C$, which shows that the difference is more systematic.

Simara Airport:

The random difference between AWS and manual data is found with higher magnitude of fluctuation. Only, about 50% differences are ranged within -1^{o} to $1\ ^{o}C$ and 80% in the range -2^{o} to $2\ ^{o}C$.

Kathmandu Airport:

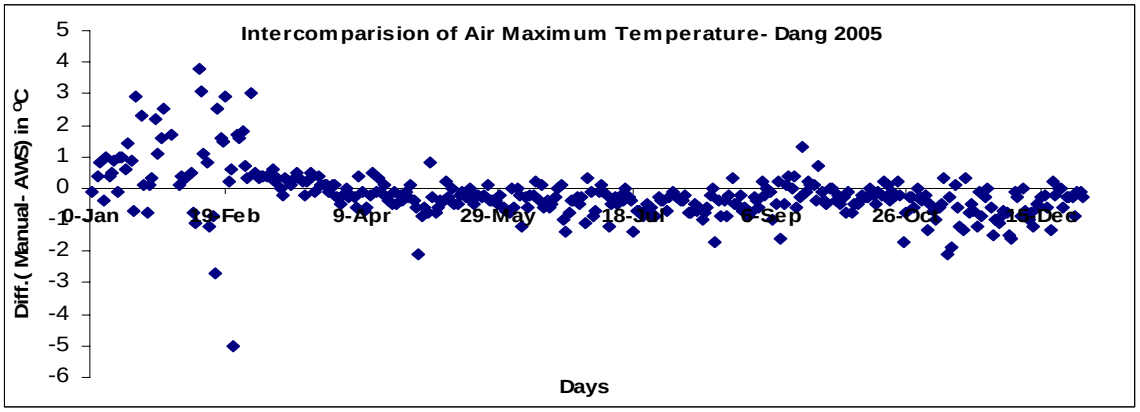
Except in 2002, the random difference between AWS and manual data is found with higher magnitude of fluctuation. In 2002, 99% differences are in the range -2 to $2\ ^{o}C$ and 92% in the range -1 to $1\ ^{o}C$. But in other years, the differences are very sparse with only about 50% data in the range of -1 to $1\ ^{o}C$.

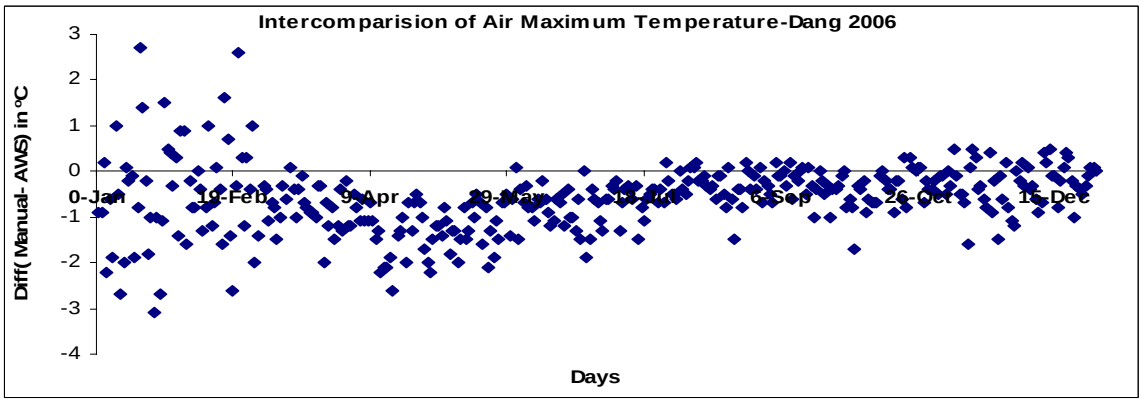
Nepalgunj:

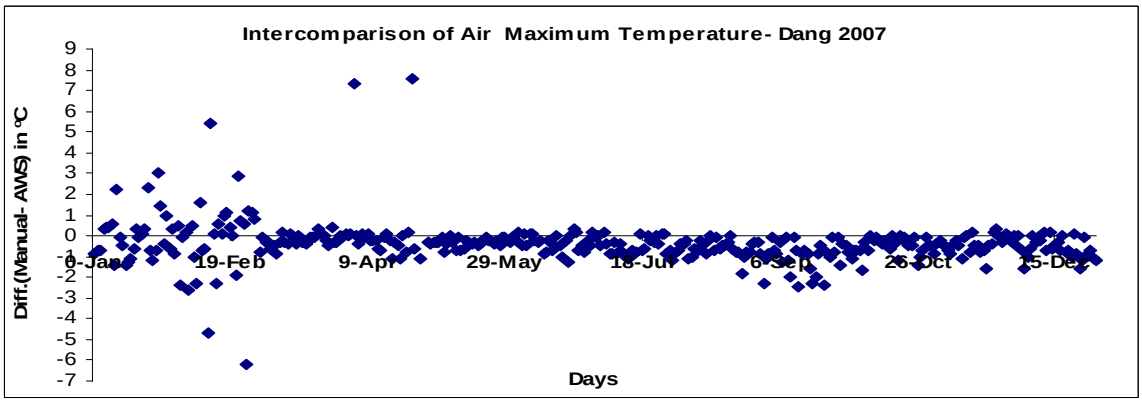
The difference is very random. Only about 40% differences are ranged within -1^{o} to $1\ ^{o}C$.This may be due to the very high temperature and dryness of the region.

In overall, very random difference have been observed in the data set.

Dang (Ghorahi):







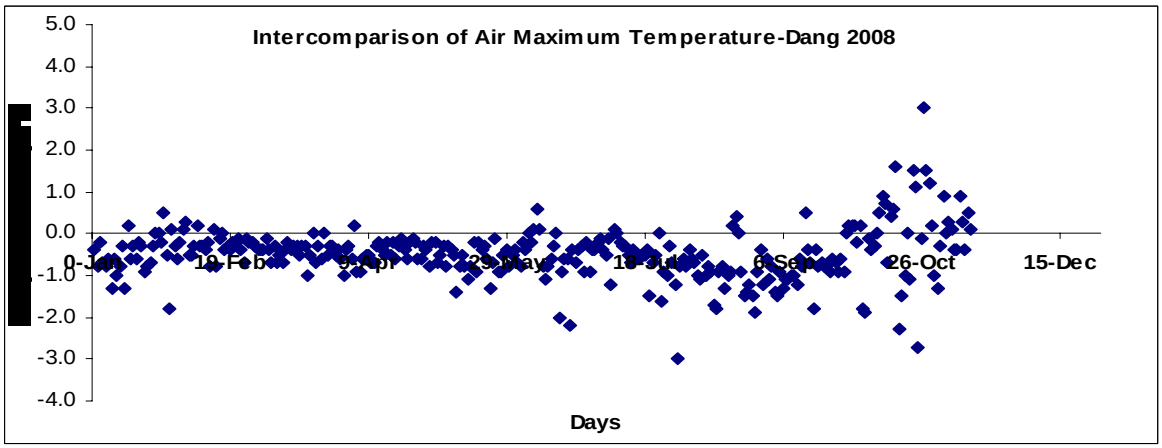
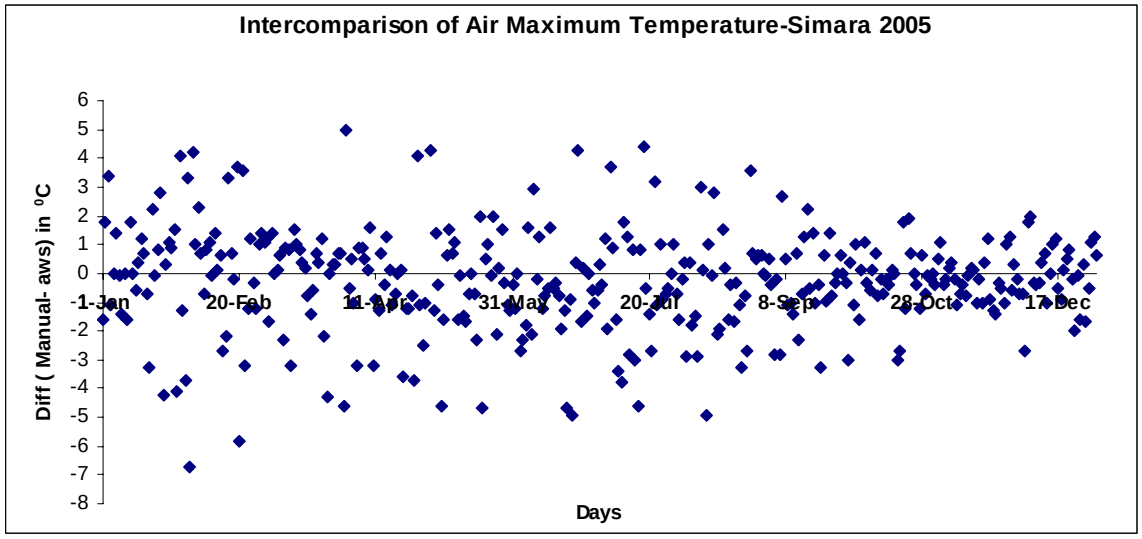
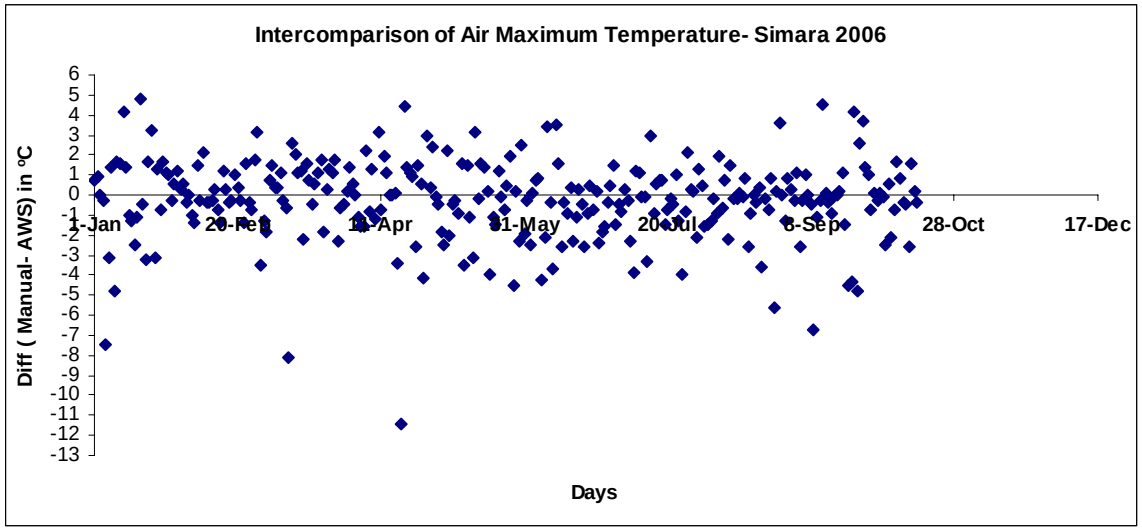


Fig 5: Daily Air Maximum Temperature Inter-comparison at Dang.

Simara Airport:





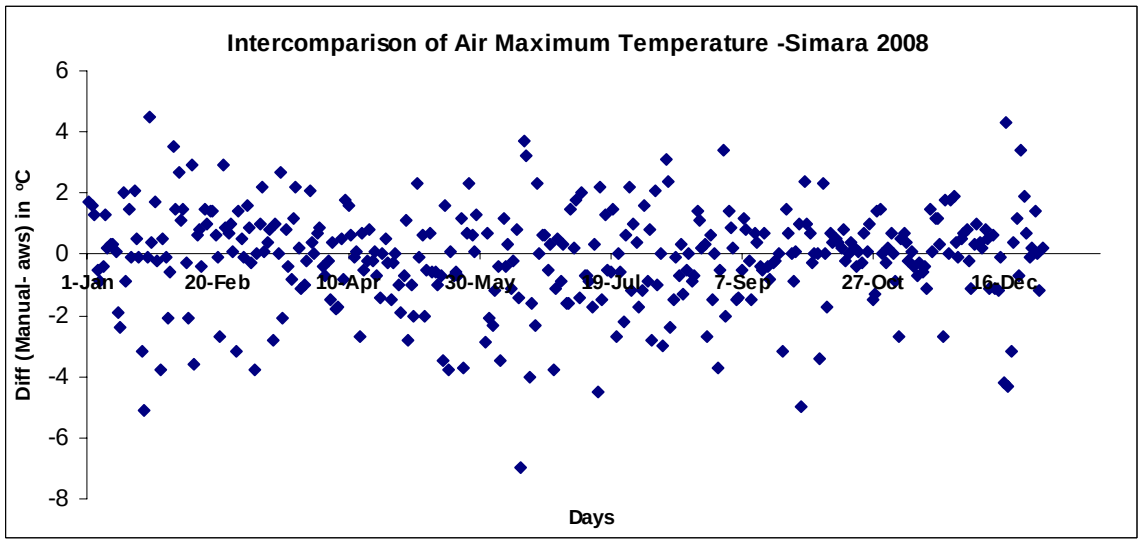
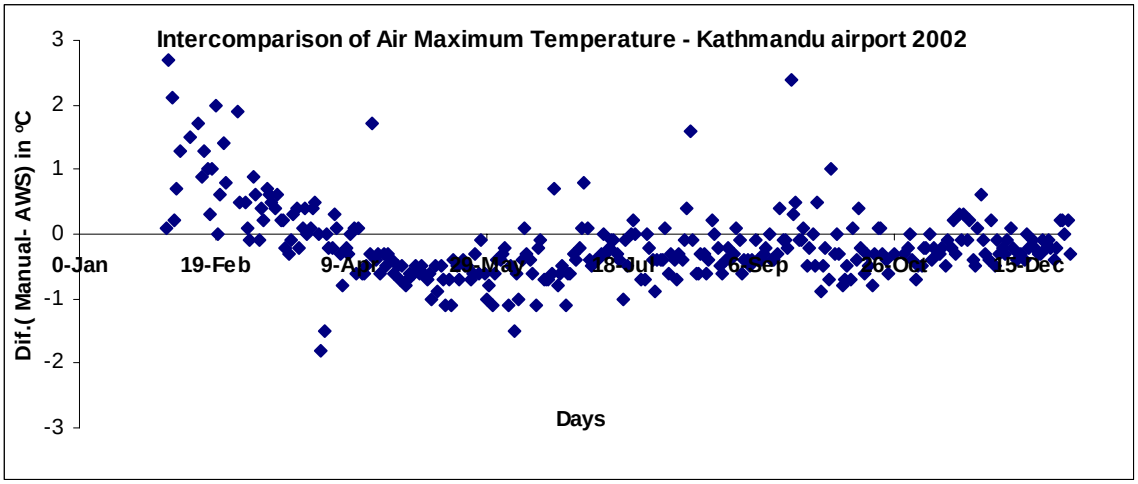
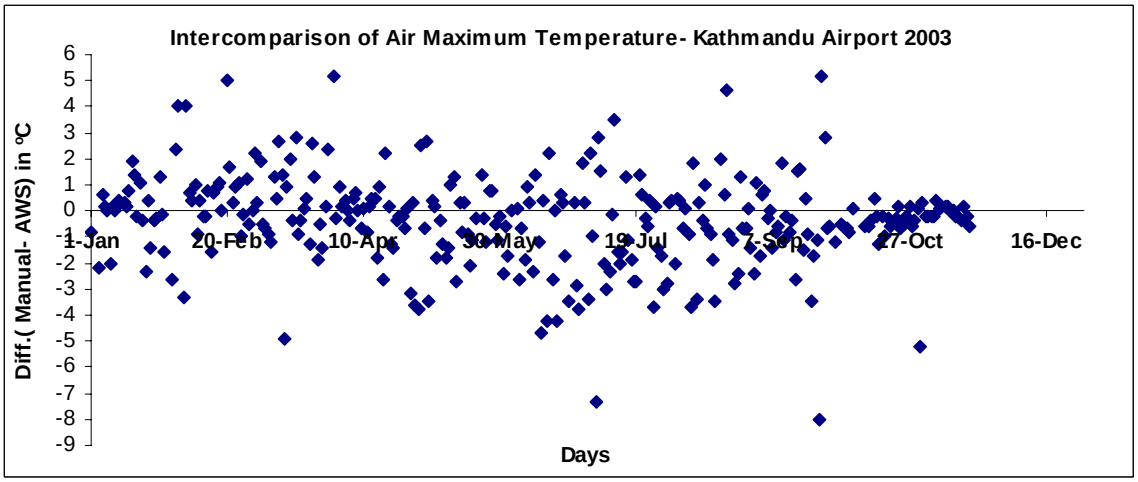


Fig 6: Daily Air Maximum Temperature Inter-comparison at Simara Airport.

Kathmandu Airport:





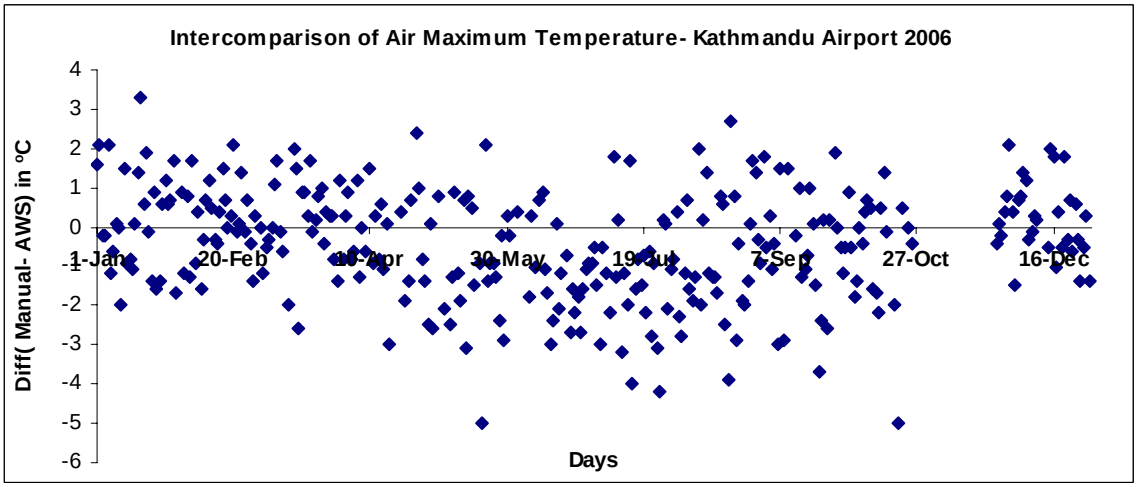
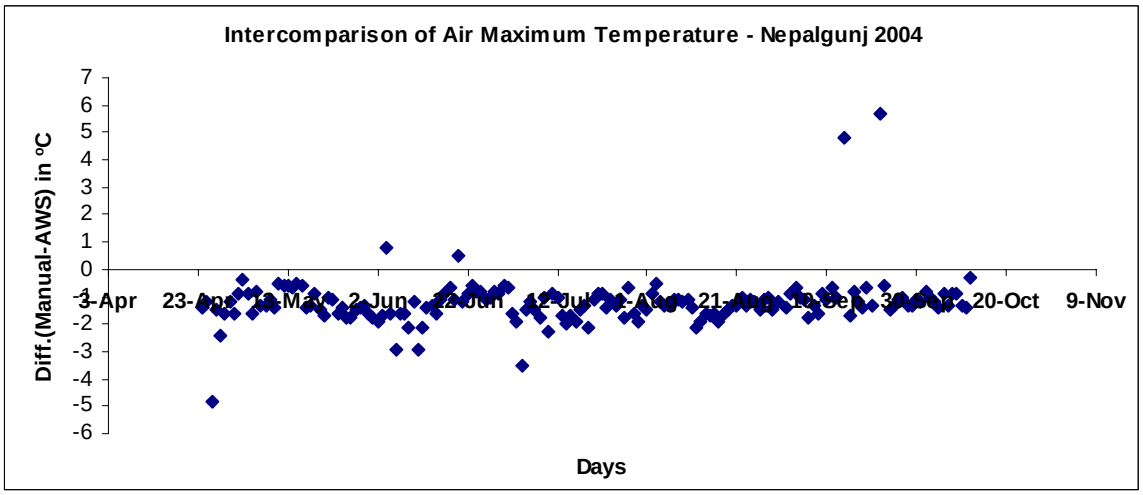
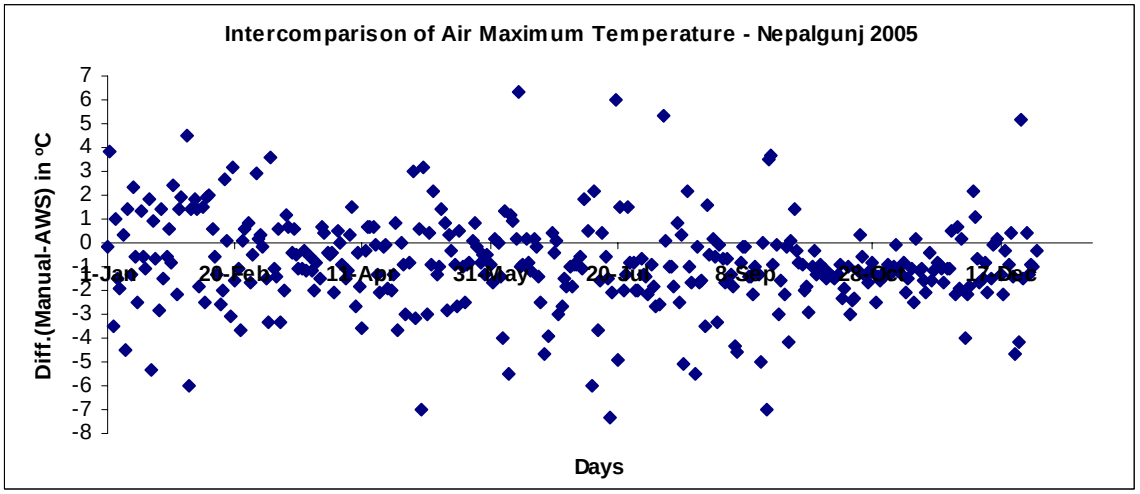


Fig 7: Daily Air Maximum Temperature Inter-comparison at Kathmandu Airport.

Nepalgunj Airport:





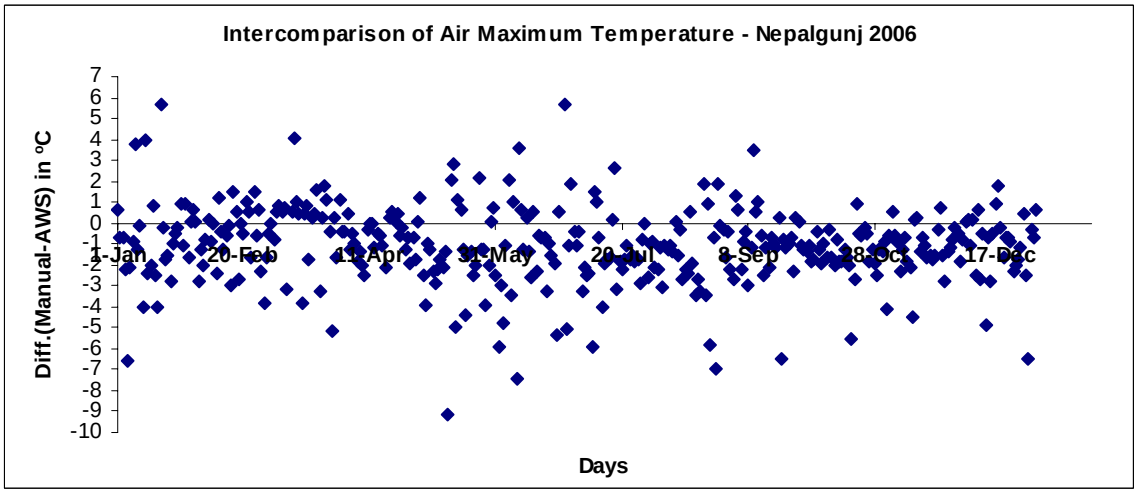


Fig 8: Daily Air Maximum Temperature Inter-comparison at Nepalgunj Airport.

3.3 Inter-Comparison of Daily Total Rainfall:

A tipping bucket Rain gauge made by Environdata, Australia of 8 inch diameter with simple intensity controller device is used for the measurement of Precipitation in AWS. The amount of precipitation for each tipping is 0.2mm.Manual rainfall measurement is also done with indigenous 8 inch diameter rain gauge. Data analysis has been carried out by calculating the difference between Manual and AWS measured 24 hour rainfall total at 03UTC. (Fig 9 to 12)

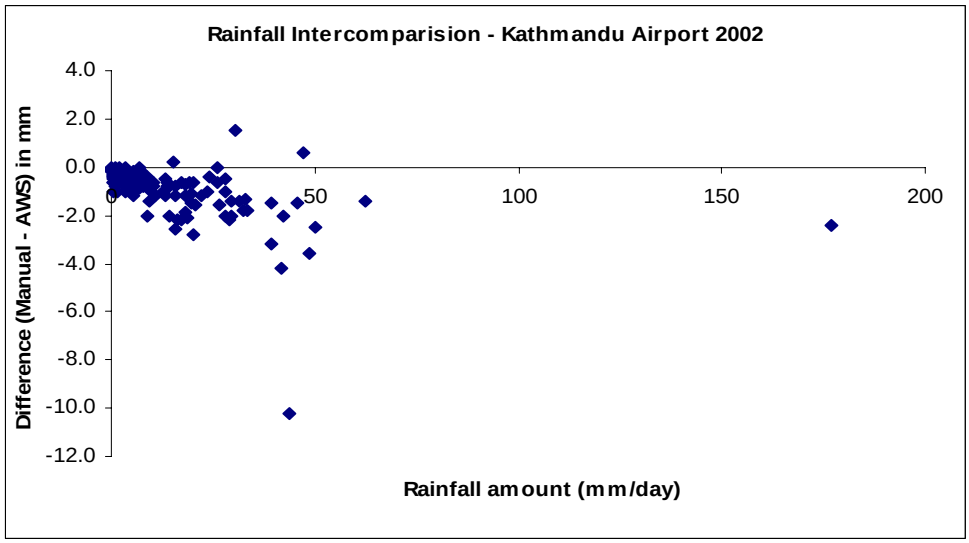
Kathmandu Airport:
Data analysis has shown that amount of precipitation measured by AWS is more compared to the amount measured by manual Raingauge in most of the rainfall intensity events, however in few isolated events the reverse pattern are also noted. When amount of precipitation measured by manual Raingauge are less than 20mm/ day, the difference between manual and AWS recordings are varied within -2mm but in few cases reverse pattern are also observed. With rising of precipitation amount the difference are increased and reaches in some cases up to -10mm.Although the difference is increased with higher precipitation total, no distinct pattern is observed, so it is difficult to determine the corrective ratio with this study which is based on daily rainfall total only. In order to get the corrective ratio in depth study in lower time interval for each intensity events considering wind effect is essential.

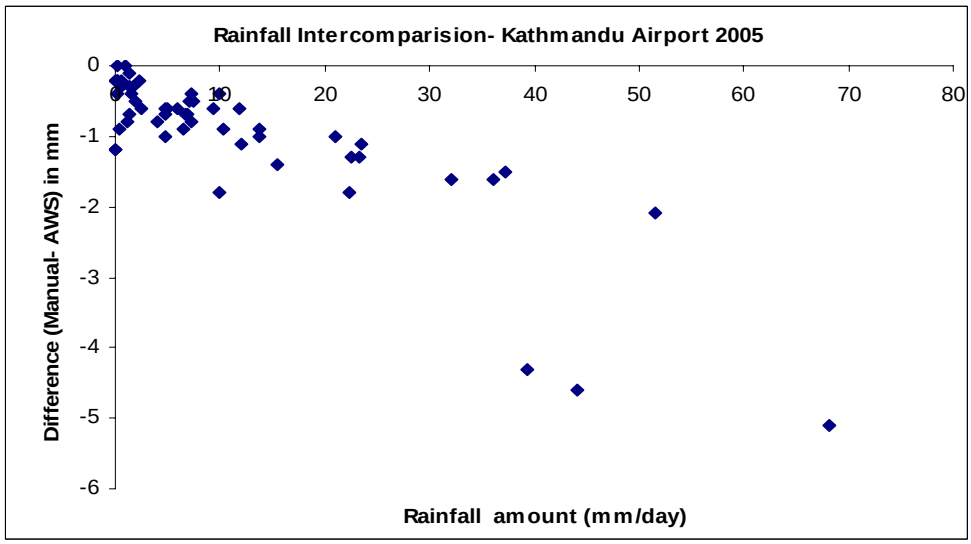
Simara Airport:
The amount of rainfall measured by AWS is more compared to manual in Simara station as well with result consistent to Kathmandu Airport. But the magnitude of fluctuation in rainfall amount between AWS and manual is remarkably higher in Simara in high rainfall intensity events with values reaching up to -50mm in the event with rainfall intensity of 200mm/day. The difference increases with increase in rainfall amount with some definite pattern except in year 2008.The rainfall amount measured by AWS is very much overestimated in high rainfall amount and is not realistic except in year 2008. Reverse pattern with Manual rainfall amount higher than AWS are also noted in few events in 2008 with the difference reaching up to 12mm

Nepalgunj Airport:
The result of Nepalgunj is also consistent to Kathmandu airport and Simara station with AWS measured rainfall values higher than manual in most of the cases but unlike other stations more reverse cases are also noted. The difference varies from +25mm to -25mm.

Laboratory:
Inter-comparison in Rainfall amount has been carried out by pouring directly certain amount of rainfall for three times and total amount is inter-compared .No marked difference in the total value has been observed even at intenstiy of 7mm/min.So, it can be concluded that intensity is not the determining factor for rainfall differences between manual and AWS system.Instability in the mechancial arms due to wind effect and lack of proper fixing of raingauge is suspected to be the prime factor for rainfall differences.

Kathmandu Airport:





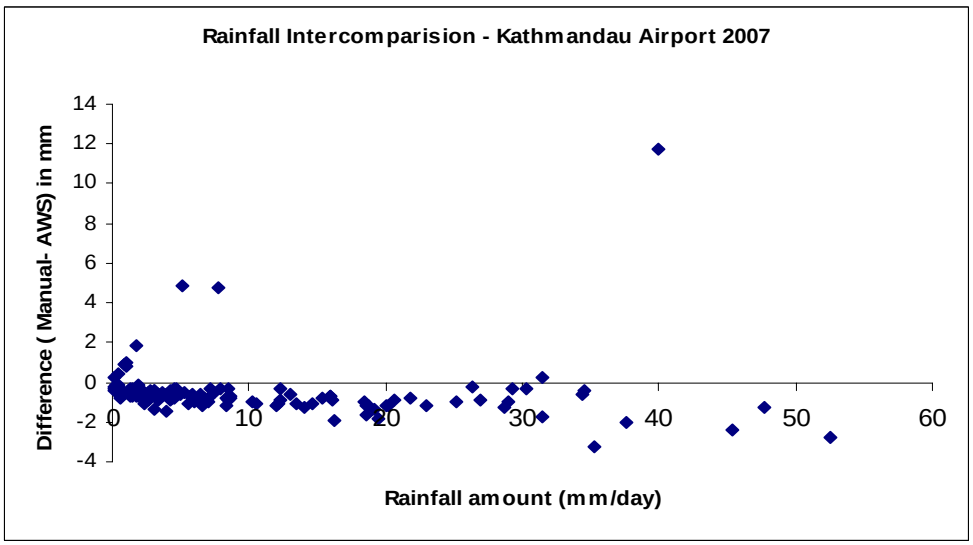


Fig 9: Rainfall Inter-comparison at Kathmandu Airport.

Simara Airport:

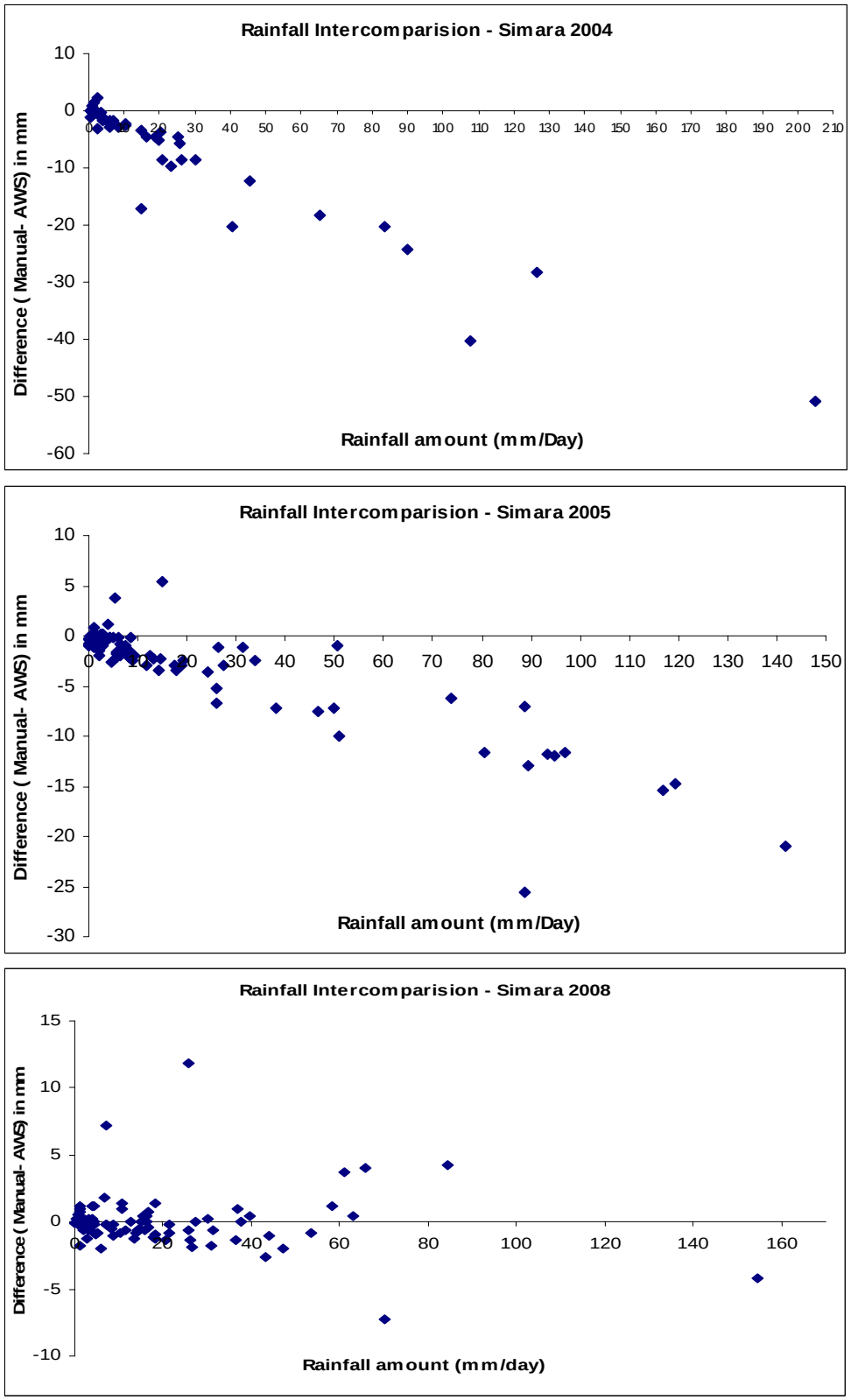
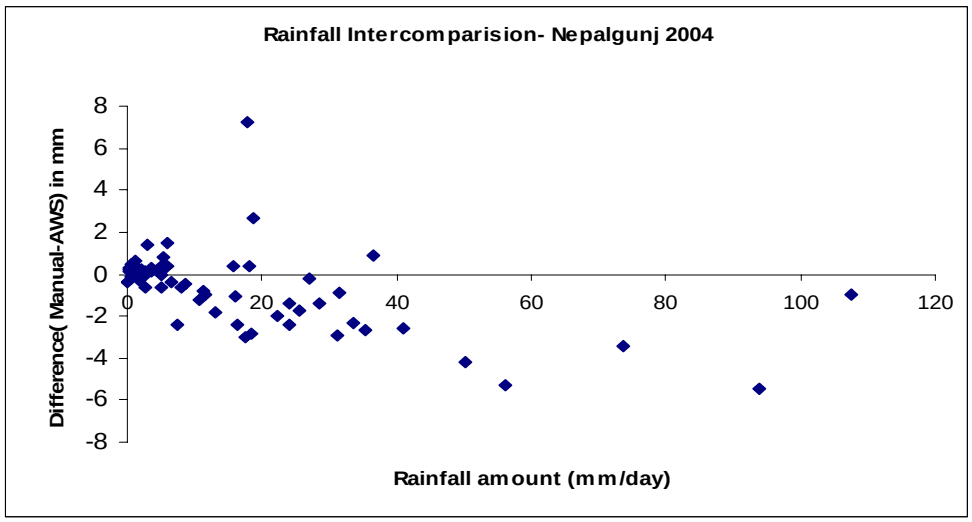
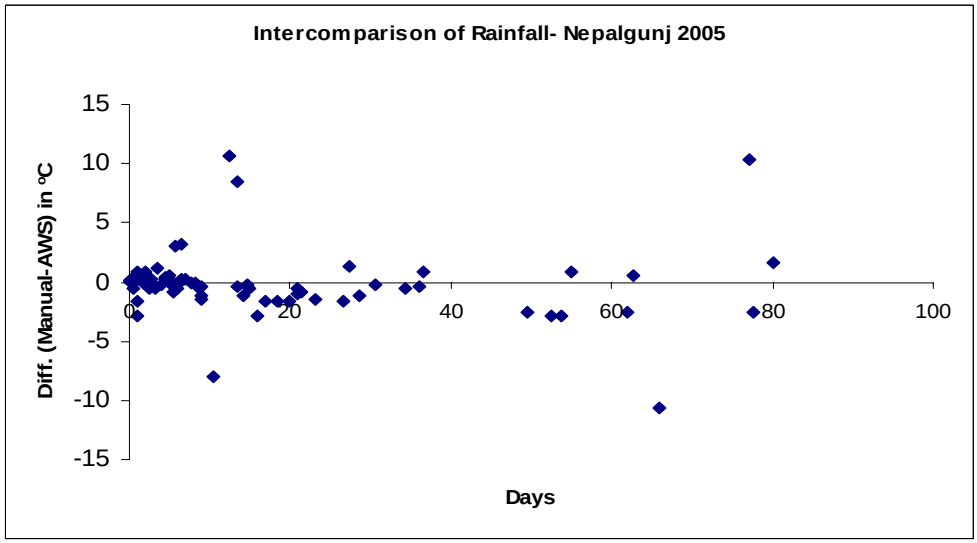


Fig 10: Rainfall Inter-comparison at Simara Airport.

Nepalgunj Airport:





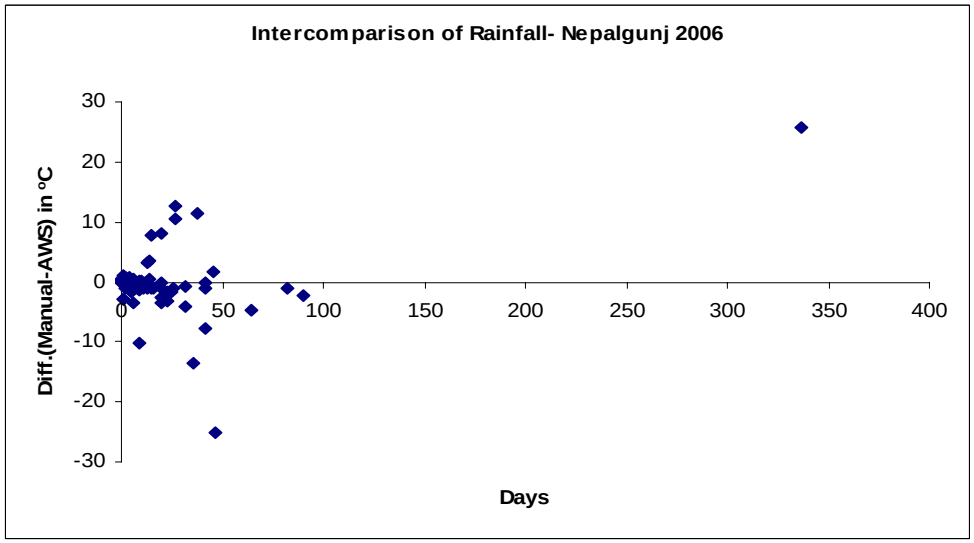
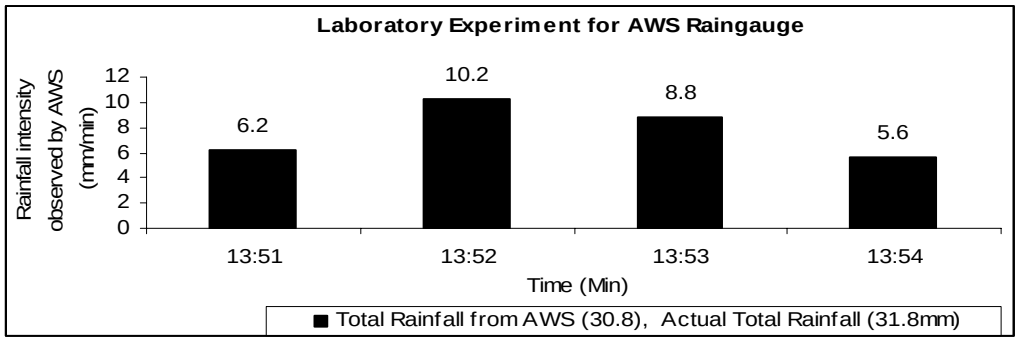
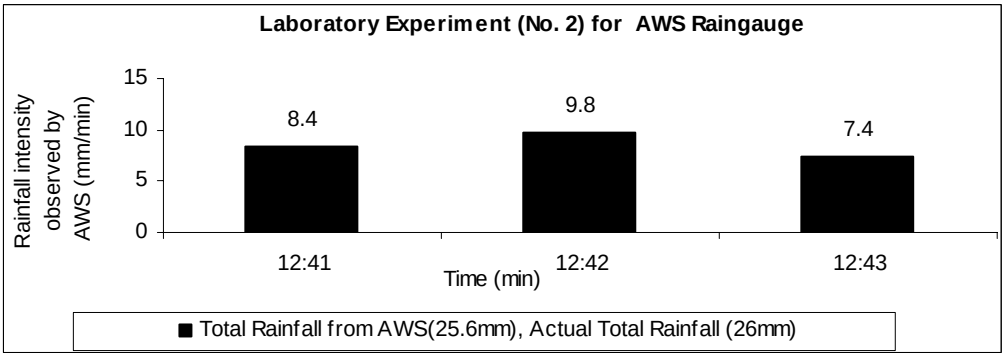


Fig 11: Rainfall Inter-comparison at Nepalgunj Airport.

Laboratory Experiment:





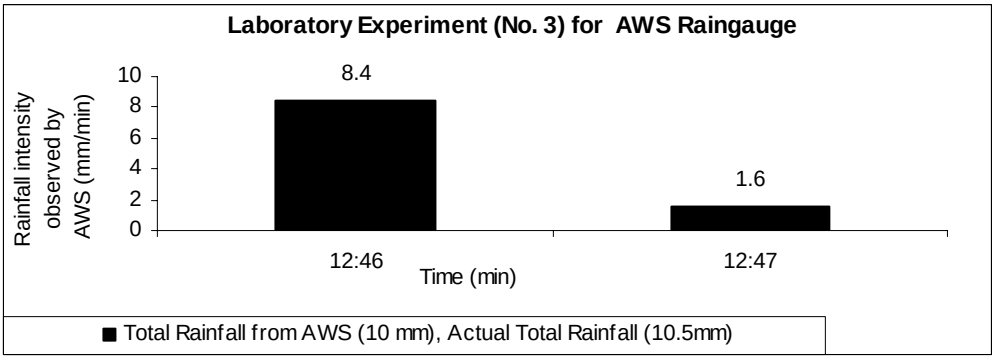


Fig 12: Rainfall Inter-comparison In Lab

4. Conclusions:

This analysis has attempted to study the difference between manual and AWS measured daily extreme temperature and daily rainfall total. Based on the data, daily minimum air temperature measured by AWS in thermoplastic radiation shield housing is found lower than the temperature readings from alcohol thermometer housed in wooden Stevenson screen with result consistent in most of the stations. The differences are systematic in all stations but the magnitude of difference varies from station to station. The mean difference in all the station do not exceed $\pm 1^{o}$C.

Although the difference between manual and AWS measured daily minimum air temperature is systematic, the difference in maximum air temperature is very random.

The minimum air temperature in general occurs during the night time(before down) and the indications of minimum air temperature value of AWS lower than the thermometer in most of the cases might be associated with the difference in the sensitivity and in design of weather shelter (i.e. wooden and thermoplastic).

Similarly, the maximum air temperature of AWS in general should be higher than the thermometer in connection to weather shelter but the difference is very random and might be associated with cloudiness, Rain, wind, radiation and the orientation of AWS shelter, and the height above the surface. In few stations, the ground below the AWS radiation shield is concrete which probably induce more difference. But it's very hard to be exact on the reason behind random fluctuation. Therefore, the detail study in hourly interval considering wind, radiation, rainfall, cloudiness and the underlying surface etc is essential to identify the reason behind discrepancies between AWS and manual observed extreme temperature.

Rainfall values measured by AWS in most of the cases exceed the value from manual. However few reverse patterns do exist. After getting such results inter-comparison work has been carried out in lab. But no marked deviation has been observed on pouring water even at intensity of about 7mm/min. So, the difference is suspected to be associated with instability in mechanical arms as a result of wind and the lack of proper fixing of Rain gauge. Therefore, detail study considering wind effect is essential to know the reason of difference between AWS and Manual observed rainfall.

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