# STUDY OF ERROR ANALYSIS AND THE EFFECTS OF RESAMPLING ON DIFFERENT DEMS

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## Abstract

*Resampling is the method of creating new pixels of different pixel size with respect to the original, using some interpolation technique from some existing pixels. Sometimes, the process may be as simple as duplication. Various approaches have been made to classify terrain based on the DEMs. To classify DEMs based on the slope into morphometric classes such as peak, ridges, pass, plane, channel & pits The main objective of the study is to compare the different morphometric results obtained for ASTER, SRTM 90 and SRTM 30 DEMs. The highlight is how the parameters from the resampled DEM appreciably agree with that of the original DEM of the same resolution, implying the importance of the resolution. In morphometric analysis, artifacts due to erroneous measurement techniques may be overlooked upon.*

***Keywords:*** *ASTER, SRTM, DEM, resampling, morphometric analysis*

## 1. INTRODUCTION

Under all circumstances, higher resolution data are always preferred over lower resolution ones. Surface features with sufficient optical contrast must exceed the size of the image resolution. (Kaab 2005) only then they can be well represented on the DEM. Various researchers have studied the impact of resolution on representation of terrain. With decreasing resolution, minimum elevation values tend to increase, whereas values for maximum elevation increase and this is because, maximum and minimum elevation values are influenced by the spatial resolution of the DEM, due to the smoothening of the terrain at a lower spatial resolution, when both tend to increase or decrease respectively (Frey et al. 2011) Maximum elevation values are more error prone, as these regions are often located in low – contrast or shadowed terrains. The lower resolution of the SRTM DEM influences the differences by underestimating the elevation of ridges and overestimating the elevation of narrow valleys (Frey et al. 2011).

Four factors that contribute to DEM accuracy are the quality of the input data, the horizontal resolution of the DEM, the methodology of data collection and the effects of terrain and vegetation. In areas of higher elevation, the magnitude of error increases because of inaccuracies due to horizontal resolution and also because lower flatter topography is more simply modeled while higher elevation topography becomes more complex. Horizontal accuracy affects the vertical accuracy of DEM data. As the pixel size increases, a single DEM pixel value reflects more land area by averaging values within the pixel (Chirico 2004) The accuracy of DEMs determines almost all types of estimation, namely geomorphological characterization of watershed, assessment of surface runoff and recharge, drainage characteristics and estimation of soil erosion potential, etc. (Rawat et al. 2012). For relatively smaller catchment, a slight variation in hydrologic estimation results in a very high level of drainage of different orders. It is therefore important to work with the most accurate DEM (Rawat et al. 2012)

Error is the departure of a measurement from its true value. In geographic analysis of complex natural systems using spatial data, the true value is often not known or there would be no access to it. The lack of knowledge about the reliability of a measurement in its representation of the true value is referred to as uncertainty and is a measure of what is not known (Wechsler 2006). Uncertainty exists in spatial data and in DEMs. The USGS recognizes that their DEM products have “blunders”, “systematic errors”, and random errors Blunders are vertical errors associated with the data collection process & are identified & removed prior to the release of the data. Systematic errors are results of the procedures or systems used in the DEM generation process and fixed patterns that can cause bias and artifacts in the final DEM product. When the cause is known, systematic errors can be removed. Random errors remain in the data after blunders and systematic errors are removed. The process responsible for introducing random errors into a DEM is not sufficiently known thus the exact nature and location of these errors cannot be precisely determined (Wechsler 2006). The USGS provides users of their products with the Root Mean Square Error (RMSE) statistic. These values do not always reflect the actual elevation rather they provide the most probable elevation DEM users often apply the DEM as a truth surface rather than as a model (as its name implies) and this assumption, looped with errors and low resolution problems can handicap the DEM from truly representing the terrain. To extract accurate DEM parameters for various applications, researchers always try to either merge data or use fusion techniques or resampling. Ravibabu and Jain (2006) found that many researchers are not concerned about the DEM accuracy and re-sampling methods while generating DEM from various sources.

## 2. STUDY AREA

The investigated areas are located in India and are representatives of different topographic relief zones. The flat, medium and rugged relief terrains were identified in the broad regions of Rajasthan, Dehradun and the Himalayas, respectively (Fig. 1). In all, a total of twelve drainage basins were investigated using SRTM and ASTER Digital Elevation Models (DEMs), out of which F4, M4 and R4 were used for validation for mathematical relations. The details about ASTER and SRTM DEMs for all the twelve areas are given in Table 1

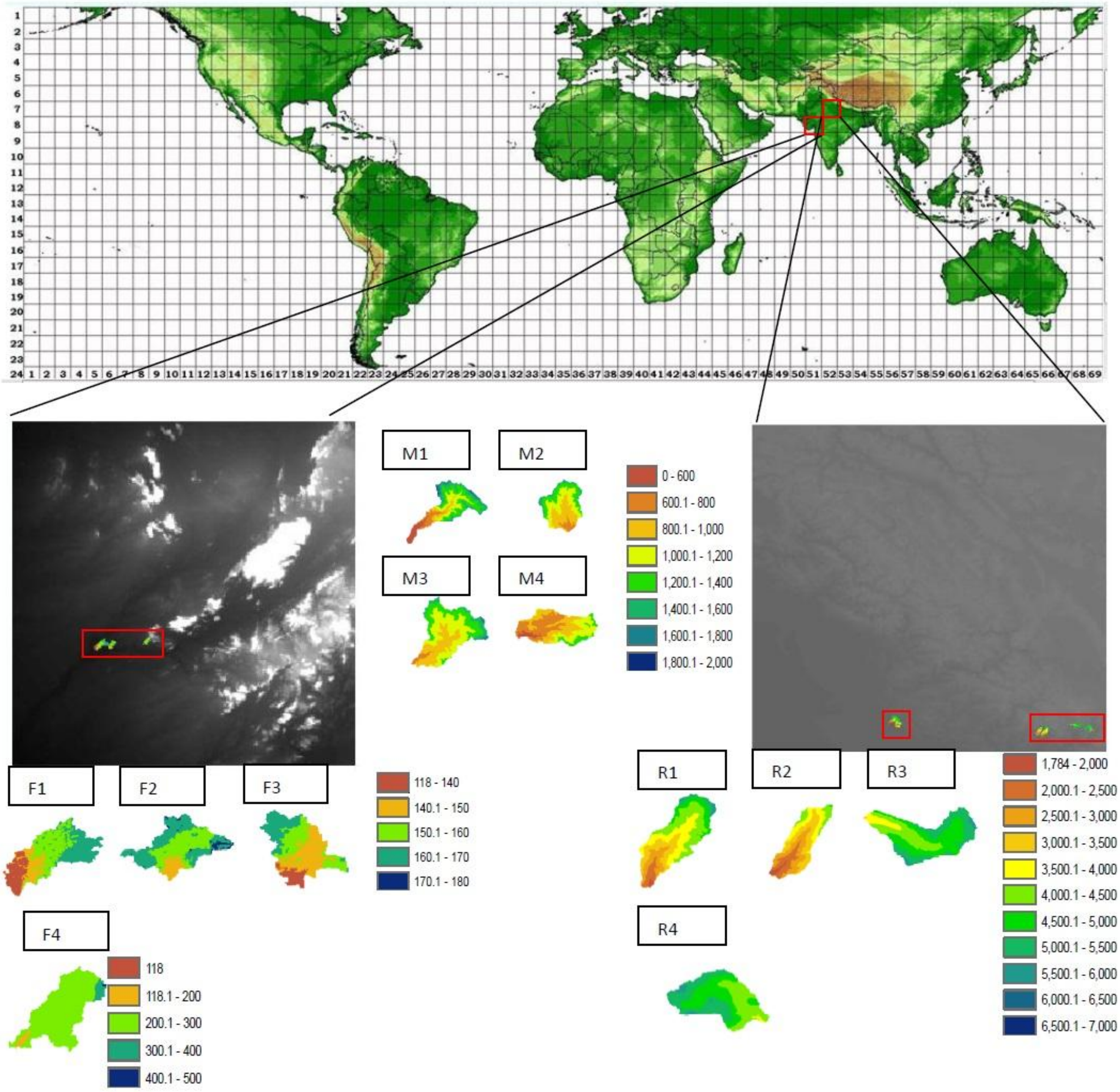


**Fig. 1:** The Study area. The Flat terrain basins (F1, F2, F3 &F4) were obtained from the tile 51_8, while the Medium (M1, M2, M3 & M4) and the rugged terrains (R1, R2, R3 & R4) were obtained from the tile 52_7.

## 3. CLASSIFICATION OF DIFFERENT TERRAINS BASED ON RELIEF

Generally, the terrain can be categorized into three classifications based on their reliefs:

- Flat terrain: 0 – 300m
- Medium terrain: 300 – 2000m
- Rugged terrain: 2000 – 5000m

**Table 1:** General information about the investigated areas (12 nos.) for each of the DEMs.

| Terrain | Area | Parameter | ASTER | SRTM 90 |
|---|---|---|---|---|
| Flat terrain (0 – 300 m) | F1 | Cell size | 24.94, 24.94 | 74.51, 74.51 |
| | | Total Basin Area (sq. km) | 7.26 | 7.17 |
| | | High, Low, Relief (m) | 173, 133, 40 | 168, 133, 35 |
| | F2 | Cell size | 24.94, 24.94 | 90.21, 90.21 |
| | | Total Basin Area (sq. km) | 2.107 | 2.184 |
| | | High, Low, Relief (m) | 177, 144, 33 | 172, 146, 26 |
| | F3 | Cell size | 24.94, 24.94 | 81.916, 90.108 |
| | | Total Basin Area (sq. km) | 1.311 | 1.364 |
| | | High, Low, Relief (m) | 170, 135, 35 | 168, 138, 30 |
| | F4 | Cell size | 24.94, 24.94 | 83.6, 83.6 |
| | | Total Basin Area (sq. km) | 2.27 | 2.173 |
| | | High, Low, Relief (m) | 426, 191, 235 | 373, 194, 179 |
| Medium (300 – 2000 m) | M1 | Cell size | 29.66,29.66 | 88.98,88.98 |
| | | Total Basin Area (sq. km) | 93.393 | 93.45 |
| | | High, Low, Relief (m) | 1910, 429, 1481 | 1889, 424, 1465 |
| | M2 | Cell size | 27.825, 27.825 | 89.06, 89.06 |
| | | Total Basin Area (sq. km) | 30.16 | 30.16 |
| | | High, Low, Relief (m) | 1667, 688, 979 | 1648, 682, 966 |
| | M3 | Cell size | 29.64, 29.64 | 88.91,88,91 |
| | | Total Basin Area (sq. km) | 23.395 | 23.42 |
| | | High, Low, Relief (m) | 1772, 688, 1084 | 1748, 683, 1065 |
| | M4 | Cell size | 29.8, 29.8 | 74.48, 74.48 |
| | | Total Basin Area (sq. km) | 26.526 | 26.55 |
| | | High, Low, Relief (m) | 1472, 500, 972 | 1422, 501, 921 |
| Rugged Terrain (2000 – 5000 m) | R1 | Cell size | 29.125, 29.125 | 74.565, 87.364 |
| | | Total Basin Area (sq. km) | 79.83 | 79.808 |
| | | High, Low, Relief (m) | 6168, 1783, 4385 | 5983, 1784, 4199 |
| | R2 | Cell size | 29.125, 29.125 | 74.565, 87.364 |
| | | Total Basin Area (sq. km) | 49.032 | 48.375 |
| | | High, Low, Relief (m) | 4799, 1701, 3098 | 4749, 1717, 3032 |
| | R3 | Cell size | 29.049, 29.049 | 87.145, 87.145 |
| | | Total Basin Area (sq. km) | 55.011 | 55.24 |
| | | High, Low, Relief (m) | 6429, 3468, 2961 | 6027, 3431, 2596 |

## 2. STUDY OF RESAMPLING EFFECT BY DIFFERENCING OF DEMS

To understand the difference between resampling to higher and lower resolutions, ASTER 30 was resampled to 90m to difference from SRTM 90 and SRTM 90 was resampled to SRTM 30 and differenced from ASTER 30, for 9 areas spanning across the 3 terrain classes. The number of zeroes help to understand which operation of resampling is better

**Table 2.** The number of zeroes obtained for the different basins by differencing ASTER and SRTM by resampling ASTER to 90m and SRTM to 30m.

| Terrain | Basin | $\rho_1$ (m) | $\rho_2$ (m) | $x_1$ (m) | $x_2$ (m) | $A_{T1}$ (km$^2$) | $A_{T2}$ (km$^2$) | No. of zeroes (SRTM90 – ASTER90) | No. of zeroes (ASTER30-SRTM30) |
|---|---|---|---|---|---|---|---|---|---|
| Flat | F1 | 40 | 35 | 25 | 75 | 7.26 | 7.17 | 210 | 1835 |
| | F2 | 33 | 26 | 25 | 90 | 2.107 | 2.184 | 21 | 306 |
| | F3 | 35 | 30 | 25 | 90 | 1.311 | 1.364 | 34 | 271 |
| Medium | M1 | 1481 | 1465 | 30 | 90 | 93.393 | 93.45 | 250 | 2450 |
| | M2 | 979 | 966 | 30 | 90 | 30.16 | 30.16 | 82 | 861 |
| | M3 | 1084 | 1065 | 30 | 90 | 23.395 | 23.42 | 40 | 347 |
| Rugged | R1 | 4385 | 4199 | 30 | 75 | 79.83 | 79.808 | 86 | 735 |
| | R3 | 2961 | 2596 | 30 | 90 | 55.011 | 55.24 | 87 | 830 |
| | R4 | 2694 | 2151 | 30 | 90 | 53.26 | 53.223 | 127 | 633 |

From Table 2 it is clear that resampling SRTM 90m to 30m gives lesser errors to the actual values. The differences may vary with the terrain, relief and the basin area. It can be generally seen that rugged terrains show more differences while flat terrains show the least. With this understanding, the SRTM 30 was used for comparison and for further analysis to study the error with the various morphometric parameters between ASTER and SRTM DEM.

## 4. ERROR ANALYSIS OF ASTER AND SRTM DEM THROUGH THE RELATION BETWEEN THRESHOLD FLOW ACCUMULATION AND DRAINAGE AREA

A relation was tried to be drawn between the threshold flow accumulation and the drainage area for ASTER, SRTM 90 and SRTM 30. The percentage error between ASTER and SRTM 30 DEMs and between ASTER and SRTM 90 DEMs were calculated for all the areas.

**Table 3.** The average Drainage Area percentage errors between ASTER & SRTM 30 and ASTER & SRTM 90 for all the basins.

| Drainage Area | Terrain | Basin | Average Drainage Area percentage error ASTER/SRTM30 | Average Drainage Area percentage error ASTER/SRTM90 |
|---|---|---|---|---|
| | Flat | F1 | 30.88 | 88.79 |
| | | F2 | 44.67 | 92.31 |
| | | F3 | 44.67 | 92.33 |
| Average | | | **40.07** | **91.14** |
| | Medium | M1 | 2.51 | 88.85 |
| | | M2 | 2.08 | 88.89 |
| | | M3 | 2.41 | 88.89 |
| Average | | | **2.33** | **88.87** |
| | Rugged | R1 | 6.1 | 88.89 |
| | | R3 | 6.65 | 88.89 |
| | | R4 | 7.36 | 84.92 |
| Average | | | **6.7** | **87.57** |

The error seems to be consistent for each terrain proving that the terrain classifications are good (Table 3). During resampling the cell size is made consistent, and hence, the drainage equations are calculated from the threshold flow accumulation value (as used by the software) using the relation Drainage Area = flow accumulation × (cell size)$^2$. In the flat terrain, an error of 40% shows that this relation does not hold very good, as compared to the medium or the rugged terrains. On the other hand there is a consistent error of almost 90% between the SRTM 90 and ASTER Drainage Areas irrespective of their terrain classification. This draws a general comparison between SRTM 90 and ASTER DEM to relate threshold flow accumulation and the corresponding threshold drainage area (table 4)

The drainage area is related to the threshold flow accumulation through the cell size as ASTER and SRTM 30 show the curve along the same line. The relations obtained are tabulated. Note that the coefficient is always close to the square of the cell size.

**Table 4.** The relation obtained between Drainage Area and the threshold flow accumulation for all the basins. Note that the coefficient is always close to the square of the cell size.

| Terrain | Basin | Type of DEM | Cell size x(m) | Cell size x(km) | $A_d$=Drainage Area, y= fac | Type of fit | $R^2$ value | Cell size $x^2(km^2)$ |
|---|---|---|---|---|---|---|---|---|
| Flat | F1 | ASTER | 24.94 | 0.02494 | $A_d=\mathbf{0.0006}y$ | Power | 1 | **0.0006** |
| | | SRTM 90 | 74.51 | 0.07451 | $A_d=\mathbf{0.0056}y$ | Power | 1 | **0.00555** |
| | | SRTM 30 | 30 | 0.03 | $A_d=\mathbf{0.0009}y$ | Power | 1 | **0.0009** |
| Flat | F2 | ASTER | 24.94 | 0.02494 | $A_d=\mathbf{0.0006}y$ | Power | 1 | **0.00062** |
| | | SRTM 90 | 90.21 | 0.09021 | $A_d=\mathbf{0.008}y^{1.004}$ | Power | 0.9999 | **0.0081** |
| | | SRTM 30 | 30 | 0.03 | $A_d=\mathbf{0.0009}y$ | Power | 1 | **0.0009** |
| Flat | F3 | ASTER | 24.94 | 0.02494 | $A_d=\mathbf{0.0006}y^{0.9999}$ | Power | 1 | **0.00062** |
| | | SRTM 30 | 30 | 0.03 | $A_d=\mathbf{0.0009}y$ | Power | 1 | **0.0009** |
| Medium | M1 | ASTER | 29.66 | 0.02966 | $A_d=\mathbf{0.0009}y^{1.0008}$ | Power | 0.9999 | **0.00087** |
| | | SRTM 90 | 88.98 | 0.08898 | $A_d=\mathbf{0.0079}y$ | Power | 1 | **0.00791** |
| | | SRTM 30 | 30 | 0.03 | $A_d=\mathbf{0.0009}y$ | Power | 1 | **0.0009** |
| Medium | M2 | ASTER | 27.825 | 0.02782 | $A_d=\mathbf{0.0009}y$ | Power | 1 | **0.00077** |
| | | SRTM 90 | 89.06 | 0.0896 | $A_d=\mathbf{0.0079}y$ | Power | 1 | **0.00802** |
| | | SRTM30 | 30 | 0.03 | $A_d=\mathbf{0.0009}y$ | Power | 1 | **0.0009** |
| Medium | M3 | ASTER | 29.64 | 0.02964 | $A_d=\mathbf{0.0009}y$ | Power | 1 | **0.00087** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| | | SRTM 90 | 88.91 | 0.08891 | $A_d$=**0.0079**y | Power | 1 | **0.0079** |
| | | SRTM 30 | 30 | 0.03 | $A_d$=**0.0009**y | Power | 1 | **0.0009** |
| Rugged | R1 | ASTER | 29.125 | 0.02912 | $A_d$=**0.0008**y | Power | 1 | **0.00084** |
| | | SRTM 90 | 87.364 | 0.08736 | $A_d$=**0.0076**y | Power | 1 | **0.00763** |
| | | SRTM 30 | 30 | 0.03 | $A_d$=**0.0009**y | Power | 1 | **0.0009** |
| Rugged | R3 | ASTER | 29.049 | 0.02904 | $A_d$=**0.0008**y | Power | 1 | **0.00084** |
| | | SRTM 90 | 87.145 | 0.08714 | $A_d$=**0.0076**$y^{1.0004}$ | Power | 0.9999 | **0.00759** |
| | | SRTM 30 | 30 | 0.03 | $A_d$=**0.0009**y | Power | 1 | **0.0009** |
| Rugged | R4 | ASTER | 28.95 | 0.02895 | $A_d$=**0.0008**y | Power | 1 | **0.00083** |
| | | SRTM 90 | 74.57 | 0.07457 | $A_d$=**0.0056**y | Power | 1 | **0.00556** |
| | | SRTM 30 | 30 | 0.03 | $A_d$=**0.0009**y | Power | 1 | **0.0009** |

## 5. ERROR ANALYSIS OF ASTER AND SRTM DEM THROUGH THE RELATION BETWEEN THRESHOLD FLOW ACCUMULATION AND NUMBER OF CATCHMENTS

For each flow accumulation threshold value ranging from 1 to 1600, the respective number of catchments or the number of stream segments are noted for ASTER, SRTM 90 and SRTM 30 DEMs. The catchments are drawn bounding each stream segment so the numbers of catchments are essentially the same as the number of stream segments. An error analysis is also performed to see how much the SRTM 30 and SRTM 90 values depart from ASTER 30 values for each threshold value, assuming that higher resolution yields more accurate morphometric results. The way the numbers of catchments are related to the threshold flow accumulation is tabulated (Table 5).

**Table 5. The relations obtained relating the Numbers of Catchments with the flow accumulation for all the basins, along with their $R^2$ values.**

| Terrain | Area | Type of DEM | Catchment eqn. | Type of fit | $R^2$ value |
|---|---|---|---|---|---|
| Flat | F1 | ASTER | $y=7687.7x^{-1.118}$ | Power | 0.9685 |
| | | SRTM 90 | $y=453.42x^{-1.017}$ | Power | 0.9698 |
| | | SRTM 30 | $y=3773.8x^{-1.065}$ | Power | 0.9901 |
| Flat | F2 | ASTER | $y=1459.3x^{-0.995}$ | Power | 0.9854 |
| | | SRTM 90 | $y=107.95x^{-0.984}$ | Power | 0.9566 |
| | | SRTM 30 | $y=904x^{-0.973}$ | Power | 0.9859 |
| Flat | F3 | ASTER | $y=793.81x^{-0.982}$ | Power | 0.9719 |
| | | SRTM 90 | $y=66.457x^{-1.015}$ | Power | 0.9358 |
| | | SRTM 30 | $y=584.49x^{-1.04}$ | Power | 0.9895 |
| Medium | M1 | ASTER | $y=55047x^{-1.011}$ | Power | 0.9974 |
| | | SRTM 90 | $y=5672.7x^{-1.001}$ | Power | 0.9974 |

| | | | | | |
|---|---|---|---|---|---|
| | | SRTM 30 | $y=51909x^{-1.011}$ | Power | 0.9931 |
| Medium | M2 | ASTER | $y=14326x^{-0.963}$ | Power | 0.995 |
| | | SRTM 90 | $y=2007.9x^{-1.034}$ | Power | 0.9887 |
| | | SRTM30 | $y=17035x^{-0.996}$ | Power | 0.996 |
| Medium | M3 | ASTER | $y=15852x^{-1.046}$ | Power | 0.9936 |
| | | SRTM 90 | $y=1531.3x^{-1.05}$ | Power | 0.9909 |
| | | SRTM 30 | $y=12891x^{-1.019}$ | Power | 0.9905 |
| Rugged | R1 | ASTER | $y=46522x^{-0.977}$ | Power | 0.9962 |
| | | SRTM 90 | $y=8231x^{-1.141}$ | Power | 0.9654 |
| | | SRTM 30 | $y=3467x^{-0.936}$ | Power | 0.9933 |
| Rugged | R3 | ASTER | $y=30726x^{-0.936}$ | Power | 0.9969 |
| | | SRTM 90 | $y=4370.5x^{-1.052}$ | Power | 0.9742 |
| | | SRTM 30 | $y=23977x^{-0.932}$ | Power | 0.9926 |
| Rugged | R4 | ASTER | $y=29550x^{-0.953}$ | Power | 0.996 |
| | | SRTM 90 | $y=6573.1x^{-1.102}$ | Power | 0.9572 |
| | | SRTM 30 | $y=22733x^{-0.935}$ | Power | 0.9898 |

As it is seen, the $R^2$ values are very close to 1, and this forms a promising relationship.

The catchment numbers from ASTER 30, SRTM 90 and SRTM 30 were tried to be inter-related to see the relation. A plot between ASTER catchment number and SRTM 30 catchment number shows a linear fit (Fig. 2). The figure shows that atleast more than two points fit in the line, or should give a good correlation. In comparison to this, the ASTER number of Catchments is compared to SRTM 90 catchment number (Fig. 3). Definitely, the resampled SRTM values seem to correlate better with the ASTER.

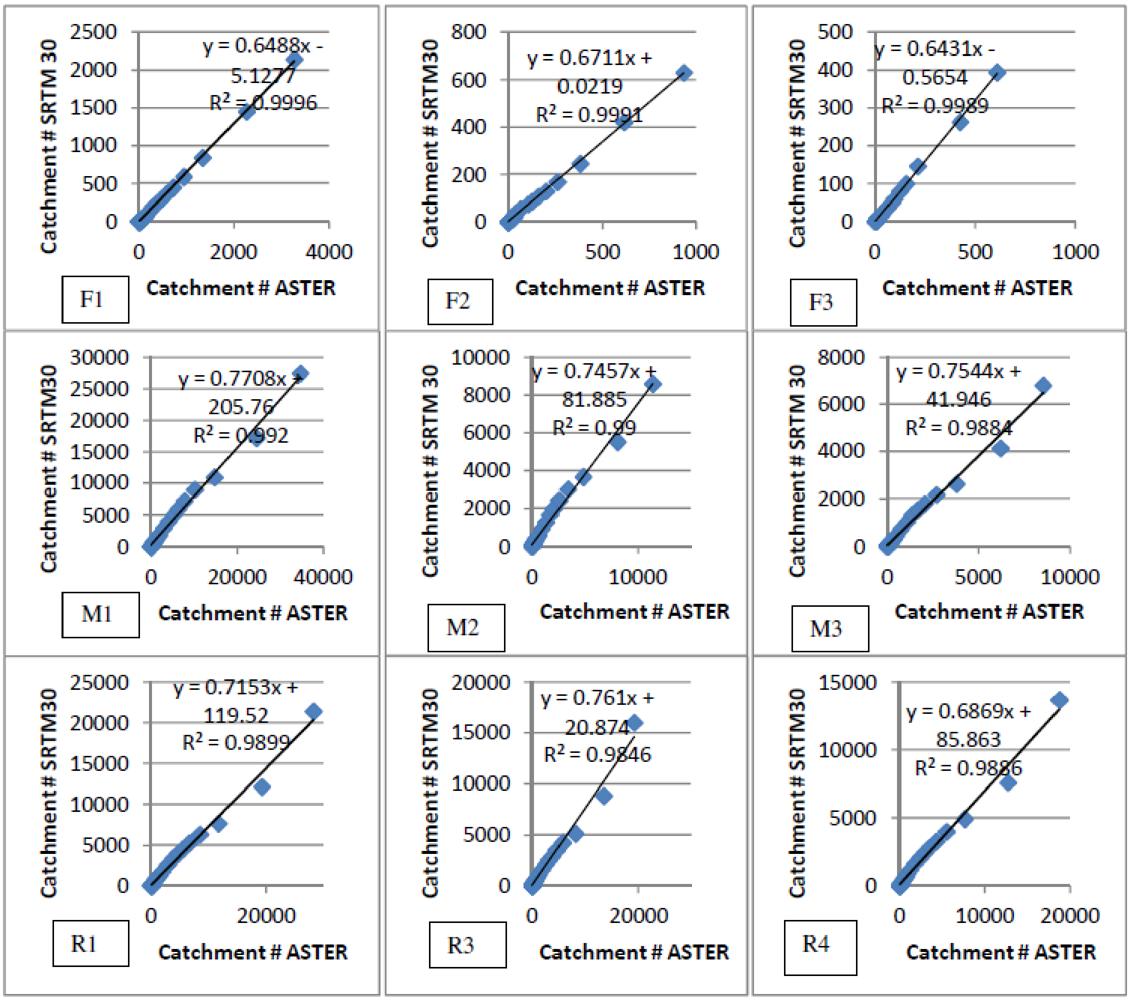


**Fig. 2** The relation between the numbers of catchments of ASTER with that of SRTM 30 for all the basins.

The relations obtained can be summarized (Table 4.5) and they show that the numbers of catchments obtained from ASTER relate better to those obtained from SRTM30 than with SRTM90, hence resampling SRTM yields better results. The difference between the ASTER & SRTM30/SRTM90 values of numbers of catchments was calculated as a percentage error and these were plotted against the threshold flow accumulation to show the variation. While SRTM90 showed more or less a consistent error with ASTER values (Fig. 4), the error values between ASTER and SRTM 30 spanned between 0 to 100% (Fig. 5).

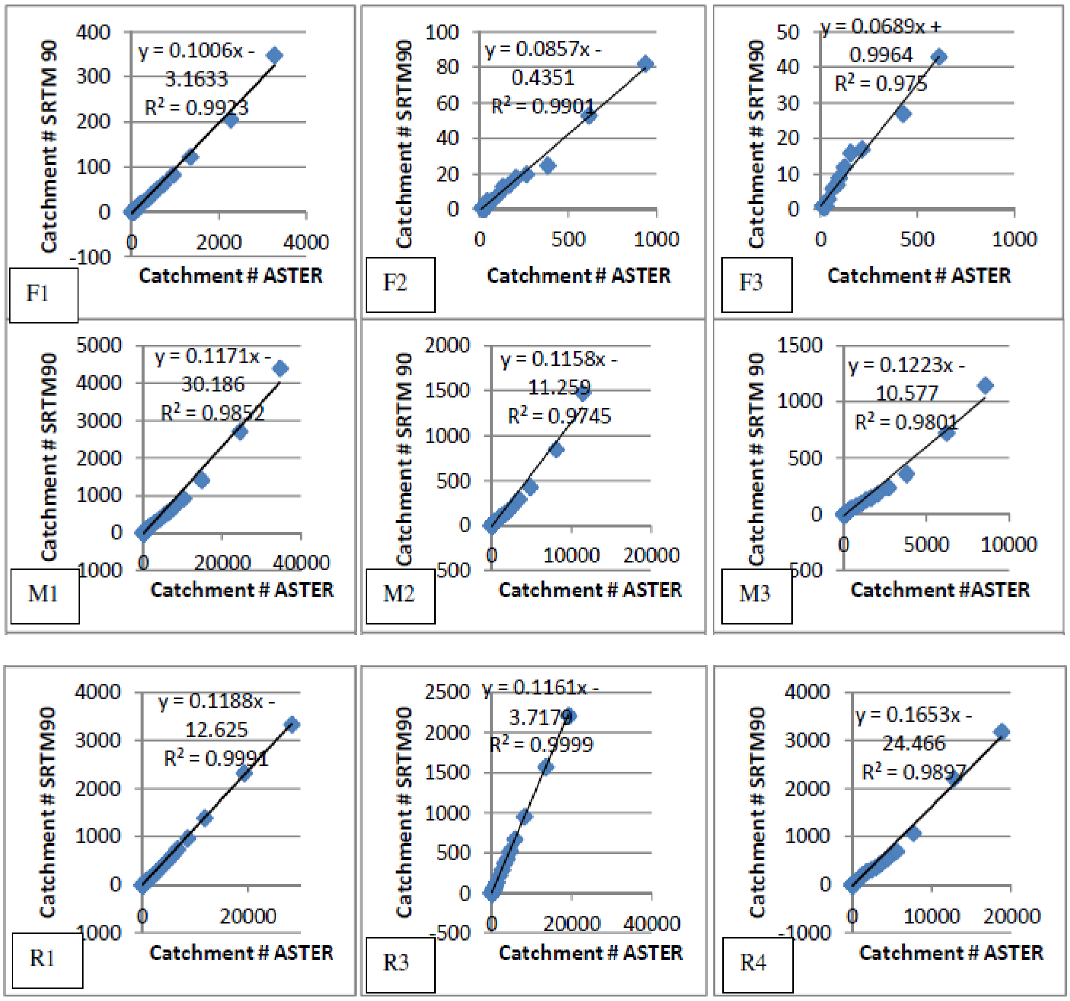
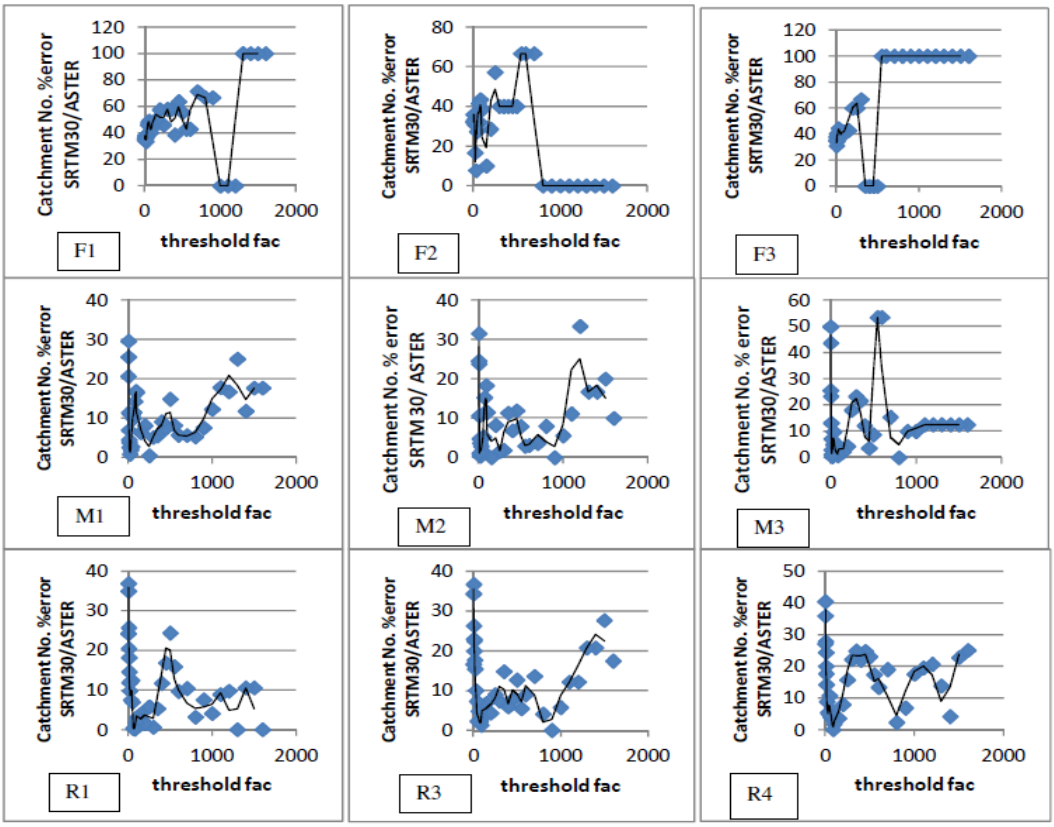


**Fig. 3** The relation between the numbers of catchments of ASTER with that of SRTM 90 for all the basins.

**Table. 6.** The relations obtained relating the Numbers of Catchments of ASTER with that of SRTM 90 & SRTM 30 for all the basins, along with their $R^2$ values.

| Terrain | Basin | Eqn for Catchment SRTM90 (y)/ASTER (x) | $R^2$ value | Eqn for Catchment SRTM30 (y)/ASTER (x) | $R^2$ value |
|---|---|---|---|---|---|
| Flat | F1 | $y = 0.1006x - 3.1633$ | 0.9923 | $y = 0.6488x - 5.1277$ | 0.9996 |
| Flat | F2 | $y = 0.0857x - 0.4351$ | 0.9901 | $y = 0.6711x + 0.0219$ | 0.9991 |
| Flat | F3 | $y = 0.0689x + 0.9964$ | 0.975 | $y = 0.6431x - 0.5654$ | 0.9989 |
| Medium | M1 | $y = 0.1171x - 30.186$ | 0.9852 | $y = 0.7708x + 205.76$ | 0.992 |
| Medium | M2 | $y = 0.1158x - 11.259$ | 0.9745 | $y = 0.7457x + 81.885$ | 0.99 |
| Medium | M3 | $y = 0.1223x - 10.577$ | 0.9801 | $y = 0.7544x + 41.946$ | 0.9884 |
| Rugged | R1 | $y = 0.1188x - 12.625$ | 0.9991 | $y = 0.7153x + 119.52$ | 0.9899 |
| Rugged | R3 | $y = 0.1161x - 3.7179$ | 0.9999 | $y = 0.761x + 20.874$ | 0.9846 |
| Rugged | R4 | $y = 0.1653x - 24.466$ | 0.9897 | $y = 0.6869x + 85.863$ | 0.9886 |



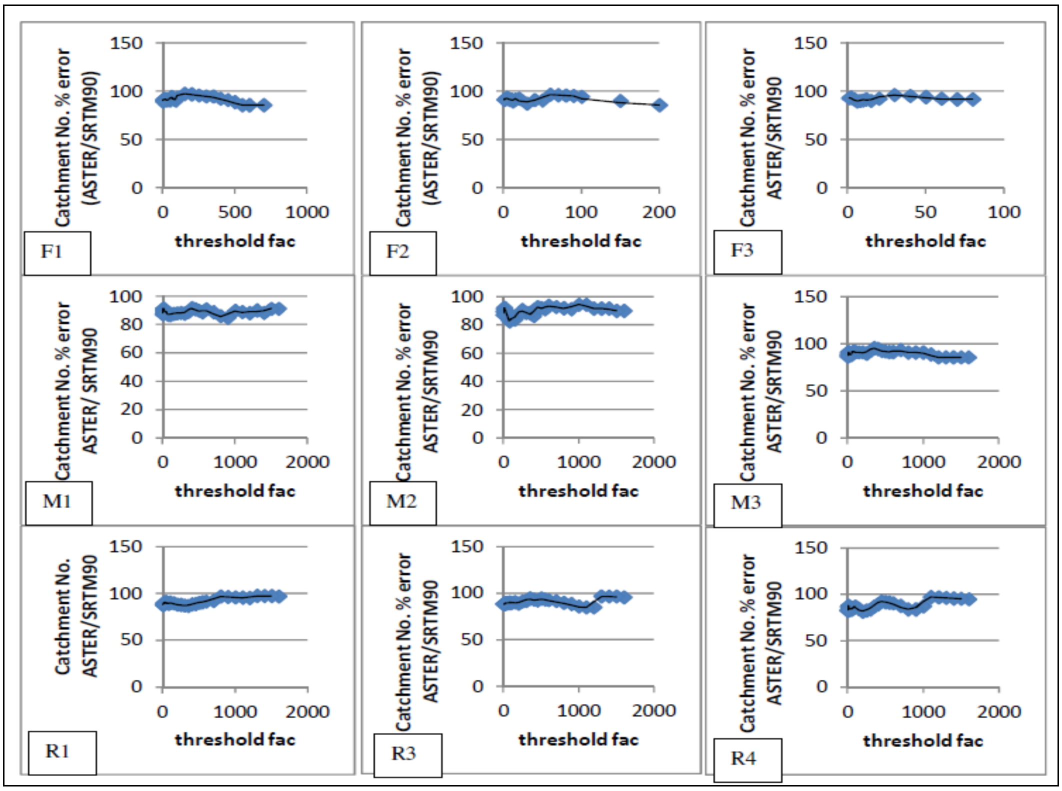


**Fig. 4** The variation of the percentage error of the numbers of catchments calculated between ASTER and SRTM 30 with increasing threshold flow accumulation.

for the flat terrain, and almost similar for the medium and rugged terrains. However, these average values are an average over a range from 0 to 100, whereas the error is consistent between SRTM 90 and ASTER catchment numbers, implying a relation between the two (table 6).

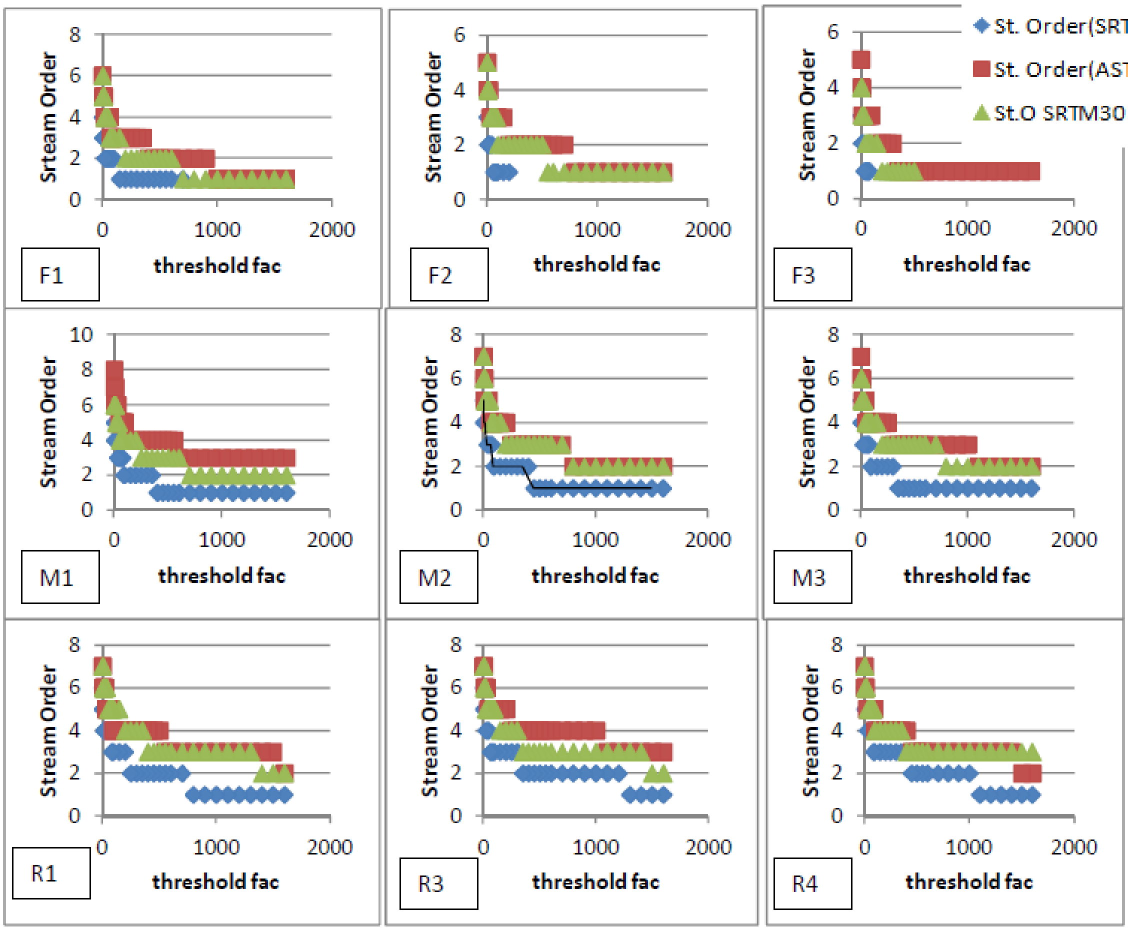
**Table. 6.** The average numbers of catchments percentage errors between ASTER & SRTM 30 and ASTER & SRTM 90 for all the basins.

| Number of Catchments | Terrain | Basin | Numbers of catchments average percentage error ASTER/SRTM30 | Numbers of catchments average percentage error ASTER/SRTM90 |
|---|---|---|---|---|
| | Flat | F1 | 48.66 | 91.62 |
| | | F2 | 28.15 | 91.95 |
| | | F3 | 35.69 | 92.23 |
| Average | | | **37.5** | **91.94** |
| | Medium | M1 | 10.77 | 89.06 |
| | | M2 | 9.55 | 89.71 |
| | | M3 | 13.74 | 90.21 |
| Average | | | **11.35** | **89.66** |
| | Rugged | R1 | 10.53 | 91.03 |
| | | R3 | 12.48 | 90.42 |
| | | R4 | 15.61 | 87.9 |
| Average | | | **12.87** | **89.78** |

## 6. ERROR ANALYSIS OF ASTER AND SRTM DEM THROUGH THE RELATION BETWEEN THRESHOLD FLOW ACCUMULATION AND THE STREAM ORDERS

The stream orders obtained for the three DEMs for the nine areas with respect to the threshold flow accumulation is as shown in Fig. 6. Resampling SRTM90 to 30 m helps to obtain stream orders similar to ASTER. Higher threshold value implies lesser clarity while lower threshold values exaggerate greatly. With increasing threshold value, SRTM 90 approaches stream order of 1 faster than ASTER or SRTM 30 showing a clear dependence on the cell size. An error analysis performed shows more differences between SRTM 90 and ASTER (Fig. 8) than between SRTM30 and ASTER (Fig. 7)

The relation between the threshold flow accumulation and the stream orders is a step relation, and the SRTM 30 and the ASTER values relate well to each other. A small error between SRTM30 and ASTER implies they relate well, while there is a considerable difference between the stream orders for the same threshold value between ASTER and SRTM90 DEM (Table 7).



The margins must be set as follows:

- Top = 2.0 cm
- Bottom = 2.0 cm
- Left = 2.54 cm
- Right = 2.54 cm

**Fig. 6.** The variation of the stream orders with increasing threshold flow accumulation for all the basins.

**Table .7.** The average stream orders percentage errors between ASTER & SRTM 30 and ASTER & SRTM 90 for all the basins.

| Stream Order | Terrain | Basin | Stream Orders percentage error ASTER/SRTM30 | Stream Orders percentage error error ASTER/SRTM90 |
|---|---|---|---|---|
| | Flat | F1 | 8.78 | 46.72 |
| | | F2 | 6.396 | 47.37 |
| | | F3 | 18.93 | 47 |
| Average | | | **11.37** | **47.03** |
| | Medium | M1 | 20.55 | 53.55 |
| | | M2 | 1.74 | 42.22 |
| | | M3 | 8.6 | 45.64 |
| Average | | | **10.3** | **47.14** |
| | Rugged | R1 | 7.32 | 39.05 |
| | | R3 | 11.31 | 38.44 |
| | | R4 | 4.37 | 29.2 |
| Average | | | **7.67** | **35.56** |

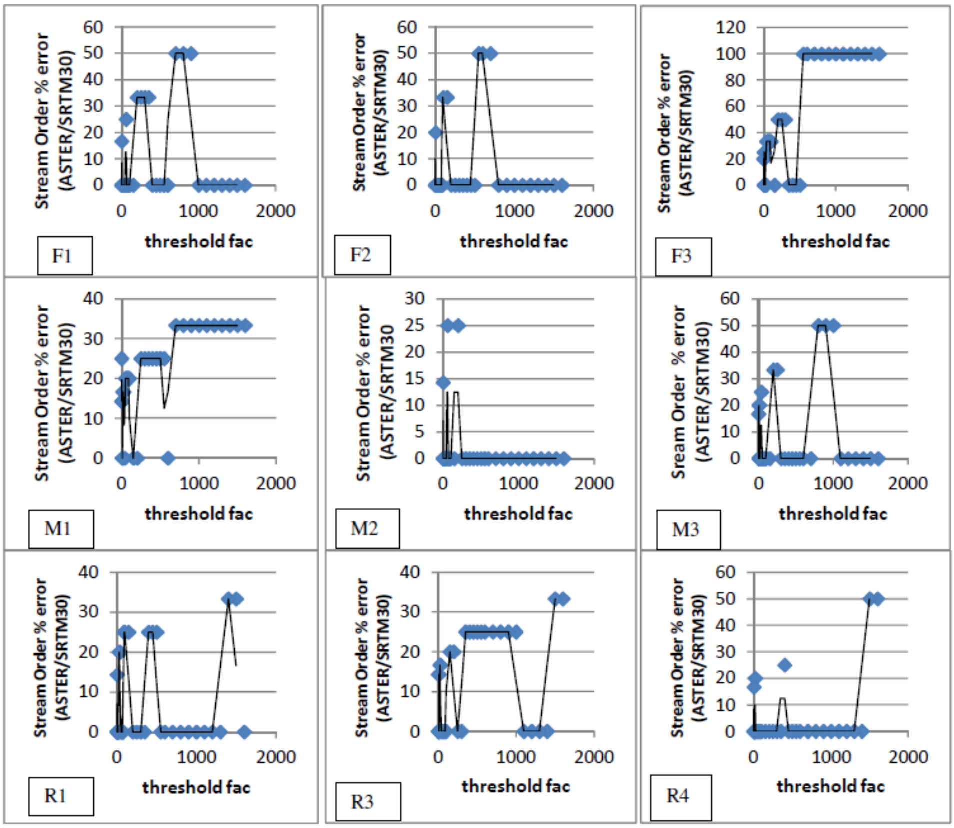


**Fig. 7.** The variation of the percentage error of the stream orders calculated between ASTER and SRTM 30 with increasing threshold flow accumulation.

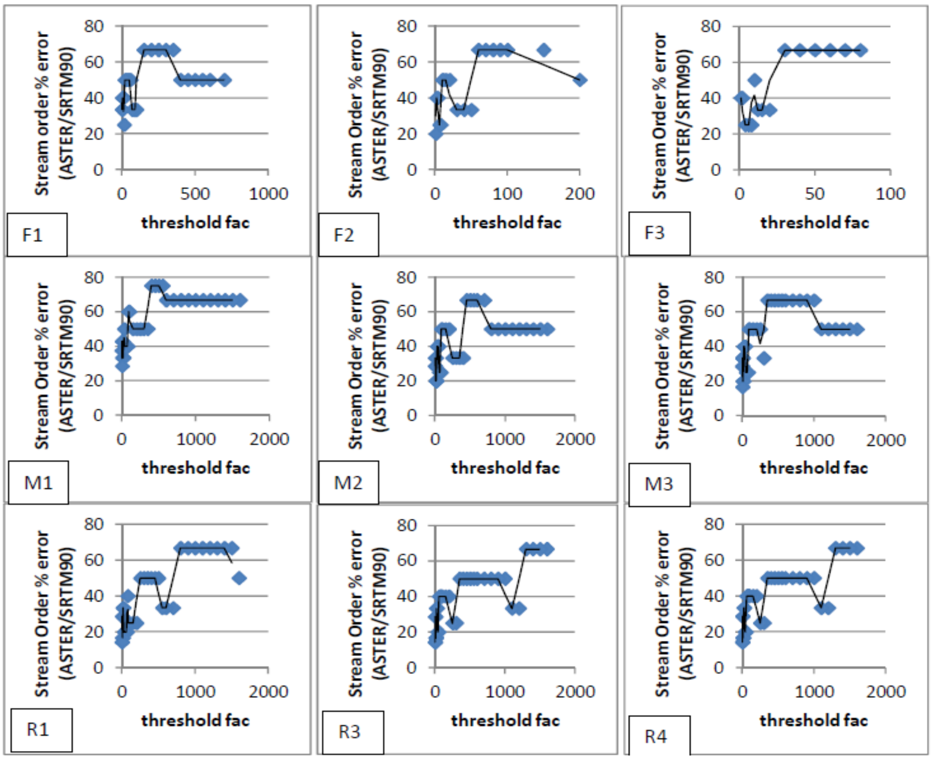


**Fig. 8.** The variation of the percentage error of the stream orders calculated between ASTER and SRTM 90 with increasing threshold flow accumulation.

## CONCLUSION

The above results were seen that since morphometric results depend heavily on the resolution of the DEM, ASTER is better than SRTM 90. This fact was proved when the morphometric results obtained from resampled SRTM 30 were comparable to that obtained from ASTER. Hence, wherever SRTM 90 DEMs are available, competent morphometric results can be obtained by resampling to a higher resolution. The extent and method of resampling is yet to be pursued. The error analysis between ASTER and SRTM DEM proved to show consistent values pertaining to the classified terrain proving the competency of the classification

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