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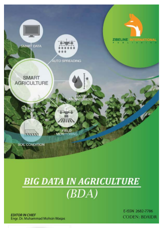

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RESEARCH ARTICLE

ESTIMATION OF HIGH-RESOLUTION RAINFALL USING MICROWAVE LINKS DATA OF CELLULAR SYSTEM

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ABSTRACT

One cannot manage what one does not measure is an old adage that is valid for the rainfall in the irrigated irrigation system. Water resources management required the efficient measurement of all water resources management component. Water resources management components measurement is the responsibility of respective organization. Rainfall measurement is the responsibility of the Pakistan Meteorological Department using standard gauge system. Deficiency in the system is the low spatial and temporal resolution. This directed the water manager towards the high resolution of satellite system. Satellite resolution is still course than the available cellular towers system and it is unable to capture the high resolution spatio-temporal variation in the Rainfall. This challenge of high resolution was conquered using microwave signals of Telenor cellular communication system in the surrounded area of Water Management Research Centre, University of Agriculture, Faisalabad. Rainfall was estimated based on the attenuation in the microwave signal between receiver and transmitter of the link. Receiver and transmitter are two different antenna on the cellular tower. One receiver and one transmitter make the single link. High resolution data at 15-minute temporal and 1.5Km spatial of total 24 links was processed using the R language written code. Results presented that the average daily rainfall using cellular system was 14.5 mm, while the satellite derived rainfall from Tropical Rainfall Measuring Mission (TRMM) was found zero and UAF meteorological showed 21.3 mm. Further the temporal resolution was found finer from cellular system that rainfall was occurred at 22:15 to 22:45. The spatial variation in the rainfall between links was found with the minimum of less than 1mm and maximum of 42.9 mm. This state-of-the-art techniques helps the hydrologist for comprehensive analysis and management of the water resources.

KEYWORDS

Microwave Signals, TRMM, Rainfall.

1. INTRODUCTION

Hydrological studies required the accurate rainfall estimation at very fine spatio-temporal resolution. Gauge measurement in the large scale cannot provide the high spatio-temporal rainfall data especially in the Indus basin irrigation system. Indus basin has limited gauge station and fall in the category of data scare basin (Cheema, 2012). Further obstacles in the rain gauge installation is unavailability of skilled people for timely and accurately measurement of rainfall. The options available and mostly used in the hydrological studies is satellite derived rainfall. The deficiency in the satellite rainfall is the low spatial resolution i.e. TRMM has 25 km spatial resolution with 3 hour temporal resolution. It directed to apply new techniques for the estimation of rainfall. Microwave link cellular based rainfall estimation is newly innovative idea for very high spatial and temporal resolution (Overeem et al., 2011). The spatial resolution of these towers is very fine that a rain gauge system will never achieve. Similarly, the temporal resolution of rainfall estimation from these links is available in the 15 minuets interval.

Estimation of rainfall works on the principle of electromagnetic signal attenuation transmitted from transmitter to the receiver by the rainfall. Some part of the incidents wave is absorbed by the raindrop, in addition to the scattering of the signal frequency. Higher the microwave frequency leads towards the higher attenuation of signals due to the increased scattering and absorption. Similarly, the attenuation increased with increased in the raindrops size and number. The rainfall-based attenuation can be calculated by measuring the received power at one end of a microwave link as a function of time. The received signals are the byproduct of telecommunication system and used only for measuring the stability of the cellular system. Microwave links data based rainfall was estimated (Messer et al., 2006; Benrne and Uijlenhoet, 2007; Leijnse et al., 2017; Zinevich et al., 2008; Goldshtein et al., 2009; Brauer et al., 2011). The research objective is fine resolution rainfall estimation using microwave links data of existing cellular telecommunication system.

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2. Methodology

A microwave link consists of a transmitter and a receiver, between which an electromagnetic signal propagates. Measurement of precipitation is based on the fact that the raindrops in the microwave link path attenuate the signal. Hence, a decrease in received signal level generally indicates an increase of rainfall intensity. A methodology was used where nearby links was used to remove signal fluctuations that are not related to rainfall in order to be able to reliably identify wet and dry weather spells. Subsequently, received signal powers was converted to path-averaged rainfall intensities taking into account the temporal sampling protocol and attenuation due to wet antennas. Commercial microwave links are widely used in mobile telecommunication. Along such links electromagnetic waves are sent from an antenna at one tower to an antenna at another tower. The waves are sent in a beam, of which the main lobe is a narrow cone widening as it leaves the transmitter (Upton et al., 2005).The rainfall intensity at a point can be estimated from the specific attenuation k (dB km^{-1}) of a microwave signal using a power law, the R-k relation (Atlas and Ulbrich, 1977).

$$R = ak^b - - - - - \quad 1$$

Where, R=Rainfall intensity (mm/h), k= Specific attenuation (dB/Km), a is coefficient and b is exponent depend on the Frequency, polarization and temp.

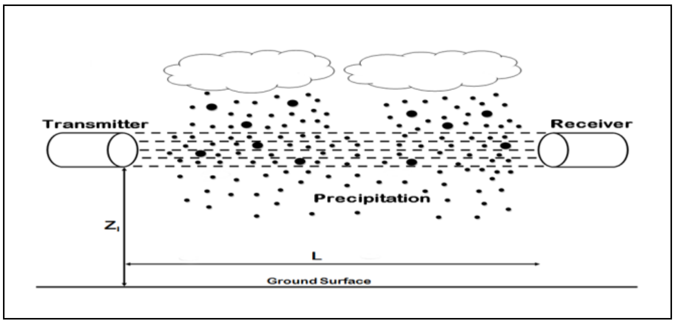

Figure 1: The basic concept diagram

For a microwave link, the relative decrease in microwave signal power is related to the attenuation Am (dB) over the link with length L (km), and thus to the rainfall intensity:

$$P_{ref}(L) - P(L) = A_m = \int_0^L k(s)ds = \int_0^L [\frac{R(s)}{a}]^{1/b} - - - - - 2$$

Where P stands for received signal power (dB/km), with P_{ref} the reference signal level or baseline, and s the distance along the link (km). These integrals have to be approximated because $R(s)$ cannot be derived from the scalar P. To be able to derive rainfall intensities from received signal powers, it is assumed that the R-k relation for the point scale provides a good approximation for the path-averaged rainfall intensity R (mm/ h) as well.

$$A_m = L(k) \approx L\left[\frac{< R >}{a}\right]^{\frac{1}{b}} - - - - - - - - - \quad 3$$

Where, k is the path-averaged attenuation (dB/km), so that R can be expressed as

$$< R > = \; a = \left[\frac{P_{ref}(L) - P(L)}{L}\right]^b - - - - - - - - - \; 4$$

Values of a and b was used from a study. Inverse Distance Weight interpolation techniques was used for spatial mapping of 24 links in GIS (Leijnse et al., 2007).

3. Results

The spatial mapping of the rainfall shows (Figure 2) the very fine results of rainfall. The maximum rainfall was 42 mm at the time of 10:15 pm. The spatial resolution of that time showed the variation of rainfall from maximum of 42 mm to the minimum of zero rainfall. Map of that time (10:15 pm) clearly showed the point variation of rainfall from point to point. Similarly, the maximum rainfall at the time of 10:30 pm was 13 mm and minimum rainfall was also zero. The spatial mapping also shows that most of the area at the time has low or no rainfall. The points describing the link location showed the variation of rainfall at that time, only few points described the high rainfall (13 mm) at that time. The spatial mapping of the rainfall at the time of 10:45 pm was not performed. Because the rainfall was occurred only at two towers.

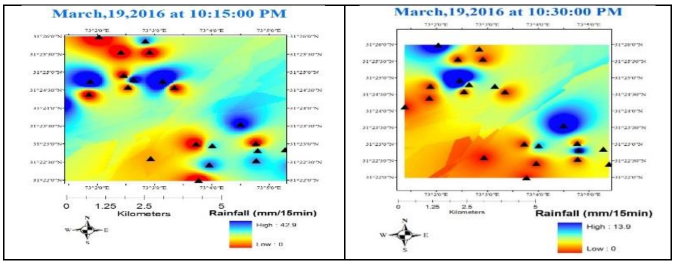

Figure 2: Spatial Mapping of the Rainfall

The figure 3 clearly showed the variation of rainfall at each tower with the temporal resolution of the 15 minutes. The rainfall at 10:15 pm was maximum 42 mm at the links number 12 and zero was found at the links 1, 6, 9, 13, 15, 16, 17, 19 and 22. Similarly, the rainfall at the time of 10:30 pm was found 13 mm maximum at the link 1. It's an interesting variation capturing in the algorithm. The rainfall at the links 1 was zero at 10:15 pm and was maximum in the next interval. The minimum rainfall was found also zero at the time of 10:30 pm at the links 5, 6, 8, 9, 10, 11, 13, 15, 17, 18, 19, 22 and 23. Similarly the variation of the rainfall at the time of 10:45 pm showed the maximum of 0.9 mm at the link number 4 and the other value was 0.2 mm at the tower link number 1, while all other values were found zero.

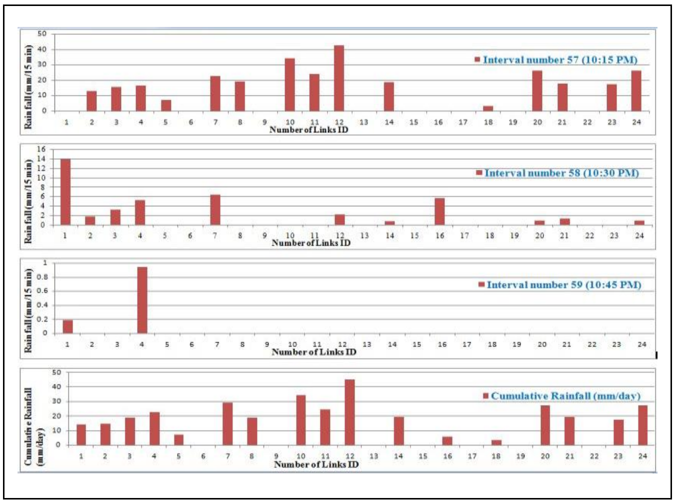

Figure 3: Point (links) rainfall with temporal resolution and cumulative of day

The interval number in the figure 2 shows the temporal resolution of 15 minutes for the rainfall estimation on 19 March 2016. The interval one starts from the 8:00 to 8:15 am and end at the 7:45 am to 8:00 am. The cumulative rainfall shows at the end of the figure 2 with the maximum of 42 mm and minimum of the zero. But the zero values was reduced only to the links number 6, 9, 13, 15, 17, 19 and 22. The average daily rainfall using cellular system was 14.5mm, while the rainfall was found zero from TRMM acquired pixel covering the area under study and the nearest available metrological station of UAF meteorological data showed 21.3mm (Berne and Ujilenhoet, 2007; Atlas and Ulbrich, 1977).

4. Conclusion

Rainfall estimation with high spatial and temporal resolution was a challenge in the data scare basin. This challenge was conquered using microwave signals of Telenor cellular communication system. This novel approach helps the hydrologist for comprehensive analysis and management of the water resources more efficiently with fine resolution.

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